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BETHESDA TERRACE:
CONDITIONS ASSESSMENT AND EVALUATION OF PREVIOUS STONE CONSERVATION TREATMENTS

CHRISTOPHER JOHN GEMBINSKI

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

1998

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INTRODUCTION

Studies focusing on the evaluation of past and current conservation treatments are critical for understanding their intended and actual weathering performance and durability. The development of applied treatments for existing and aged architectural materials has long been based on empirically derived knowledge. Recognizing the need for more objectively derived data, most architectural conservation interventions incorporate methods and materials drawn from contemporary and traditional building practice as well as from performance evaluations based on laboratory testing. Although this process has resulted in improved treatment performance, problems still exist in the lack of designed products or test methods and the resultant data necessary for long-term evaluation and performance predictions of treated and untreated aged building materials.

Current conservation practice must now address buildings whose histories often include previous preservation interventions. Building and material decay mechanisms, treatment performance, and overall sustainability including re-treatment are all affected by these previous measures initially designed to aid in preservation.

Ideally, conservation treatments are designed to extend the life of the material fabric of structures; however, treatments sometimes cause unintended changes. Investigation and evaluation of previous treatments can provide essential information on actual field performance and for the development of appropriate reapplication and/or new methods leading to conservation measures that are more effective.

A comprehensive program for the restoration of the Bethesda Terrace and its surrounding landscape was designed by New York City's Central Park Conservancy and Ehrenkrantz Architects in 1983-85. At that time, only the exterior masonry of the terrace was completed. The interior arcade was cleaned, but no other conservation treatments were implemented. The encaustic tile ceiling was dismantled and placed in storage for future consolidation.

Site surveying began during summer 1997 to record the existing conditions of the interior arcade, and to examine and document representative areas of previous treatments from the 1980s work. This research was conducted to aid the Central Park Conservancy in a new initiative to complete the overall restoration of Bethesda Terrace. The conditions survey of the entire interior of the terrace was completed, as well as representative areas of the exterior terrace. Field and laboratory analyses were also conducted to evaluate the post 1980s exterior

conditions. These areas were chosen for their complete representation of parameters deemed influential in the deterioration of the stonework. The western half of the terrace was selected for examination given the symmetry of the terrace design. Within this section, the areas determined most representative were: the northwest balustrade and cheekwalls (both east and west sides), the northern staircase (both cheekwalls), and the complete northwest balustrade and screening on the lower terrace (see figure 2). Sandstone elements exposed to full and partial weathering (north, south, east and west), above and below grade, and both untreated and treated in the 1980s restoration were included as variables critical for stone performance comparison.

OBJECTIVES

The current stone conservation program was developed and initiated in May 1997 as part of the ongoing masonry restoration of Bethesda Terrace in Central Park, New York. This research builds on previous restoration work conducted from 1983-85, and includes comparative analysis and evaluation of past and existing conditions and decay mechanisms. Factors studied in assessing stone conditions have included stone type and variability, construction methods and stone orientation, microclimate and environment, and past treatments and maintenance.

Phase I of the current program includes documentation and evaluation of past treatments of the sandstone of Bethesda Terrace. A survey of existing stone conditions of the untreated arcade interior and representative areas of the previously treated exterior sandstone is included. The field observations combined with the laboratory assessment of representative past treatments in Phase II will provide the Central Park Conservancy with information critical to the continuing conservation and maintenance of the terrace. It will also provide a model approach focused on the potential benefits of the analysis and assessment of previous stone conservation treatments in the field of architectural conservation. The following questions were posed to guide the assessment and

potential re-treatment of the structural and aesthetic conditions of the sandstone elements at Bethesda Terrace.

- Is deterioration occurring as an active condition?
- Has past deterioration of the sandstone elements changed over time in type pattern or extent?
- Have previous treatments halted, retarded, accelerated, or had no effect on deterioration?
- Do any untreated areas now exhibit active deterioration?
- Have treatments themselves deteriorated and if so how and to what effect?
- Are the types and extent of conditions within the arcade and the terrace unique based on the critical parameters of stone type, orientation, location and treatment?

This project was developed as a three-month summer field internship followed by an eight-month laboratory research thesis. Project research personnel include C. J. Gembinski, Project Fellow, working under the supervision of Project Directors Frank Matero and A. E. Charola, Department of Historic Preservation, University of Pennsylvania and Mark Rabinowitz, former Historic Preservationist and Peter Champe, Monuments Conservator at the Central Park Conservancy. The summer internship phase of this project was generously funded by The Getty Grant Program, The National Endowment for the Arts, and the Samuel H. Kress Foundation.

PHASE I: CONDITIONS SURVEY AND PRELIMINARY RESEARCH

CHAPTER 1: PROJECT METHODOLOGY

The methodology employed for this study included archival research, site survey, investigation, and materials analysis. During Phase I, all available documentation about the structure was examined so that current observations and analysis of the baseline information could be established for the new work. A site survey was next conducted to detail current physical conditions of the sandstone including type, location and pattern of deterioration, and representative previous treatments. Description of stone decay was created from on-site observation and existing research and definitions. Finally, observations were recorded in a graphic format for conditions documentation and deterioration diagnosis. During Phase II, comparative analyses of the above data in conjunction with physical and chemical analysis of the stone and the various 1980s treatments were conducted to answer the above questions on performance, durability and weathering. The results of this study will also assist in designing a new treatment and maintenance program at Bethesda Terrace. This thesis offers predictions for the future performance of the sandstone and makes recommendations for future conservation strategies.

DOCUMENTATION

Past documentation of the construction, maintenance and restoration of Bethesda Terrace was collected to assist in assessing the current conditions observed at Bethesda Terrace. By comparing information recorded in the conditions survey with earlier historical images, such visual comparisons provide the simplest method by which past deterioration may be measured, albeit qualitatively, and performance trends observed. Historical documentation also aided analytical techniques in the determination of provenance, composition and performance of the sandstone originally used in the construction of the terrace.

Many files and archives located during summer 1997 contain information relevant to the restoration treatments at Bethesda Terrace and include the history of its design and past maintenance and restoration. Organization of the documents included compiling photographs and slides of the terrace from the 1870s to the present.

A literature search and review of published and unpublished material focusing on Bethesda Terrace, general stone decay and especially sandstone decay mechanisms, and previous treatment and maintenance records was prepared. Original contract specification drawings and documentation dossiers detailing day to day treatment records from the restoration in the 1980s were also located.

Most of the written documentation from the 1980s restoration of the terrace is published.[1] Copies of unpublished theses[2] were collected and proved helpful in cases where they specifically document past conditions, maintenance or treatment of the sandstone at the terrace. Technical literature[3] on the classification of sandstone and its decay was also gathered to form a foundation from which to draw the definitions for the conditions survey conducted this summer at Bethesda Terrace.

Photographic documentation in the form of 35-mm color slides and black and white photographic prints was chronologically organized when it was possible to determine exact dates. Slides were organized within years by subject ranging from the 1970s to the 1990s. Most of this material documents the restoration work at Bethesda Terrace from 1983-1985. The few recent photographs found include information similar to the slide collections. Some nineteenth century stereopticon views at the New York Historical Society have proven helpful in

[1] For a full listing, see the bibliography at the end of this document. Documents related to Bethesda Terrace are available at The Avery Art and Architectural Library, Columbia University, New York and Fisher Fine Arts Library, University of Pennsylvania, Philadelphia.

[2] Theses by Eileen G. P. Brown and Sharon Frederick were especially helpful. Both include histories of the terrace and its previous restoration.

[3] Bernard Fitzner et al, Weathering Forms at Natural Stone Memorials - classification, mapping and evaluation," 1997; Anne E. Grimmer, "A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments," 1984; NORMAL 1/88; and World Monuments Fund, "Survey of the State of Conservation of the Tower of Belem," 1994 were the most helpful resources for definitions and examples of stone deterioration.

identifying the earliest visible decay at the terrace, however, many are of poor quality or detail.

The photographic documentation collection at the Central Park Conservancy Preservation Office, reorganized during this research, can now function as a vital visual tool in cataloging information relevant to the evaluation and performance of the Bethesda Terrace sandstone over the last fifteen years. This archive also provides information regarding the processes used in previous restoration work at the terrace including, cleaning, replacement in kind (dutchmen), composite repair, pointing, honing, and chemical consolidation.

Copies of original design drawings from the Calvert Vaux, Jacob Wrey Mould and Frederick Law Olmsted offices are cataloged on microfilm at the New York City Municipal Archives. Copies of these drawings were obtained and aided in the completion of new measured drawings of the terrace for the conditions survey of the present study. Approximately forty copies of the original Ehrenkrantz Architects specification drawings from the 1980s restoration project were also found in the Central Park Archives. These drawings provide essential information as to areas identified for conservation treatments. Careful study of these drawings allows speculation of past conditions occurring at Bethesda Terrace in the 1980s.

No previous detailed conditions surveys of Bethesda Terrace were located, however, the exterior treatments *proposals* from the 1980s restoration project are shown on the architect's specification drawings. Based on personal interviews with some of the 1983-85 restoration project personnel it can be speculated that the type of treatments proposed in specific areas were carried out as planned. Correlation of these areas with specific types of decay mechanisms occurring on site was made to ascertain treatment efficacy. Nevertheless, recommendations developed from the following research could not rely on this conjecture alone; therefore, the development of a thoroughly detailed conditions survey was necessary.

Compilation of the above information into a research archive will provide organized data on the restoration and conservation at Bethesda Terrace now and for the future. This archive should continue to grow throughout the course of this project and provide a valuable source for future monitoring of the conditions and assessment of treatments over time at Bethesda Terrace.

CHAPTER 2: CONDITIONS SURVEY

OBJECTIVE

The objective of the conditions survey conducted during summer 1997 at Bethesda Terrace is twofold. First, it is to provide diagnostic information for the determination of the weathering of the sandstone and its past conservation treatments. Observing and recording the type, extent, and pattern of deterioration of the sandstone elements of the interior arcade help to accomplish this. Determination of the nature and sources of decay of the sandstone is important since future performance, maintenance, and risk assessment of structural and architectural damage to the site will depend on these factors. The information from this project will be used as a planning tool by the Central Park Conservancy to design a new restoration program for the interior arcade and possible re-treatment of other areas. It will also provide the information necessary to develop a continued monitoring and maintenance plan for the preservation of the terrace. Secondly, the project at Bethesda Terrace will provide a model for similar analyses at other sites regarding both the value and method of previous treatment evaluation and the determination of comparative data for establishing relative treatment performance and efficacy for other structures.

DESIGN OF THE TERRACE

Bethesda Terrace was designed to be the heart of Central Park and a respite for the citizens of New York. It is openly situated near the center of the Park terminating The Mall on its south side at the 72nd Street Transverse Road and bounded on the north by The Lake. The terrace offers views of the park and city as well as cool places to sit during hot summer days. Today it is still utilized as a central meeting place in the park. Design drawings at the Municipal Archives in New York City illustrate the original intention of the architects Jacob Wrey Mould in association with Calvert Vaux. The terrace is an east-west biaxially symmetrical plan with a stone viaduct supported by an arcade, and upper and lower terraces flanked by curvilinear promenades. The 72nd Street Transverse Road crosses the viaduct in an east/west direction. Bethesda Terrace is oriented on a north/south axis with a staircase leading down from the southern end under the road and into the arcade. The interior arcade leads north through a central aisle with two flanking loggias on the east and west sides. A glass skylight illuminates the central aisle. Carved sandstone elements comprise the interior structure originally designed with a steel-frame supported polychrome encaustic tile ceiling by Minton Tile of London, England. The original design of the arcade called for marble inlay, diaper-patterned designs with alternating niches containing sculptures representing the Four Seasons. This aspect was never realized in the original construction of the terrace. Decorative panels painted on

the walls in the 1990s between delicately carved squared pilasters mimic the original design. The honorific pathway through the terrace opens to the north onto the lower terrace where the *Angel of the Waters* fountain now stands framed by the vista of The Lake beyond. Sandstone dies and wall screens display exquisite relief carving depicting seasonal flora, fauna and associated symbols.

The architectural elements include arches, capitals and highly carved screening sections between arches. Many elements are unique design by the architects and artisans which, according to early photographs, were carved in place during construction. The sandstone is a light greenish-yellow "freestone", a fine-grained sandstone able to be carved in all directions due to the absence of interfering bedding planes as a result of the stone's formation in large deep beds of sediment. Almost no visible bedding planes exist in the stone at Bethesda Terrace. Some original interior sandstone elements have weathered to a dark brown, especially the benches lining the walls between arcade panels subjected to rising damp. However, the sandstone for the most part retains its color, sharp edges and crisp details where unaffected by decay.

Historical documentation revealed that Bethesda Terrace was originally constructed of sandstone quarried in the Northeastern Provinces of Canada,

primarily from New Brunswick.[4] At least nine different quarries in northeastern New Brunswick and Nova Scotia are referenced by Parks and it is estimated that as many different sandstones were used in the original constructions and later restorations[5]. Replacement stone for the 1980s project was obtained from a quarry in Wallace, Nova Scotia reopened by Bybee Stone and rough cut stone was dressed in the state of Indiana.[6] Balustrade screens and other carved stone work were fit on site by contract sculptors during the restoration.

The climate of New York City is subject to great variations in seasonal weather. Summers are extremely hot and humid at times, however drought is also known. Winters can be icy and snowy or remain wet and damp for weeks at a time. The variation of such changing weather creates a harsh climate of wet/dry and freeze/thaw cycling. The sandstone elements of Bethesda Terrace have been subject to this aggressive environment since construction – equaling 136 years of multiple cycles of seasonal change since 1861.

Structural features of the terrace design also create microclimates within the site. The southern staircase dips below grade under the 72nd Street Transverse Road

[4] William A. Parks, *Report on the Building and Ornamental Stones of Canada,* 3 vols. (Ottawa: Governments Print Bureau, 1914).
[5] Ibid.
[6] Martin Stecklow, a contractor who worked for Central Park during the 1980s restoration, provided information on the quarrying and dressing of restoration stone work at Bethesda Terrace during a telephone conversation on 2 June 1997. This information was also confirmed by Mark Rabinowitz, former historic preservationist at the Central Park Conservancy.

to enter the arcade. The arcade displays lower temperatures and higher relative humidity than the surrounding area most of the year due to its subterranean environment. A long history of water and salt penetration from the 72nd Street Transverse Road above combined with rising damp and condensation has exacerbated the moisture problems evident in the pronounced deterioration of the stone in this area. In addition, the design and orientation of the southern staircase create a wind-tunnel effect keeping moisture concentrated or allowing the wind to rapidly dry the interior surface depending on the ambient humidity and temperature. The two loggias of the arcade create two interior sub-rooms where it is likely that concentrated moisture and salts create yet another different microclimate. The exterior cheekwalls northeast and northwest of the arcade passage out to the lower terrace exhibit biological growth of different microclimate requirements in the form of algae and mosses. Overall, the design by Mould and Vaux to create interior and exterior spaces also resulted in the creation of different environments. Subsequently, these largely varying environments and microclimates have also created distinguishable conditions and decay mechanisms for the same stone used elsewhere at Bethesda Terrace.

Sandstone Conditions at the Terrace

The ever-changing climates and uses of Bethesda Terrace create a variety of sandstone conditions at the site. Natural erosion from weathering, physical

alterations, structural modifications and physical abuse of the structure all exist. Human abuse, such as breakage, graffiti and vandalism persistently jeopardize sandstone elements. Sports and recreation batter the sandstone in areas with baseballs, in-line skates and skateboards. De-icing salts on the 72nd Street Transverse Road penetrate the terrace as moisture barriers fail causing increased moisture and salt penetration resulting in staining and erosion. Finally, repairs to the terrace, while proving effective mechanically, have altered the aesthetics of the site as illustrated below.

Fig. 1 - Composite repair showing signs of visual alterations.

Overall, the conditions range from previous long-term loss of sandstone elements, to deposits and discoloration, to recent active mechanical decay, both

natural and human induced. The survey below records the type and extent of conditions as symptomatic responses to a range of factors of variable influence. It provides the information detailing the physical conditions of the sandstone on the interior arcade and representative areas of the exterior terrace. It illustrates the conditions of naturally weathered and untreated sandstone elements as well as representative areas of previously treated sandstone. It is designed to reveal areas in need of immediate intervention and to show patterns of decay. Determination of actual causes are discussed in conjunction with the analysis of the survey in combination with the Phase II program of chemical analysis and physical testing of the treated and untreated stone.

RESEARCH FOR CONDITIONS SURVEY DEVELOPMENT

Development of the survey of sandstone conditions at Bethesda Terrace began in April 1997. Research included unpublished and published documents, articles and previous surveys detailing stone decay mechanisms and their recordation. A format was developed based on the work of Benard Fitzner[7] and others.[8]

[7] B. Fitzner et al, *Verwitterungsformen - Klassifizierung und Kartierung,* (Berlin: Verlag, Ernst and Sohn, 1995). Fitzner revised this document in June 1997.

[8] The "Reports on the Conditions Surveys of the Lincoln and Jefferson Memorials," produced by F. G. Matero et al., Department of Historic Preservation at the University of Pennsylvania were consulted for documentation formats and possible future analytical testing. The National Parks Service report by Anne E. Grimmer on stone decay mechanisms was also influential in defining specific type of stone deterioration.

Research for the survey process was completed in June 1997. The final format was based on a graphic overlay system where observed types of decay were field traced on acetate overlays over digitized photographs or measured drawings. The survey was started in the middle of June and was completed by the middle of August. Diagrams were drawn in three colors (red, green and blue) and several graphic symbols (see figures 3 and 4). Overlay pages, drawings and photographs were archived in three ring binders during the digitization process.

The final format for the Bethesda Terrace survey includes three major categories of decay symptoms, each divided into levels qualified by degree or severity of damage. Categories surveyed recorded **previous long-term surface loss**, **surface deposits and discoloration**, and **recent active deterioration**. Further levels are outlined in the key section below.

AREAS SELECTED FOR CONDITIONS SURVEY

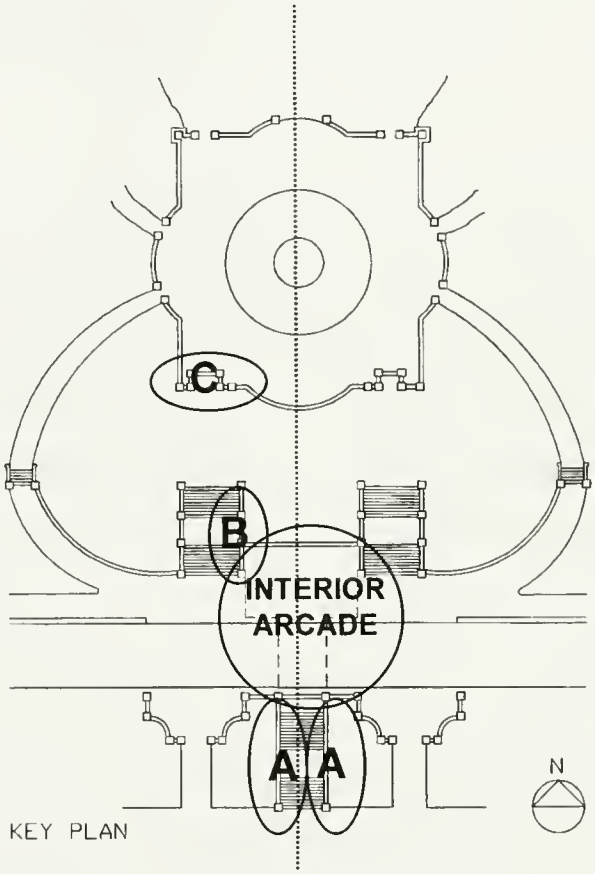


Fig. 2 - Key plan of survey areas

Bethesda Terrace is a biaxially symmetrical design with exposure of the sandstone elements in all cardinal directions throughout the site. Two factors determined the selection of the areas to be surveyed. Survey of the entire arcade interior was necessary to document the type and degree of deterioration of the sandstone as it is the area under consideration for future conservation treatments. The entire interior of the arcade including both east and west loggia was surveyed for all categories. All sandstone elements including columns,

arches, screening elements and benches were documented on overlays placed upon measured drawings based on the original designs found in the Municipal Archives.

Representative exterior sandstone areas were surveyed based on their display of current sandstone conditions, exposure (directional and above/below grade) and previous conservation treatments (honing, composite patching and consolidation). The sample areas of the exterior included: (A) the southern arcade staircase walls (east and west); (B) the northwestern stair balustrade and cheekwalls (both east and west sides on both upper and lower levels) and; (C) all elevations of the northwestern balustrade, separating the middle and lower terraces (see figure 2). These selections provide a complete representation of all parameters considered and conditions recorded in each category and exposure. They offer the possibility of examining the conditions of the sandstone at Bethesda Terrace with regard to natural weathering processes and the weathering and performance of conservation treatments. In so doing, the current survey serves as a diagnostic tool for the comparative performance of the treated and untreated sandstone as well as a datum for observed conditions in 1997-98.

PHOTOGRAPHY AND DRAWINGS FOR THE SURVEY

Photo-documentation of the interior arcade sandstone element conditions proved problematic due to the low level of illumination and the lack of proper photographic equipment and light to produce rectified images. Therefore, illustrations of the interior architectural elements were drawn at the Central Park Conservancy Preservation Office based on photocopied drawings of the original design drawings of the terrace. The New York City Archives has a collection of microfilmed copies of the original Vaux, Mould and Olmsted design drawings for Bethesda Terrace. These drawings are to scale and illustrate the design intent of the terrace in detail. Copies from the microfilm provided information for accurate dimensioning of the new drawings. These new drawings were photocopied and used as the base drawings over which the conditions of the interior sandstone elements were recorded. All exterior areas surveyed were photographed and the photographs were scanned and digitized using Adobe PhotoShop 3.0 at the University of Pennsylvania, Graduate School of Fine Arts computer lab. These files were printed and used as the base illustrations over which conditions were overlaid based on field observations.

The surveys of the interior arcade and the selected sections of the exterior terrace began the third week of June 1997 (for two weeks). They were completed after three weeks of observation and recording in August 1997. The

entire survey took place over a period of approximately six weeks. Surveying of the exterior was weather dependent.

GLOSSARY OF CONDITIONS CATEGORIES

The following glossary outlines the conditions surveyed during the summer 1997. Not all conditions in the following list were observable in the sandstone at Bethesda Terrace. However, all are listed in this section as reference to the overall conditions classification system that defines architectural stone decay. The conditions existing at Bethesda Terrace are signified with an asterisk (*) in this list. Level I represents the overall collective categories of *Previous Long-term Loss*, *Discoloration and Deposits*, *Recent Active Decay*, *Fissures and Deformations*, and *Replacements*. Level II classifies each condition by type and Level III identifies the suspected source of the condition. The overall interior arcade and the selected representative exterior areas were surveyed at Level I. Areas of special interest were surveyed at Level II and if possible at Level III.

CATEGORIES

(1) PREVIOUS LONG-TERM LOSS OF STONE MATERIAL

(1a) **Retroweathering:** Defined by Fitzner as "backweathering," and "uniform loss of material parallel to the original stone surface."[9] This phenomenon is further subdivided into the following categories:

(1a.a) *Retroweathering through exfoliation or the loss of leaf-like plates of the substrate.*

(1a.b) *Retroweathering due to loss of stone elements dependant on stone structure and/or composition.*

(1a.c) *Retroweathering due to loss of crusts.*

(1a.d) *Retroweathering due to loss of indefinable stone elements.*

(1b) **Relief:** Defined as a morphological change of stone surface due to partial or selective weathering of stone. This category is further subdivided into:

(1b.a)* *Rounding/notching* of stone elements to smooth concave pockets of loss or the rounding down of carved details to smooth convex surfaces.

(1b.b) *Alveolar weathering* of stone to a honeycomb like surface due to differential erosion of the stone components.

[9] Fitzner, et al., (1995): 44.

(1b.c)* *Differential erosion pattern dependent on stone structure* defined as relief dependent on structural features such as bedding, foliation, banding, etc. It is frequently seen as striped patterns.

(1b.d)* *Differential erosion through exposure of stone components* where aggregate is found standing proud of the surface of the stone due to the loss of matrix or where differential erosion of bedding planes causes a grooved stone surface.

(1b.e)* *Roughening* of the stone surface that removes the original finish and creates a textured appearance not readily identified with the weathering out or erosion of a specific stone component.

(1b.f) *Microkarst*: Defined as the erosion of soluble elements of the stone creating a manifold textured surface.[10]

(1b.g)* *Pitting* of the stone surface due to the weathering out or erosion of the matrix or aggregate creating small concave cavities.

(1c) **Breakage:** Defined by Fitzner as "break out" and loss of compact stone fragments. This category is subdivided in Level III to include speculated causes of the breakage including:

(1c.a)* *Breakage due to direct anthropogenic influence.*

(1c.b) *Breakage due to constructional cause.*

(1c.c) *Breakage due to natural cause* (roots, earthquakes, etc.).

[10] Fitzner, et al., (1995): 56.

(1c.d)* *Breakage resulting from unrecognizable causes.*

(2) **DISCOLORATION/DEPOSIT**

Defined as alterations to the surface of the stone due to the addition or removal of stone components or soiling substances. This category is subdivided in Level II to differentiate between the additions of soiling materials from the removal of stone components that alter color. The accretion of crusts in the form of efflorescence is included in this category.

(2a) **Discoloration** is either the addition of coloring agents to or the removal of colored components from the stone surface. This category is therefore divided into:

(2a.a)* *Coloration* defined as an addition of color that darkens the original color of the stone surface, usually due to the deposit of a soiling agent or the accumulation of organic or chemical substances.

(2a.b)* *Bleaching* or the lightening of the stone surface, usually due to the leaching out by chemical reaction colored stone components.

(2b) **Soiling** included the deposition of materials that alter the appearance of the stone surface and build up to form layers. These deposits are further defined in Level III by their origins as follows:

(2b.a) *Soiling from atmospheric pollutants.*

(2b.b)* *Soiling from ground water and rising damp.*

(2b.c)* *Soiling from animal droppings.*

(2b.d)* *Soiling from direct anthropogenic causes* (e.g., graffiti).

(2b.e)* *Soiling from other causes.* The latter distinction introduced to account for the black deposit found on and surrounding replacement mortars used in the 1980s restoration.

(2c) **Loose salt deposits** are further distinguished by their location on or under the surface of the stone.

(2c.a)* *Efflorescence* occurs on the surface of the stone where light colored crystalline powders or needle-like crystals form during the crystallization of soluble salts in the stone.

(2c.b) *Subflorescence* is the crystallization of the soluble salts below the surface of the stone. This phenomenon is more difficult to observe than efflorescence.

(2d) **Crusts** on the surface of the stone are distinguishable by morphology and color. Many variations are possible. The survey at Bethesda Terrace looked for the following crusts:

(2d.a)* *Dark colored crust tracing the surface.*

(2d.b) *Dark colored crust changing the surface.*

(2d.c)* *Light-colored crust tracing the surface.*

(2d.e) *Light-colored crust changing the surface.*

(2d.f)* *Colored crust tracing the surface.*

(2d.g) *Colored crust changing the surface.*

(2e) **Biological colonization** is the growth or presence of biological life on the surface of the stone or between blocks of stone. This category is further divided in Level III into:

(2e.a)* *Microbiological colonization* by algae, fungus or bacterium.

(2e.b)* *Colonization by higher plants*, mosses, lichen, plants, trees, etc.

(3) **RECENT ACTIVE DETERIORATION**

The following category identifies the types of conditions, which currently result in the loss of stone material. They are distinguishable from past loss in that they are on going alterations directly related to current decay mechanisms, whereas past loss is attributed to mechanisms no longer visibly altering the stone. These conditions are further defined by their resultant alteration to the stone surface.

(3a) **Granular disintegration** is the disintegration of the stone surface due to the loss of the matrix binding the aggregate into the stone. This category is further defined in Level III by the size of the aggregate

found as a loose surface deposit or directly below the area affected by this condition.

(3a.a) *Powdering* occurs when the aggregate and/or matrix are powder-like fines.

(3a.b)* *Sanding* results from the disintegration of the stone into sand grains.

(3a.c) *Sugaring* is the result of various sand grains attached to one another as the are weathered from the stone surface.

(3b) **Crumbling** is the detachment of larger, compact stone elements in the form of crumbs. This condition was not observed at Bethesda Terrace.

(3c) **Spalling** as defined by Fitzner is the "splintering" of the stone seen as detachment of larger, compact stone elements in the form of "splinters", e.g. as for compact carbonate rocks and quartzite. The word spalling was chosen because it matches the definition (with photograph) in the National Parks Service Glossary of stone decay mechanisms defined as spalling.[11]

[11] Anne E. Grimmer, "A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments," (Washington, DC: Department of the Interior, National Park Service, Preservation Assistance Division, 1984): 177.

(3d) **Flaking** is defined as the condition that results in the development of loose flakes on the surface of the stone. Theses conditions are further defined by their number and morphology in Level III as:

(3d.a) *single flakes*

(3d.b)* *multiple flakes*

(3e) **Contour scaling** observed as "detachment of larger, platy stone elements parallel to the stone surface, but not following the stone structure."[12]

(3e.a) *contour scaling* due to tooling of the surface

(3e.b) *single scales*

(3e.c) *multiple scales*

(3f) **Detachment** of stone elements dependent on stone structure is subdivided in Level III as:

(3f.a) *exfoliation* occurring where the leaves of a foliate stone are weathered into layers which detach from the sound stone substrate.

(3f.b)* *delamination* occurring in laminar stones when layers separate from one another and/or the sound stone substrate.

(4) **Fissures and Deformation**

(4a) **Fissures and cracks** that are further defined by their relation to the structure of the stone. These conditions are either

[12] Fitzner, et al., (1995): 66.

(4a.a)* *Fissures and cracks independent of stone structure.*

(4a.b)* *Fissures/cracks dependent on stone structure.*

(4b)* **Deformation** is the physical movement of architectural stone elements from their original placement in the structure.

(5) **REPLACEMENT**

Stone or artificial stone used to compensate for lost architectural material. Level II of this survey records:

(5a)* **Stone replacement**, referred to as dutchmen in architectural restoration work, or the replacement in kind of lost stone elements with new stone pieces cut and carved to represent the original designs and mechanically pinned and bonded to a sound substrate of original fabric.

(5b)* **Artificial stone replacement or mortar patch** also defined as composite patching material that is mixed to match the original fabric and applied to the substrate to compensate for a loss of original fabric.

Fitzner does not address mortar conditions in his survey outline. However, surveying of mortar conditions at Bethesda Terrace was performed with respect to the following categories:

(1) **sound** mortar

(1a) correct color.

(1b)* different color.

(2) **deteriorated** mortar.

(3)* **missing** mortar.

Only the conditions marked above with an asterisk were documented as they represent observed mortar deterioration. Documentation of sound mortar is extrapolated from unmarked areas in base drawings and photographs similar to sound areas of sandstone.

Quantitative evaluation or severity of condition as defined by Fitzner is divided into 6 categories. It was reduced for this survey to the following four:

0 - No damage.

1 - Slightly damaged.

2 - Moderately damaged.

3 - Very damaged.

FORMATTING THE SURVEY

The overlay conditions survey system developed for Bethesda Terrace details the specific sandstone conditions observed through representative colors and graphic symbols. This system was developed out of other systems utilizing layering of graphic systems to represent differing levels of information.[13] At Bethesda Terrace, the following symbols were used in the initial sandstone conditions field survey to represent the prevalent conditions from the ones outlined above. Each colored area on the overlays were then annotated to record the category, sub-category and severity (e.g. severe granular disintegration to sand = 3.a.b.4). The final presentation of the Bethesda Terrace sandstone conditions survey has a similar key modified for lucidity.

Surface Loss

Surface Deposits and Coloration

Active Deterioration

Rising Damp and Moisture Penetration

Mechanical Repairs

[13] The conditions assessment projects at Mesa Verde (1995-97) and Casa Grande (1997-98), produced through the Architectural Conservation Laboratory at the University of Pennsylvania, were consulted. These projects have developed a complex overlay system of graphic symbols and colors on acetate sheet over photographs to record the conditions on site. This format was modified for the Bethesda Terrace conditions survey.

The format of the survey consisted of base photographs or drawings copied at 8.5" x 11" and inserted into three hole punched high gloss acetate sleeves. These were carried to the site in three ring binders. The conditions were observed and hand traced over the photographs onto the acetate with fine-point permanent markers. Four colors were used and several different graphic symbols to designate the specific condition (see figures 3 and 4).

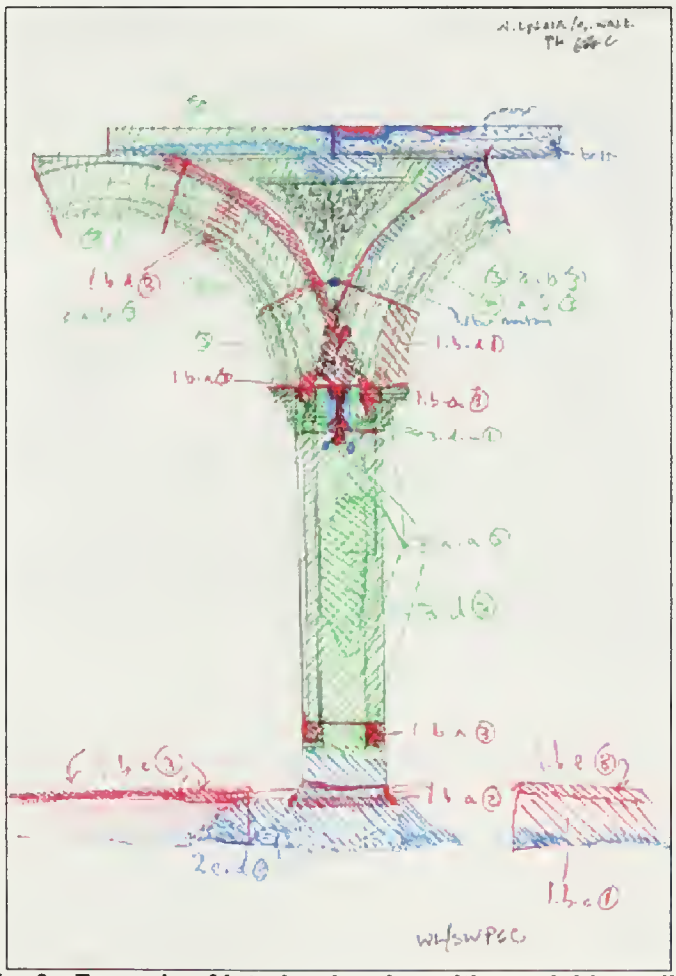


Fig. 3 - Example of interior drawing with overlaid conditions.

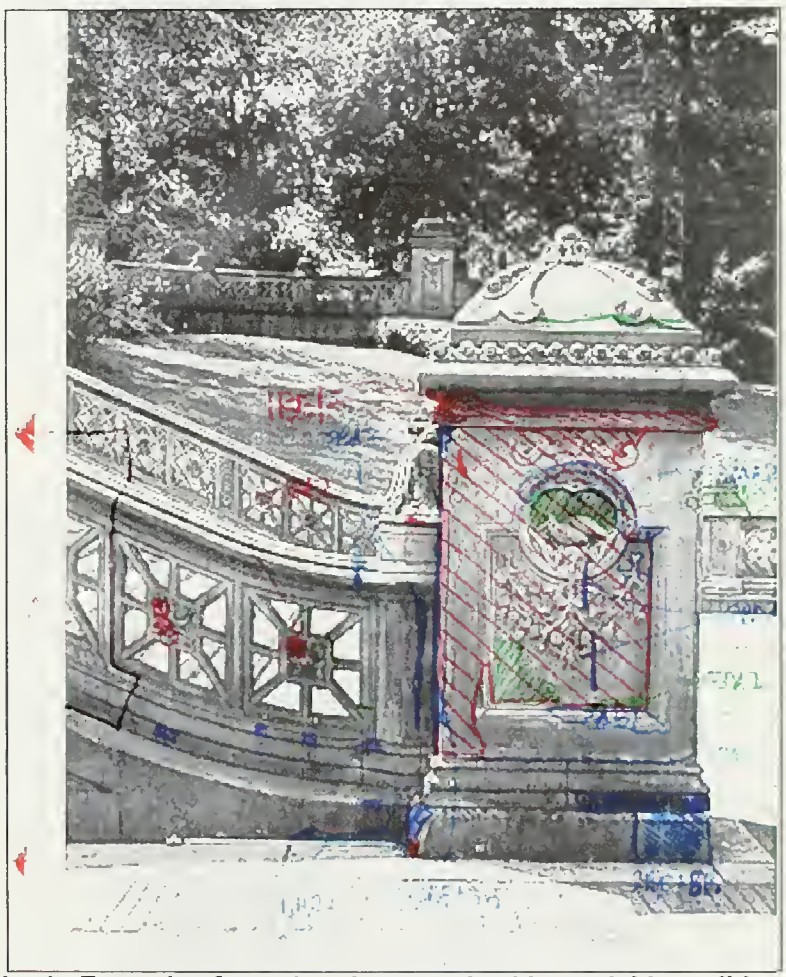


Fig. 4 - Example of exterior photograph with overlaid conditions.

Descriptive Symptomatic Conditions Terminology

Level 1 - Previous Long-term Surface Loss

Fig. 5 - Retroweathering - uniform back loss parallel to the original stone surface due to various weathering determined at individual occurrences.

Fig. 6 - Retroweathering - retroweathering on wall panel base of north arcade stair.

Fig. 7 - (1b.a) Rounding/notching - concave/convex weathering forming soft edges and hollowed areas.

Fig. 8 - (1b.c) Weathering pattern dependent on stone structure - relief of stone surface caused by weathering dependent on structural features such as bedding.

Fig. 9 - (1b.d) Exposure of stone components - raised exposure of stone aggregate through loss of less stable stone components.

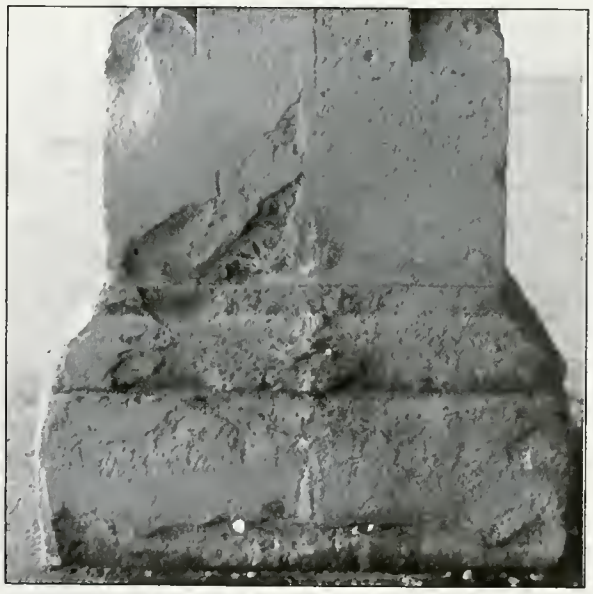


Fig. 10 - (1b.e) Roughening – alteration of original stone surface causing loss of smoothness, gloss or original tooling marks.

Fig. 11 - (1b.g) Pitting – alteration of stone surface resulting in pitted areas where less stable components weather out of the stone.

Fig. 12 - (1c) Breakage due to direct anthropogenic influence.

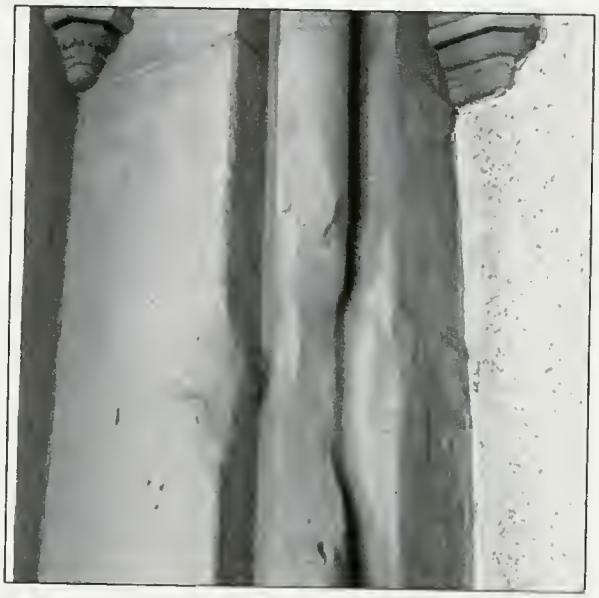


Fig. 13 - (1c.d) Breakage resulting from unrecognizable causes.

LEVEL 2 - SURFACE DEPOSITS AND COLORATION

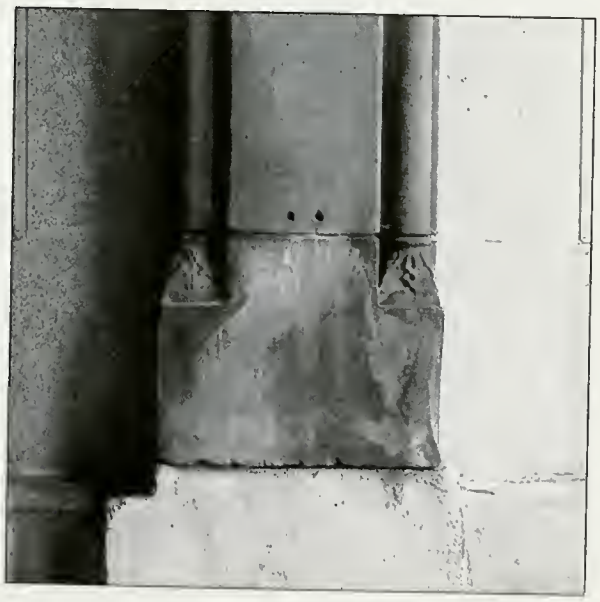


Fig. 14 - (2a.a) Coloration - chromatic alteration of original stone surface resulting from accumulation of coloring matter through natural weathering or chemical treatments.

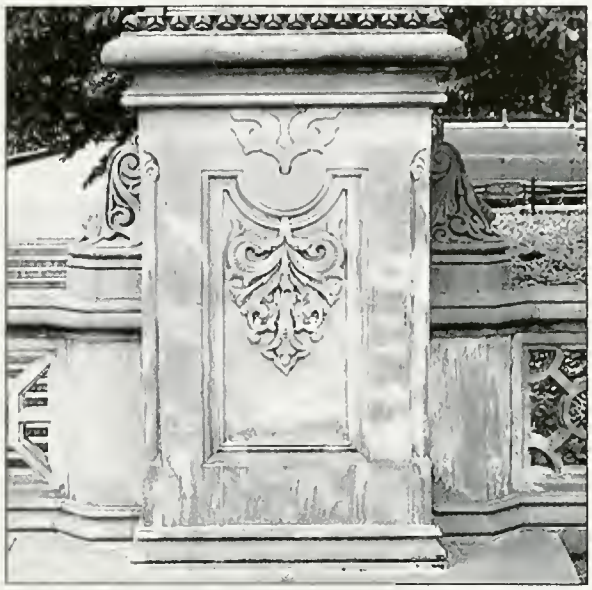


Fig. 15 - (2a.b) Bleaching - chromatic alteration of original stone surface resulting from extraction of coloring matter through natural weathering or chemical treatments.

Fig. 16 - (2b.b) Soiling from ground water - often the result of rising damp and water penetration.

(2b.c) Soiling from droppings - deposits of droppings from birds, etc. on stone surface. (Not illustrated)

Fig. 17 - (2b.d) Soiling from direct anthropogenic causes - graffiti, paint, stickers, etc. (2b.e) Soiling from other causes (Not illustrated).

Fig. 18 - (2c.a) Efflorescence - loose salt deposits on stone surface.

Fig. 19 - (2d.a) Dark/light or colored crust tracing the surface - crust tracing the morphology of the stone surface usually due to moisture related processes.

Fig. 20 - (2e.a) Microbiological colonization - algae, fungi, lichen and bacteria.
Fig. 20 (2e.b) Colonization by higher plants.

LEVEL 3 - ACTIVE DETERIORATION

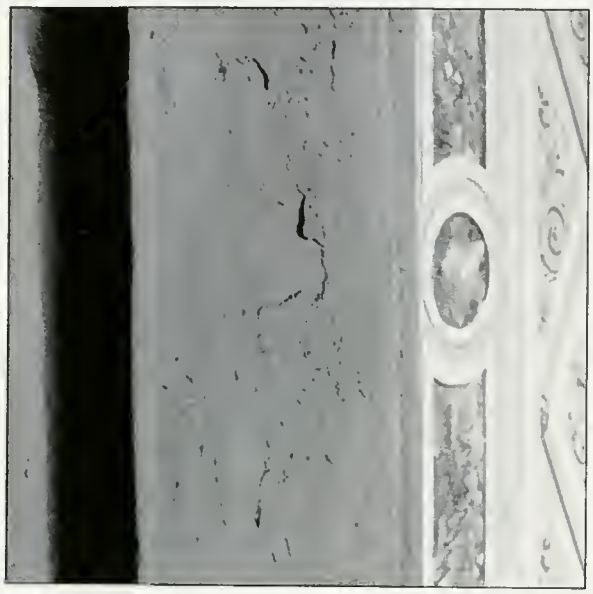


Fig. 21 - (3a.b) Granular disintegration resulting in sanding - detachment of granular stone components of sand aggregate size specific to Bethesda Terrace.

Fig. 22 - (3d.b) Flaking resulting in multiple flakes - detachment of multiple layers of flaking parallel to the stone surface.

Fig. 23 - (3f.b) Delamination - detachment of larger stone elements parallel to stone structure, but not necessarily to stone surface.

(4a.a) Fissures/cracks independent of stone structure - individual fractures or systems of cracking independent of natural stone features such as bedding, etc. or constructional causes (static stress, rust, etc.) (Not illustrated).

(4a.b) Fissures/cracks dependent on stone structure - individual fractures or systems of cracking dependent of natural stone features such as bedding, etc. (Not illustrated).

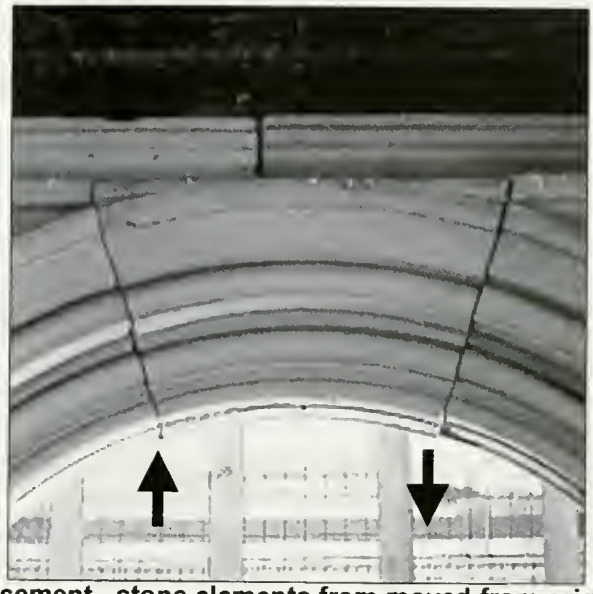


Fig. 24 - (4b) Displacement - stone elements from moved from original location due to natural or anthropogenic causes.

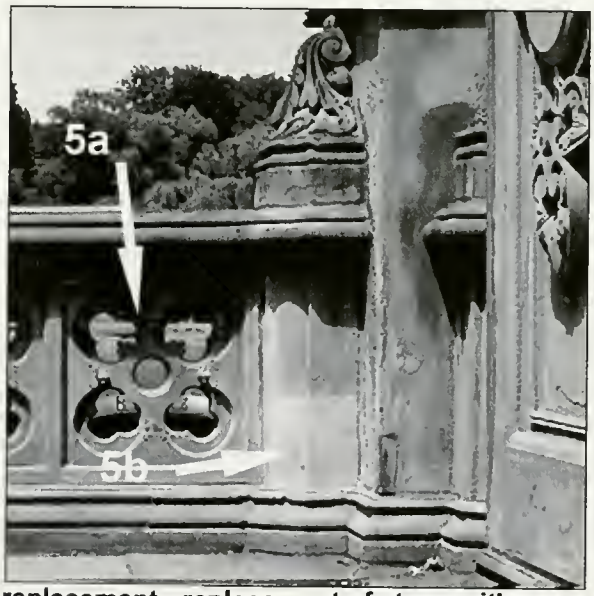


Fig. 25 - (5a) Stone replacement - replacement of stone with new stone. (5b) Artificial stone replacement/mortar patch - replacement of stone elements with artificial stone or mortars.

(6b) Different color mortar - replacement of original or most recent mortar with inappropriately colored mortar (Not illustrated). (6c) Missing mortar - loss of original or most recent mortar (Not illustrated).

DIGITIZATION

The option of scanning the specification drawings was researched; cost and time were considered. The poor quality of the specification drawing copies did not allow for effectively reproduced scanned images. A large amount of interference in digitized files would require several hours of clean up time. Clean up could take up to forty hours after which time, their translation to AutoCAD r14 could take place. Therefore, it was determined more cost/time efficient in this case to redraw the base drawings in AutoCAD r14 and overlay the digitized conditions layers directly in the digital drawing files. At this time, the completed drawings are stored on Iomega zip disks.

Measured elevations of the interior arcade at Bethesda Terrace were produced in AutoCAD release 13/14 based on the original Vaux and Mould drawings and the Ehrenkrantz specification measured drawings from the 1980s restoration project. These drawings detail the entire interior arcade walls. The drawings illustrate the interior arcade at Bethesda Terrace sandstone block by block. Drawing were printed on 11"x17" paper with color graphic symbols representing the conditions observed during the summer 1997 recording of the conditions survey(see appendix B).

Overlays for specific conditions recognized as of primary concern were developed, selected from the already comprehensive conditions categories already described. Previous long-term loss categories include the loss as the result of *breakage*, *rounding*, *differential erosion* due to weathering of stone components and *roughening*. Recent active loss and active conditions layers included *granular disintegration*, *flaking and delamination*, and *moisture penetration*. Surface deposit layers include *efflorescence and crusts*. Most of the crust material tested in the lab contained high quantities of soluble salt; therefore, crusts were included in the category with efflorescence. The major coloration found on the sandstone of the arcade was due to rising damp; therefore, coloration was included in the overlay with moisture penetration. See appendix B for conditions survey drawings.

PHASE II: ANALYSIS AND ASSESSMENT OF DECAY MECHANISMS AND PREVIOUS TREATMENTS

CHAPTER 3: COMPARATIVE ANALYSIS

Phase II of this project addressed the comparative analysis of the type, degree, pattern and location of the major weathering phenomena observed at Bethesda Terrace. It is important to establish past, present and future trends in the performance of the stone in order to determine the effectiveness of the previous treatments in comparison to the weathering of untreated stone. Overall patterns of visual change are observed and rates of decay hypothesized through the comparative visual analysis of historical images with contemporary photographic documentation. Analyses of the conditions survey by viewing the various combinations of deterioration type, extent and level in combination with historical documentation of areas previously treated provides comparative information on treatment effects on decay over time.

PREVIOUS TREATMENTS

The 1983-85 conservation program included a variety of treatments focused on improving both aesthetic and structural conditions of the sandstone observed at that time. A conservation assessment was performed based on the current conditions survey and material examination and analysis of the treated areas.

Honed surfaces were examined and their water permeability measured to determine possible physical surface alterations beyond aesthetics. Formulation of new composite repairs for the interior is probable given the aesthetic alterations, discoloration and staining of the existing patching on the exterior. Possible replacement in kind with compatible stone requires further analysis to determine its overall visual effectiveness over time in sustaining a coherent whole. Consolidation must be researched with regard to its effectiveness as well as its applicability, especially where water and salt penetration is expected to continue in the arcade. Previous interior waterproofing systems will need research and development.

The only previous treatment to the interior arcade sandstone elements was the removal of graffiti and the consequent cleaning of the stone, according to interviews with Kate Ottavino, the project architect for Ehrenkrantz, Architects. No consolidation, honing, composite repairs or dutchmen replacements were performed at that time. Removal of several construction additions, which formed the walls of a restaurant kitchen, occurred, as did the dismounting of the Minton encaustic tile ceiling. The ceiling was stored for future conservation. Consolidation testing was conducted by Norman Weiss on selected sandstone panels of the interior arcade according to Martin Stecklow, project contractor.[14]

[14]Stecklow, telephone conversation.

Consolidation experiments were also conducted by George Wheeler on three screening elements of the northwest balustrade and two diaper panels of the south stair walls.[15]

Previous treatments performed on the exterior sandstone elements at Bethesda Terrace are documented in the Ehrenkrantz, Architects' contract drawings for the general site work in connection with the Restoration of Bethesda Terrace including the Bridge and Landscape.

STRUCTURAL MOISTURE PENETRATION

Observations of leakage problems in the interior arcade at Bethesda Terrace were made during the conditions survey period. Water actively runs down the interior of the southern arcade columns during and after heavy rainstorms. This area is located underneath the base of the northern balustrade flashing on the 72nd Street Transverse Road. Other areas of penetration include the southwest and southeast ends of the central aisle of the arcade and the south wall of the west loggia where pooling of water occurs, possibly from rising ground water or blocked drainage.

[15] The areas treated were determined from information found in the thesis by Eileen Brown. The areas treated were clarified by telephone communication with G. Wheeler in March 1998, however no further information regarding observations or data related to this testing were available.

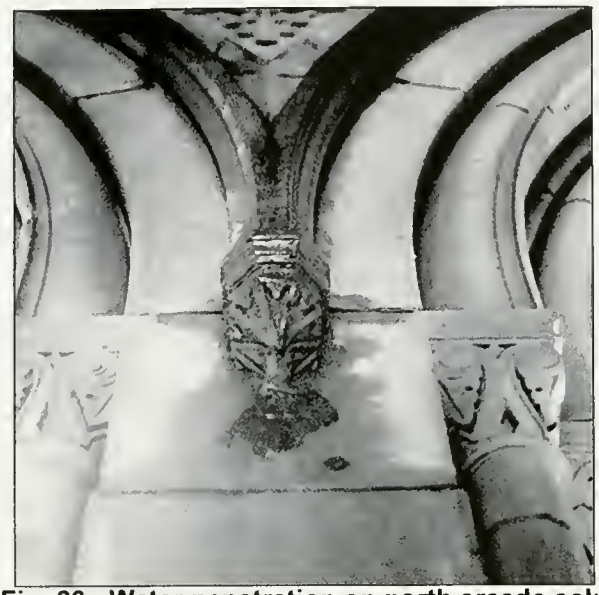


Fig. 26 - Water penetration on north arcade column.

Determination of the source of this leakage is critical. Water may be entering the interior by different paths. Possible sources are failing waterproofing coatings or flashing, mortar failure and open joints, rising damp from the ground or other means. A possible clogged drainage system could also create a backup of water in the area.

High levels of the water in The Lake at the end of the terrace caused flooding in the area in the past. Research of this aspect may reveal increasing water levels related to the lake and its effect on the terrace. It must be determined if today's water penetration issues in the interior arcade at Bethesda Terrace have worsened since original construction or the 1980s restoration, or are new conditions.

Existing arcade conditions strongly illustrate that water penetration has been a chronic problem that has led to damage and loss. Continued research into previous maintenance of this problem was beyond the scope of this project but is necessary to determine what treatments historically addressed similar issues at the site and what is viable today.

Waterproofing is essential in this case and completely dry, salt-free sandstone is optimally required in the interior arcade if any consolidation of stone is considered. Wet stone and salts can compromise the effectiveness of all treatments, especially consolidation, by limiting penetration, disrupting cure, causing staining and reducing bonding to the stone.

Environment

The environment of the arcade is sufficiently different from the exterior that the modification of the previous exterior conservation interventions must be considered for interior application. The interior arcade stonework experiences several types of unique exposure. The space is technically both above and below grade in certain areas. The southern terrace stairs descend to below grade exposing interior sandstone elements indirectly to both eastern and western exposures. This stairway also creates a wind tunnel through which

atmospheric pollution, rain and snow are at times rapidly carried deep into the interior of the arcade. The northern arcade also forms an open archway to the interior, however the wind tunnel effect seems lessened in this area probably due to its wider breadth. Rain, snow, dust and occasional spray from the fountain are sometimes carried to the interior through the northern opening. The interior arcade also experiences wet/dry and freeze/thaw cycling as the exterior; the cycles being fewer but probably longer in duration than the exterior.

Weather data shows that Bethesda Terrace is exposed to extreme temperatures recorded in both the summer and winter. According to the National Oceanic and Atmospheric Administration's *1986 Local Climatological Data Annual Summary for Central Park,* temperatures ranged from a low of 8°F to a high of 98°F.[16] The lowest average temperature was 22.1°F in February 1977 and the highest average annual temperature was 80.3°F in August 1980. Future monitoring of the interior/exterior climate the sandstone elements at Bethesda Terrace could provide further information concerning past and current conditions.

[16] National Oceanic and Atmospheric Administration, "Local Climatological Data: Annual Summary with Comparative Data, New York, Central Park, New York." (Ashville, NC: NOAA, 1986, photocopy).

RATE OF ALTERATION AND DETERIORATION

Stone performance and decay are a function of time. Historical documentation is often the only record available from which conditions can be deduced however, records often only note conditions as visible damage when materials, designs or treatments fail. This is particularly beneficial in assessing a site with repeated failures. Photographs and drawings can illustrate material conditions in some areas even if the original rationale for the image was not for conditions information.

Detailed historical documents of Bethesda Terrace are limited in their scope before the 1970s. Several reports to the Commissioners of Parks and Recreation mention the weathering of the sandstone balustrades at Bethesda Terrace, however no actual photographs clearly illustrate any characteristic quality of weathering observed today. The Archives of the Historical Society of New York City and the Museum of the City of New York hold a repository of historical photographs of Central Park. In these collections are several photographs of Bethesda Terrace which reveal deterioration in areas such and the carved bird panel screens which is still active and visible today.

Photographic records from the 1970s provide a second period of illustration. These records form a foundation for the first comparison of any measurable

amounts of alteration and deterioration over time (~25 years). Elements of the sandstone are illustrated between 1960-1980 in only a few photographs (slides) in the Central Park Conservancy archives. The bulk of the images archived in this collection are from the 1980s restoration project. The clearest illustrations of previous observable deterioration at Bethesda Terrace are seen in slides from the 1980s restoration project. The focus of most of these photographs was to record the restoration project. All sandstone conditions recorded in the survey this summer were previously recorded in the 1980s project. Documentation from the 1980s restoration project was designed with the idea of reassessing the performed treatments several years after their completion.

CHAPTER 4: FACTORS AFFECTING THE CONDITIONS OBSERVED

The conditions occurring at Bethesda Terrace vary from the interior to the exterior. This is revealed by a comparison of the areas studied in the conditions survey conducted during summer 1997. The conditions survey recorded with high detail the decay patterns. Dominant conditions observed on the interior arcade were identified in the survey and graphically represented in the following drawings(see appendix B). These drawings were used as a tool to determine the type, status, extent and pattern of various conditions of damage requiring future treatment. The following categories were identified as the major conditions observed in the arcade at Bethesda Terrace over time.

Previous long-term loss (drawings 1-CA, 1-EL, 1-NS and 1-WL) is defined as the loss of stone surface approximately one half inch or deeper. This loss is divided into two types, natural stone decay occurring from weathering, climate, construction, and anthropogenic damage (human alterations or destruction of the stone).

Surface deposits (drawing 2-CA, 2-EL, 2-NS and 2-WL) are accretions on the surface of the stone represented by crusts, efflorescence, or discoloration. In the conditions survey this category was overlaid with water infiltration and rising damp. The following drawings separate these into two categories with

efflorescence grouped with crusts because the majority of the crusts in the arcade were found to contain salts. Rising damp and water infiltrations are grouped together as ***Moisture infiltration*** (drawings 4-CA, 4-EL, 4-NS and 4-WL).

Recent active deterioration (drawings 3-CA, 3-EL, 3-NS and 3-WL) on the interior sandstone was found to consist primarily of sanding and flaking. These categories were separated into two drawings. Active deterioration from flaking also includes the category of delamination because these phenomena are similar although their specific causes have not yet been determined.

There is no strong correlation between the condition of the exterior sandstone at Bethesda Terrace and the interior sandstone of the arcade. This does not exclude the fact that similar conditions can exist in both areas. Both the terrace and the arcade were constructed from the same sandstone from New Brunswick, Canada. The stone is a homogeneous aggregate of uniform quartz crystals mechanically bound with almost no matrix. Further analysis is required to classify this sandstone in petrographical terms given the lack of a visible matrix. Feldspars are present in very small quantities.

Weathering out of bedding planes is rarely observed in this stone. When seen, this weathering is probably due to micro-fabric inconsistencies in the block of stone and orientation rather than the geo-chemical composition.

The environments, climatic conditions and decay mechanisms affecting both areas are very different. Temperature, moisture, and relative humidity all differ dramatically from the interior to the exterior. The exterior stone is affected by evaporation that is more rapid and general cycles of freeze/thaw due to exposure. The interior arcade remains wet for longer periods allowing a greater potential for chemical degradation. It also has a high degree of salt contamination because it is located under the transverse road. Thermal change is less likely due to its protected exposure.

Differential conditions will cause differential treatment performance. This suggests that the differing conditions on the interior arcade will require modification of the treatments applied to the exterior.

Factors affecting the sandstone in the terrace and arcade at Bethesda Terrace are varied. Factors responsible for the decay of the sandstone can be classified into six specific categories based on research and observations.

- Stone composition and type
- Location
- Construction and design
- Orientation
- Tooling and surface finishing
- Past treatments

Ideally, these factors influence stone performance in different magnitudes at different times in the weathering cycle of the stone. The action or effect of each factor must be studied singularly and comparatively through the conditions survey to identify the order and sources of the decay mechanisms. A comparative reading of past and present conditions in conjunction with related data such as environmental monitoring, and stone and treatment analysis offers the best method to identify decay mechanisms and predict future performance and durability.

Location

The major factor affecting the sandstone in both the terrace and the arcade apparently is location. This category includes several sub-factors. Environment, climate, sub-surface levels, drainage and topography define the *location* of the sandstone. Cardinal orientation (north, south, east and west) is also included in this category. The siting of Bethesda Terrace in the park in an open area near a small lake creates a setting with a specific and unique environment. The overall

temperate climate of Central Park is marked by great variability in seasonal weather. Hot and humid as well as cold and wet variations create a location where wet/dry and freeze/thaw cycling can stress the sandstone. The exterior terrace exhibits differential erosion of the sandstone that is directly related to the cardinal orientation of the architectural elements. This effect is seen most clearly on the western exposure as the differential weathering of small elements of high surface area relative to their size such and the carved stair and terrace balustrade screens.

National weather data confirm that storms come from the northwest causing the weathering observed. Differential surface erosion is conditioned by the variability of strata, composition and bedding structure, common in sandstone. Observed moisture penetration and rising damp on the interior stone suggest that the decay seen correlates with the prolonged moisture occurrence. The more severe nature of the erosion on the interior may be attributed more to the disruptive pressures of crystallizing soluble salts, the chemical dissociation of soluble minerals and the instability of the clays in the stone.

CONSTRUCTION AND DESIGN

The design of the terrace created microclimates within the site from the beginning. The below grade area under the 72nd Street Transverse Road sustains lower temperatures and higher humidity than the surrounding area most

of the year due to its subterranean environment. In addition, high evaporation from the wind-tunnel effect keeps moisture cycling throughout the arcade. The two loggias of the arcade create two interior rooms of additional differing microclimates. The spatial configuration of the interior arcade is formed by walls of inset granite panels and sandstone pilasters. These perimeter walls are built into the surrounding terrain of the site. The perimeter walls of the loggias and the southeast and southwest walls of the central arcade are in direct contact with the earth. The northern screens of the central arcade are formed by three-dimensional freestanding square columns.

The 72nd Street Transverse Road crossing over the arcade in an east/west direction was originally structurally supported by the arcade's brick vaulting and steel beams which carried the load to the stone arcade screening and masonry walls. A new structural support system of steel I-beams was installed during the 1980s restoration. Past and active conditions recorded during the survey suggest that moisture penetration has been a long-term recurrent problem associated with the road above. Roadbed water and snow in association with de-icing salts used by the park account for the large amount of water and salt infiltration observed in the arcade. This has been the major factor contributing to the deterioration of the sandstone.

The construction of the shallow barrel vaulting of the arcade ceiling may also create a potential for surface water transport to the sandstone. The iron girders lead water directly from the vaults to the voussiors of the perimeter wall pilasters where it collects at the impost blocks and runs down the pilasters. This mechanism may have been even more pronounced before the removal of the Minton tile ceiling because water was pooling on the backsides of the panels and probably running directly to the stone. The dismantling of the ceiling probably diminished moisture collection and enhanced salt efflorescence as the stone dried.

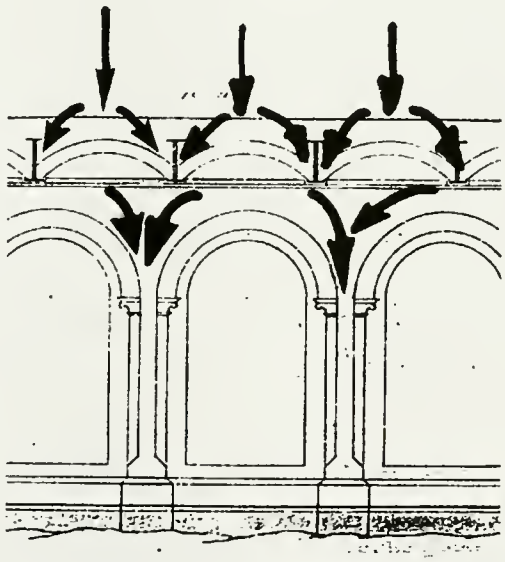


Fig. 27 - Path of water penetration through ceiling to voussiors.

The location of the arcade below grade also creates a potential for moisture penetration from rising ground water. This is clearly seen in the lower interior

sandstone elements that have weathered and darkened. It is not known what, if any, moisture barriers remain at road and arcade pavement levels. Limited air circulation allows the stone to remain wet for long periods regardless of the water source.

The perimeter walls of the terrace show the most pronounced sandstone decay, relative to the freestanding arcade screens. This decay is explained by moisture penetration through the adjacent earth and rubble fill that abuts the brick and rubble stone foundation of the arcade. No metallic cramping was drawn in the original construction drawings and no staining from cupric or ferric oxides are evident in the stone today. This suggests that the sandstone, which is a semi-load bearing veneer, is masonry bonded into the structural support wall behind. This penetrable bonding can carry moisture directly to the stone especially in areas where the air space between the stone veneer and the foundation wall has been filled with porous materials.

SURFACE FINISHING OF THE STONE

Tooling and surface finishing of stone can often affect the physical properties of the stone creating a potential for specific decay. The major areas apparently affected are those that are point-carved, bush-hammered, sawn and rub finished. The bird panels of the exterior cheekwalls and the carved capitals of the interior arcade exhibited erosion and delamination as early as the late nineteenth century

as documented in historical records.[17] The original sawn and rubbed finish on the exterior, especially under drip moldings, and the bush hammered surfaces of the dados at ground level were removed by honing in the 1980s restoration. This suggests that deterioration of these finished surfaces was acute enough to require removal and probably most affected by prolonged moisture-related damage.

The degree of deterioration of the interior capitals in some areas has resulted in complete loss of the elements, and deep rounding out of the stone surface. This is due to a combination of factors including the high relief surface carving increasing the surface area, coupled with the more readily available water in the arcade. The increase in surface area allows greater evaporation of the water containing soluble salt, therefore enhancing salt crystallization and more rapidly degrading the stone.

On the exterior, the weathering of the carved panels results in a delamination in areas where moisture tends to linger on the carved areas. Deeper erosion of this nature is seen on the west facing panels because of exposure. Although, some areas below the drip moldings and protruding carved detail where water pools are eroded on all panels.

[17] Late nineteenth century stereopticon photographs of Bethesda Terrace found at the New York Historical Society documented the carved sandstone details in close-up pictures. In the bird panels and terrace pier, die, and apron carvings early deterioration of the stone can be seen.

Fig. 28 - Norhtwest bird panel, western exposure.
Note erosion under drip molding along the top.

The deep pockets of erosion are possibly a function of the protected location on the panel coupled with the highly carved areas creating watersheds, which also cause differential erosion. The deeper carved areas of the panels are eroding out more rapidly than stone located directly under run-off water. This condition is possibly due to moisture accumulation and freeze/thaw cycling especially in the winter where snow fills these pockets. This adds to the hypothesis that the sandstone of Bethesda Terrace is highly sensitive to prolonged water saturation.

Consequently, appears that water penetration is a major factor originating from several sources and transported by several ways throughout the arcade. The accumulations of rainwater due to exposure, poor drainage and possibly clogged storm drains or broken drainage pipes provide sources of moisture for the exterior terrace. The interior stone is subject to the same factors plus the penetration from above by pooling salt-contaminated water on the paving of the middle terrace. The perimeter walls are exposed to moisture penetration from behind through the foundation walls and the rising damp from the surrounding earth.

STONE TYPE AND COMPOSITION

The sandstone of the Canadian Maritime Provinces became popular in the United Stated during the late 1800s. It was used in the construction of Bethesda Terrace and throughout New York City.[18] The stone was known for its durability, consistency of weathering, color, fine-grained composition, and its ability to be carved in detail in any direction- classifying it as a "freestone." The variety of colors available and the documented performance of the sandstone from the Maritime Provinces, coupled with the ease of transportation to the States, created a profitable and long history of quarrying and exportation. The maritime deposits provided a great variety of light colored rocks that were extracted and

[18] The Maritime Provinces of Eastern Canada including New Brunswick, Nova Scotia, and Prince Edward Island, produced most of the sedimentary sandstone for building purposes used in eastern Canada and exported to the eastern United States.

used as smoothly dressed ashlar masonry. Quarries in this region remained open in some cases up to the present day. The use of presently quarried sandstone from the region is mainly as restoration material.

The Dorchester stone (named after the Dorchester Quarry in New Brunswick) used in the construction of Bethesda Terrace was known throughout New England markets in the 1800s as Nova Scotia Sandstone. Merrill notes this confusion among Canadian sandstone names at that time.[19] The original Dorchester excavations provided stone for the construction of many structures, including Central Park's perimeter wall, Bethesda Terrace and The Dakota apartment building. In the 1980s, the reopened quarry also supplied blocks for their restorations. The name "Beaumont Quarry" has come to represent all stone quarries situated in the western half of Fort Folly peninsula including the historic Dorchester Stone Works, Ltd.

The former Boudreau quarries, now Bee Stone Co. Inc., first operated under the guidance of the Dorchester Olive Freestone Company of New York[20] incorporated in 1848. They are located just outside of Boudreau village on the

[19] George Perkins Merrill, *Stones for Building and Decoration.* (New York: John Wiley, 1910).

[20] Gwen L. Martin, *For Love of Stone*, (Nova Scotia: New Brunswick Department of Natural Resources, and Energy, Mineral Resources Division, 1996). It was disputed locally whether the company had the right to own land in Canada because it was based in the United States. A rival firm, The Dorchester Manufacturing Company, also New York based, was one of the petitioners against Dorchester Olive Freestone Company. Speculation suggested that this was done to obstruct their progress in the province. The government ruled in favor of The Dorchester Olive Freestone, however and their business was launched.

Fort Folly Peninsula in New Brunswick. The Dorchester Union Freestone Company sold most of its property to John Furlong and John Deery of New York in 1895. The two men did not continue the business however. In 1989, the property was bought by Fred Pellerin and re-opened mainly for restoration purposes.[21] The company now operates under the name of Bee Stone Company Incorporated and holds quarrying rights to the nearby Caledonia quarries. Bee Stone Co., Inc. provided the Central Park Conservancy with restoration sandstone for Bethesda Terrace in 1983-85.

Sedimentary rocks are formed from the sedimentation of fragmented rock. The various strata, whether thick or thin, are separated by planes of parting called bedding planes. Splitting of the rock occurs most easily along these planes. Most problems with sandstone used in building are associated with the improper laying of stones in relation to the bedding. Other problems arise from the mineralogical and chemical composition of the stone during exposure. The matrix, or cementing material between the aggregate of the sandstone is either calcareous (lime based), ferruginous (iron oxide based), siliceous (silicon based), or argillaceous (clay based).[22] As mentioned, the grains of the Bethesda Terrace sandstone are mechanically bound with almost no matrix.

[21] Fred Pellerin, mentioned in a telephone conversation that recent exploration drilling showed a great deal of valuable building material and he stated that his company, Bee Stone Co., Inc. will pursue this market.
[22] Some sandstone may contain a combination of matrices.

The difference in the color of sandstone is the result of chemical composition and the presence of accessory minerals such as hematite, limonite and pyrite.[23] In the case of the gray to yellowish-gray stones used at Bethesda Terrace, greater oxidation produces a mellowed yellowish tint to the original color of the stone. Thin section microscopy revealed that the sandstone at Bethesda Terrace is made up of mainly quartz with traces of plagioclase feldspars and iron magnesium. Decomposition of the feldspars to clay can prove problematic. The iron magnesium exists in the stone in a highly altered state with iron oxide. This alteration imparts the stone with its color.

The size, shape and distribution of the grains within the stone help to determine its durability and workability. The finer, more evenly distributed the grains the more valuable the stone is for building. The New Brunswick sandstone used at Bethesda Terrace has fine even grain size and even distribution (see figures 29-33). The clear isotropic grains in the stone were identified with cross-polarized light as quartz crystals. The plagioclase feldspars were identified as feldspar, biotite and albite. Visual microscopy with cross-polarized light identified the characteristic twinning of feldspar crystals. Biotite exhibited the characteristic

[23] Sandstone quarried in the Maritime Provinces varies in color from olive-green to blue, brown and red. The "grey" stones tend to weather to a buff or yellow, whereas what is called a "blue" stone will weather to a truer gray color depending on the amount and type of oxidation. The "blue" stone tends to contain lower amounts of iron containing minerals, but the color of sandstone can also be due to the composition of its matrix. In the case of argillaceous sandstone, most Maritime Province sandstone, the high clay content can also create a Gray hue.

birefringence of mica. The ferro-magnesium particles were identified with plane-polarized light. These particles appear as anisotropic inclusions ranging in color from dark browns to black depending on the level of alteration to the iron magnesium due to geologic water and high pressure and temperatures during formation. In addition, the oxidation in these particles causes them to shrink and create voids in the rock.[24]

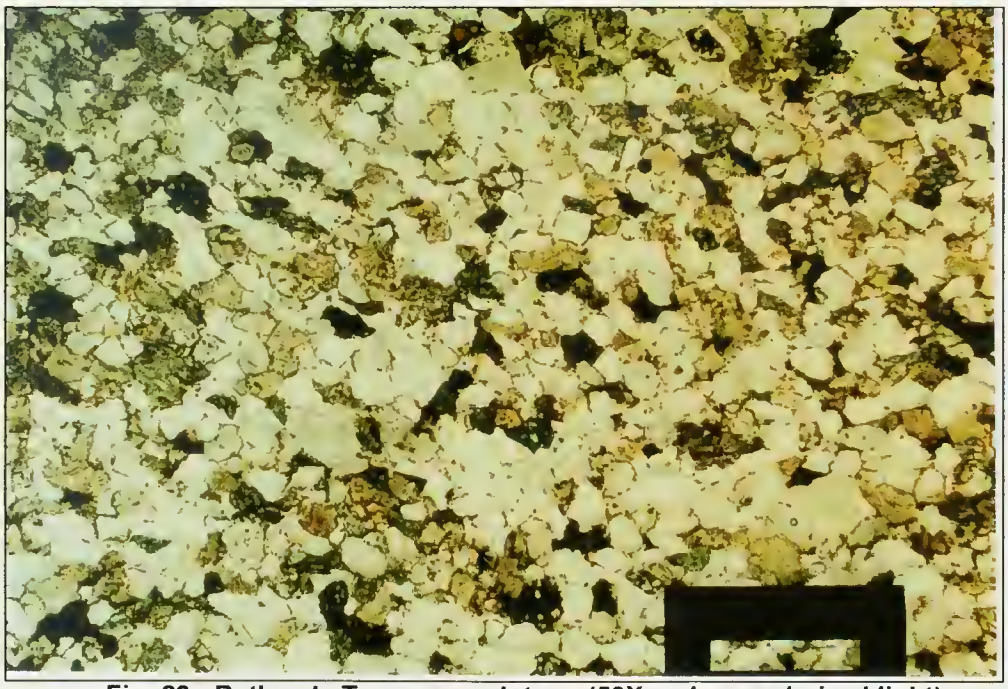


Fig. 29 - Bethesda Terrace sandstone (50X – plane-polarized light). Note densely packed, well-sorted grains of quartz. Black inclusions are altered ferro-magnesium. Other trace minerals include plagioclase feldspars.

[24] Dr. G. Omar assisted in the identification of the trace minerals of the Bethesda Terrace sandstone. He suggested that the oxidation and shrinkage of ferro-magnesium components in the stone during it formation could create a potential access for water into the stone.

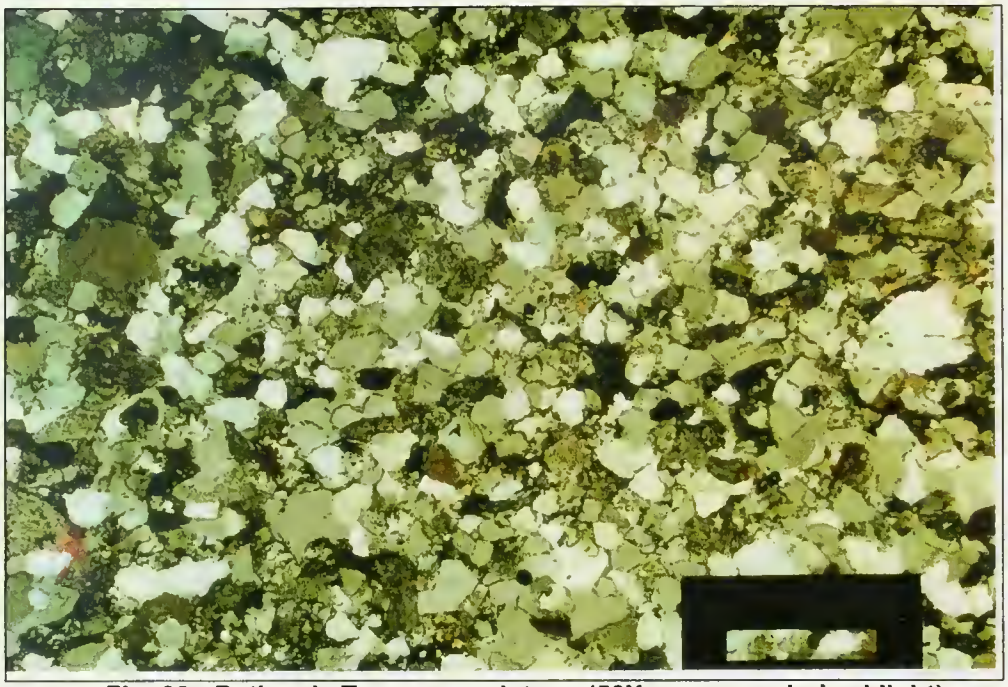


Fig. 30 - Bethesda Terrace sandstone (50X – cross-polarized light). Isotropic quartz grains appear as various shades of gray with cross-polarized light.

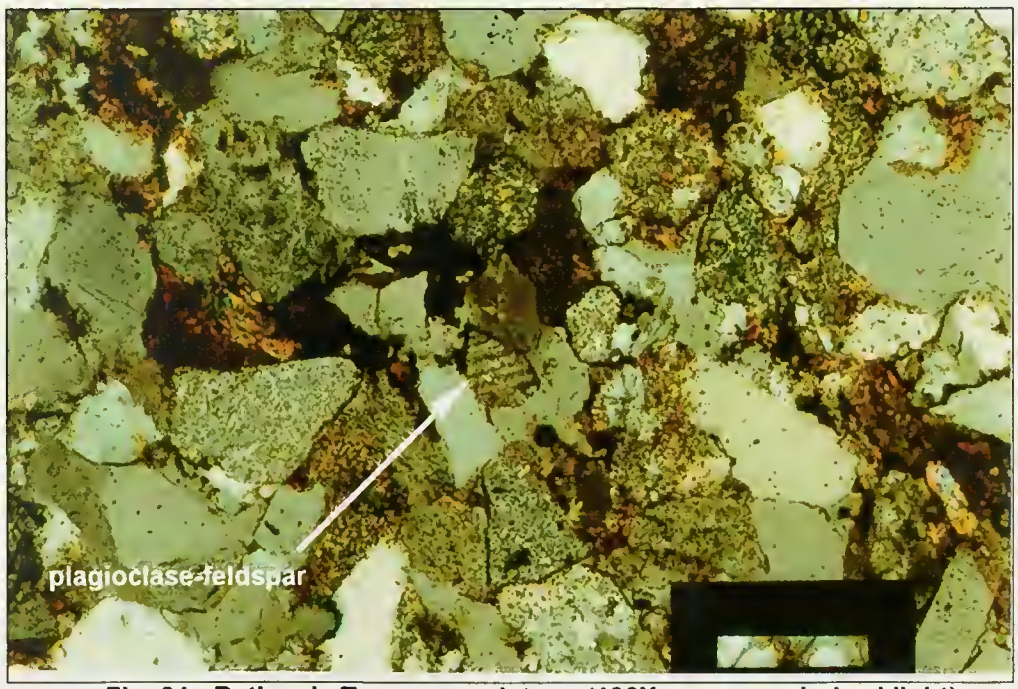


Fig. 31 - Bethesda Terrace sandstone (100X – cross-polarized light). Note twinning of plagioclase-feldspar inclusion.

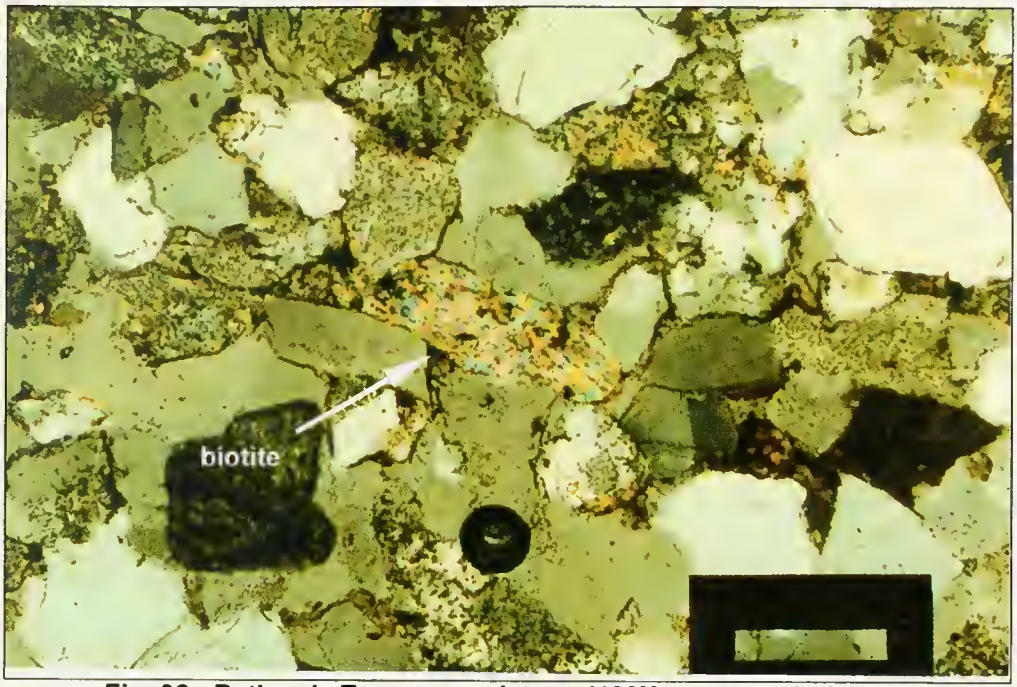


Fig. 32 - Bethesda Terrace sandstone (100X –cross-polarized light). Note birefringence of biotite (probably mica) crystal.

Fig. 33 - Bethesda Terrace sandstone (100X – plane-polarized light). Large inclusion of iron-magnesium in highly altered state.

Toward the end of the nineteenth century, the first Geological Survey of Canada was published by the Canada Department of Mines.[25] It provides additional notation of the performance and decay of the stone used at Bethesda Terrace. In general, olive-green and gray sandstone, the type used at Bethesda Terrace varies greatly in texture, from coarse grained to fine-grained, with the olive-green being the coarser of the two. The average crushing strength was determined by Parks to be between 8,869 - 17,893 pound per square inch (psi). Transverse strength was recorded at 809 - 1700 psi, specific gravity ranged from 2.64 - 2.69. Pore space was not less than 10% with an average of 13.73% recorded in 1914. Finally, the average weight for olive-green/gray sandstone was 143 pounds per square foot.

All samples tested by Parks showed considerable loss of strength when saturated with water resulting in a measurement on average of just less than half their dry weight strength. An experiment for the "coefficient of saturation" determined that the effects of frost on the stone were "not to be seriously apprehended."[26] He also mentions that the most important factor in the durability

[25] Parks, Geological Survey of Canada, v. 2, 1914. Parks offers an in-depth study of the physical properties of Canadian building stones. His studies included information regarding specific gravity, porosity and permeability, water absorption rate, weight, saturation, dry and wet crushing strength, tensile strength, corrosive effects of oxygen and carbonic acids, "chiseling factors" (to express the ease with which a stone can be carved), and "drilling factors". His testing methods were taken from Merrill's testing procedures for the United States Geological Survey and therefore create a consistent basis for comparison to other North American sandstone.
[26] Ibid., 27-8.

of sandstone's color is the durability of its matrix. There is a greater chance for discoloration in cases where ferrous salts are present.

Composition is important in any study of stone deterioration and treatment performance. Physical and chemical properties of building stone determine the basic performance and weathering characteristics of stone. The consistency or variability of composition determines the economic viability of quarry operation. Historically, the Dorchester freestone was favored for its good durability and consistent performance block to block. This was noted at Bethesda Terrace where it was rarely observed that blocks displayed a completely different deterioration. However, it was observed that neighboring blocks occasionally exhibited differing degrees of deterioration especially in the southern arcade stairs. Bedding and orientation of the stone was occasionally visible from the differential weathering of the strata. Given the overall durability of the stone, the variation in type and degree of deterioration at Bethesda Terrace is attributed largely to extrinsic factors rather than intrinsic composition and orientation.

PAST INTERVENTIONS

Finally, it was observed that some of the previous treatments have directly altered the weathering and appearance of the stone. The honing altered the cosmetic appearance of the stone creating smooth faceted planes where previously they were uniformly sawn and rubbed finished. The replacement stone dutchmen have weathered to a different color from the original stone causing noticeable visual disunity. Composite repairs were well installed, however alterations in the color of the patches and a black crust and staining formation surrounding the patch have altered the aesthetic appearance of the compensation and thus the whole. No observable conditions or decay could be attributed to the consolidation.

CHAPTER 5: CORRELATION AMONG CONDITIONS

The major conditions occurring at Bethesda Terrace were observed and recorded on the conditions survey. Through analysis of the drawings produced, each major category was divided into the dominant conditions within the category. Categories have been defined in previous sections. The three prominent conditions of *Previous Long-term Loss*, defined as the areas where the stone surface is worn or broken more than one quarter inch back from the original surface prior to the recording of conditions in the summer 1997 are *differential erosion* of the stone components, *rounding* out of the surface of the stone, and *roughening* of the surface. *Breakage* was separated into a category by itself to differentiate it as anthropogenetic deterioration. The dominant condition in the *Surface Deposits* category was the formation of efflorescence and crusts, which were graphically combined after analysis, showed that the crusts had strong concentrations of salts. *Moisture Penetration* and rising damp were combined to create a new overlay of deterioration mechanisms. Finally, the *Recent Active Deterioration* mechanisms were separated into two categories; *granular disintegration*, the loss of matrix or aggregate resulting in friable sandy surfaces, and *delamination and flaking* of the stone or crusts described as loose lamellae flakes. The following are the observed correlations for differing conditions.

PREVIOUS LONG-TERM LOSS: DIFFERENTIAL EROSION, ROUGHENING AND ROUNDING

Analysis of the *Previous Long-term Loss* categories revealed that most of the previous deterioration in the arcade is found on the perimeter walls of the central arcade and the west loggia (see drawings 1-CA and 1-WL). The majority of the loss is from a rounding out of the stone surface. *Rounding* is found primarily on the masonry of the perimeter walls, the most loss evident is on the west wall of the west loggia and the capitals and bases of the columns of the arcade. A large number of the decorative filigrees between the arches are also rounded out.

Roughening of the stone is observed in the west wall and freestanding arcade of the west central arcade bases and benches. *Differential Erosion*, dependent on the structure of the stone, is most often observed in the arches of the central arcade and the south wall of the loggias. Only one freestanding column of the arcade exhibits weathering of the stone.

Breakage of the stone is primarily due to human factors such as alterations to the interior of the arcade located in the lower columns and benches. Some drilled holes were observed mainly in the east loggia. This information was confirmed with the Ehrenkrantz specification drawings from the 1980s restoration.

Overall, if all three conditions are analyzed together it is observed that the inactive past loss is located in the arches and pilasters of the perimeter walls, some column bases in the central arcade and loggias and the west loggia. It is probable that the decay agents affecting these areas were removed or stopped in the past. The existence of this old damage indicates past water and salt infiltration and poor maintenance as the probable causes. The location, above eight feet and above the usual maintenance level, of the majority of the damage is high enough to have been overlooked during routine maintenance.

All three conditions may be varying symptoms of the same deterioration mechanism exhibited in different ways based on the location, orientation and bedding of the stone. Where all three occur together, they exist in segregated and overlapping association according to their location in the upper, middle or lower areas of the arcade. This is very evident on columns 1 and 2 of the west loggia (see drawing 1-WL) and the perimeter walls of the central arcade (see drawing 1-CA). Roughening and rounding out of the stone occur peripherally to the weathering stone with some overlap in the carved details. All may be ultimately caused by the same decay mechanisms, showing correlative but differing conditions when compared. Rounding and weathering are mainly observed in the upper regions of the arcade. Roughening tends toward the lower regions and fills in between the greater areas of weathered and rounded stone.

The probable cause of this deterioration is the loss of grain to grain cohesion in the sandstone caused by freezing water and/or crystallizing salts.

Breakage

Breakage falls in a category by itself. Most of the breakage of the sandstone is attributed to human causes due to the construction and removal of the restaurant and kitchen additions that were located in the loggias and the dismantling of the ceiling panels. Some areas where breakage has occurred exhibit efflorescence, however the loggias are saturated with salts, therefore no conclusions can be drawn based on the lack of a pattern elsewhere. Five of the eight areas showing breakage are not clearly anthropogenetic and do exhibit moisture penetration. Some fracturing from water penetration is possible, however breakage is not prevalent throughout the arcade or terrace therefore this correlation cannot definitely prove that water is causing the sandstone to fracture and break apart. Losses due to breakage do not correlate with any other condition observed and are therefore considered unique, as they were one-time actions resulting in a permanent loss.

Previous long-term loss and salts

Efflorescence and crust formations are not often observed on the weathering sandstone elements in the central arcade. It is possible that the weathering out of the sandstone carries salts, crusts and aggregate away. Efflorescence is seen below the weathered stone. In addition, efflorescence and crusts are less

prevalent on the roughened surfaces when compared to the rounded surfaces. Efflorescence is observed on 55% of the occurrences of rounded sandstone elements and 90% of the occurrences of rounding are surrounded by efflorescence. This is the greatest percentage of previous long-term loss exhibiting efflorescence or crust formation. The weathering stone shows that 45% of the occurrences have efflorescence on them with only 80% surrounded by these conditions. Roughened surfaces exhibit the least amount of efflorescence with 40% of the occurrences showing efflorescence or crusts and only 70% surrounded by these conditions. Roughening tends to be in the column bases in open arcade areas. These areas show less water and salt saturation. This suggests either the salts remain in the upper regions of the stone, penetrating directly from the roadbed, or possibly are carried by rising damp, or they are washed away from the lower regions by moisture penetration. This condition is not observed anywhere on the exterior sandstone of the terrace.

PREVIOUS LONG-TERM LOSS AND MOISTURE PENETRATION

The relationship between moisture penetration and weathered, rounded and roughened areas suggests that stone that stays wet longer deteriorates less because salts will crystallize outside the stone due to evaporation. This is evident where there is weathering of the stone on the perimeter wall above the line of active moisture penetration. Rounding is also seen on the perimeter walls where moisture penetrates, but no distinct patterns reveal that the current

moisture is responsible for this previous long-term loss. If rounding is a factor of water penetration then past water infiltration may have caused this past loss. Roughening of the stone does occur above areas where current moisture is high or constant. This pattern is seen in the bases of the freestanding columns and where the perimeter walls are subject to water penetration from behind. If this deterioration is directly tied to moisture penetration and its location in the arcade then the patterns of previous weathering, rounding and roughening indicate a shift in the areas affected by moisture. This suggests that the severity of erosion on the areas previously affected and the current areas of active deterioration indicate the amount and duration of the moisture penetration. Current areas of previous long-term loss affected by moisture penetration experience both active loss and no loss at all. It is possible that in areas that remain wet, no soluble salts will crystallize and therefore less damage from this factor will occur. Determination of the differential amounts of previous long-term loss caused by salt crystallization related to moisture penetration and deterioration due to freeze/thaw cycling requires documentation and photographs that have not been made. Prolonged moisture may be, however, responsible for other decay mechanisms such as biological attack and chemical dissolution.

Recent Active Deterioration

The analysis above summarizes the relationships between the previous long-term losses observed in the arcade of Bethesda Terrace and their correlated interplay with the conditions of efflorescence, crusts and moisture penetration. The following analysis details the interrelated aspects of the active decay mechanisms with the previous long-term loss categories and efflorescence, crusts and moisture. In general the two conditions do not overlap suggesting that they are the results of the same decay mechanisms working in different ways on the stone based on the observed factors of location, orientation, design, finishing and stone type. The active decay in the arcade is primarily from flaking of crusts, delamination of the stone and granular disintegration.

Granular disintegration

Granular disintegration occurs on the pilasters of the central arcade that tend to dry quickly and do not remain wet. This phenomenon is possibly due to repeated wetting and drying of the stone causing salt crystallization within the pores of the stone. The result is a loss of grain to grain cohesion. Granular disintegration is observed in the capitals, arches and pilasters of the central arcade wall stone where weathering out of the stone components also occurs (see drawing 3-CA). Most of these flat surfaces of the pilasters dry faster than the highly carved areas. The disintegration is seen below the weathering stone. The weathering of the stone may result in the loss of sand particles and salt deposits mainly

visible on the lower stones. Granular disintegration is also observed below roughened stone surfaces. Approximately 25% of the occurrences where previous long-term loss is due to a rounding out of the stone exhibit the condition of granular disintegration. Granular disintegration is seen surrounding the perimeter of 40% of these areas. This is the major pattern and correlation between all of the conditions of the survey. This combination occurs on all of the perimeter walls. Where rounded blocks exhibit granular disintegration, the resultant aggregate deposition is mostly around the rounded areas or above the boundary of the erosion suggesting that this deterioration is more rapidly occurring near the edges of the affected areas.

DELAMINATION, FLAKING AND CRUSTS

Flaking and delamination is mostly seen on the blocks above the column bases on the north and south arcades and the arches near the north and south of the arcades. Flaking is primarily the loss of the already formed crusts associated with efflorescence, however, in the column base areas the condition is distinct delamination of the stone surface. These conditions, like the granular disintegration are the result of soluble salts, and water infiltration, and wetting and drying. Flaking and delamination are not seen on rounded or weathered areas, however it is seen above roughened areas. This corresponds with the idea that the roughened areas are subject to higher amounts of saturation while flaking is due to the crystallization of salts below the surface of the stone. This

subflorescence suggests that the evaporation zone of the sandstone is below the surface of the stone. Evaporation occurs quickly within the sandstone at Bethesda Terrace.[27]

The crusts observed on the interior arcade are primarily the result of a buildup of the sand grains disintegrating from the substrate combined with the salts evaporating out of the stone. The result is a loosely attached crust that forms over the carved surfaces retaining the shape and color of the substrate. This crust distorts through expansion and contraction with relative humidity and temperature fluctuations. It flakes off, disintegrates, and is therefore distinguishable from areas of delaminating stone on the exterior terrace.

ACTIVE DETERIORATION AND SALTS

Another major relationship between conditions is observed when correlating efflorescence and moisture penetration with recent active deterioration. The occurrences of areas exhibiting granular disintegration also show that approximately 75% of these areas have associated efflorescence on and 90% have efflorescence surrounding them. Delamination and flaking show slightly less visible salt contamination with approximately 60% on the occurrences and approximately 80% surrounding the occurrences. Flaking and delamination is

[27] This is based on the results of the NORMAL 29/88 test conducted to determine the Evaporation Index of the Bethesda Terrace sandstone.

definitely from the loss of crust buildup. Crusts are loosely attached to the substrate and they detach because of expansion and contraction, and possibly from vibrations from the road above. In addition it is noted that delamination occurs in the column bases. Where there is intermittent moisture in the arcade there is efflorescence. Delamination and disintegration occur with moisture in the corners of the loggias and at the corners of the entrances to the central arcade and loggias.

Overall active deterioration

The overall correlation between the active deterioration and the areas of previous long-term loss show that delamination and flaking occur above the roughened stone saturated with water in the freestanding columns. Granular disintegration overlaps with the weathering stone in the east arches of the central arcade and the perimeter walls. Disintegration is below the roughened surfaces in the arcade arches. The rounded areas of previous long-term loss and granular disintegration are the two conditions that most strongly correlate. Overall, disintegration is peripheral to delamination, most commonly with the disintegration below the flaking or delaminating areas. This is clearly seen at the ends of the central arcade and the northern entrances to the loggias where exposure to the outside air creates rapid evaporation cycling (see drawing 3-CA).

Finally, the active deterioration is observed as the continuation of past activity in the central arcade perimeter walls (see drawings 1-C and 3-CA). The active deterioration in the loggias is possibly a new condition. These areas do not exhibit large amounts of past losses, especially in the southern wall of the west loggia where the current active loss is high, but the total loss of stone is still of shallow depth.

Moisture penetration is the major factor affecting the stone as it is responsible for many conditions including the transport of soluble salts and the destructive results of their presence due to evaporation, expansion during wetting, and freeze/thaw cycling. Additionally, moisture penetration is occurring not only from chronic rising damp from groundwater and speculated drainage problems, but also in the form of constant saturation from falling damp from the terrace and road above the arcade.

CHAPTER 6: CHARACTERIZATION AND ANALYSIS OF UNTREATED AND TREATED STONE

Laboratory testing, chemical analysis and physical characterization of the sandstone and its previous treatments at Bethesda Terrace were conducted at the Architectural Conservation Laboratory, the Laboratory for the Research on the Structure of Matter and the Department of Geology at the University of Pennsylvania. Some FTIR analyses were also conducted at the conservation laboratory of the Philadelphia Museum of Art. Water absorption by capillary action was also tested in-situ at Bethesda Terrace. These investigations aided in the assessment of the effects of the consolidants, patching materials and honing treatments on the sandstone.

Five 1 ¼" diameter core samples from the Bethesda Terrace sandstone were retrieved with a water-cooled core drill. Three of the samples were taken from the east elliptical arm of the upper terrace. Each of these samples represented a specific treatment from the 1983-85 restoration project: one sample from a honed area, one from a composite patch, and one from an area previously recorded as consolidated with Wacker OH™.[28] The other two samples were taken from the diapered panels of the north stair cheekwalls. One represents the documented

experimental application of Wacker OH™,[29] the other the consolidant Brethane.[30] Three samples in the form of flakes were taken from the delaminating northwestern stair balustrade and a sample of patching material was taken from the northwest pier on the lower terrace that showed the most black staining. Samples of the crust were also scraped from this area. Finally, salt and efflorescence samples were taken from the pilasters of the west loggia of the arcade. The following matrix illustrates the testing proposed for each sample taken and the corresponding questions to which the results of these tests were applied.

[28] Kate Ottavino, project architect for the 1980s restoration verified during a site visit in summer 1997 that the exterior piers panels were consolidated with a spray application of Wacker OH™. The roll molding of the panel and the edge of the die were considered the boundaries of the treatment application.
[29] George Wheeler confirmed by telephone conversation in March 1997, that the location of experimental consolidation applications were as illustrated on page 32 of the thesis written by Eileen G. P. Brown.
[30] Ibid.

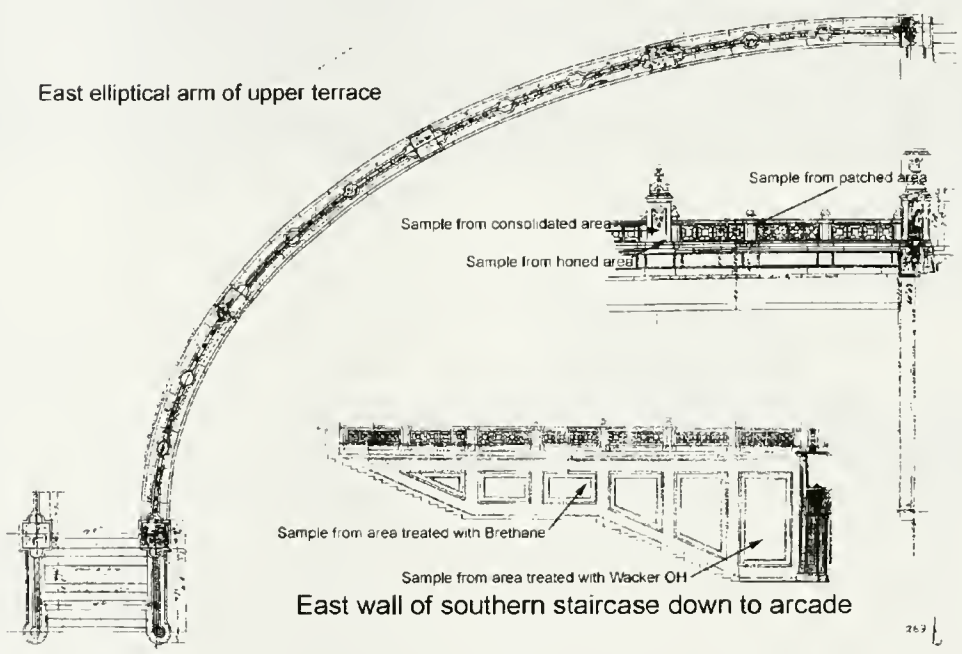


Fig. 34 - Map showing location of samples taken from Bethesda Terrace.

TABLE 1 – TESTING MATRIX FOR BETHESDA TERRACE ARCADE SANDSTONE PROJECT.

	STONE	PREVIOUS TREATMENTS		
	CHARACTERIZATION	HONING	PATCHING	CONSOLIDATION
	1.) What are the physical characteristics of the stone which may need to be matched if replaced? 2.) What is the current salt content and composition?	1.) Does honing create a new surface resistant to past/existing decay mechanisms? 2.) How does it mechanically alter the stone surface? 3.) Does it change water absorption/vapor transmission rates?	1.) What is the composition of the patching material? 2.) What is the composition of the black staining? 3.) Are there organic components in either?	1.) Does consolidant still remain in the stone? 2.) How far did it penetrate? 3.) Is it still effectiove as a consolidant?
MICROSCOPY (core)	2 cross-sections (interior of core samples - EEA pier, diaper) 2 thin-sections (same)	**2 cross-sections** (EEA pier) (*compaction*)	2 cross-sections (EEA balaster)	**1 cross-sections** (Wacker OH), **1 cross-section** (Brethane)
FTIR (flakes)				**3** (flakes) (*consolidants*)
XRD (core/powder)	1 (powder -*salts*)		**1** (patch - *composition*)	
DSC-MS (staining sample)			**2** (sample of crust from stain- NW pier)	
SEM (core)		**1** (exterior of core sample - EEA pier) (*surface change*)	1 (exterior of core samples - EEA pier) (biological growth, salts)	**2** (core sample - Wacker OH area), **1** (core sample - Brethane area)
RILEM (in-situ)	**5** (untreated piers SW/NW, diaper)	**5** (exterior honed surface - piers SW/NW)	**5** (exterior patched surface - piers SW/NW, diaper)	**5** (exterior consolidated surface - piers SW/NW, diaper)
WATER ABSORPTION - NORMAL/ASTM (core)	**5** (cores)			
VAPOR TRANSMISSION - NORMAL/ASTM (core)	**12** (discs from cores)			
CAPILLARY ACTION - NORMAL	**5** (cores)			
DRYING ACTION - NORMAL	**5** (cores)			
SALT TESTING - Teutonico (powder)	**9** (powder - Arcade salts)			
SALT QUANTIFICATION - Teutonico (core)				
TOTAL SAMPLES	**Quantity of salt powder from Arcade interior**	**1 core sample from honed surface**	**1 core sample from patched areas/1 piece of patching material/quantity of staining crust**	**3 core samples/3 flakes from consolidated areas**

PRELIMINARY OBSERVATIONS

THE ARCADE

Preliminary observations of the stone conditions recorded in the arcade at Bethesda Terrace reveal the overall loss of grain to grain cohesion as the primary decay mechanisms of the sandstone elements. Erosion characterized by the rounding out of the stone elements is the frequent resulting condition where sanding occurs. Erosion is differential depending on the geo-chemical composition of the individual stones and their location in the arcade.

Severe efflorescence is recorded in many areas of the arcade especially in corners and on edges of areas experiencing high rising damp or penetration from above by water and moisture. The formation of crust also occurs in these areas, but is not strictly confined to these locations. Crusts are found tracing surfaces over many unit elements which seemingly experience no rising damp or water penetration. These crusts are usually light in color or match the color of the stone. It is possible that these crusts were formed when previous water penetrations occurred. Their formation may now be reduced by moisture barriers, waterproofing or re-paving of the road above. Reconstruction of the terrace in the 1980s included patching with silicon sealant to repair the waterproofing system of the arcade ceiling. Re-paving of the 72nd Street surface road also addressed waterproofing issues. Documentation since the 1980s

restoration project does not note the effect of this treatment. At this time water penetration remains a general recurrent problem in the interior arcade.

The most eroded stone is clearly seen in areas where cycles of water penetration and drying occur, resulting in a loss of grain to grain cohesion seen as sanding. Where moisture tends to linger on the sandstone elements of the interior combined with water penetration, efflorescence, and freeze/thaw cycling occurring in the winter, crusts form on the interior surfaces of the arcade. The light coloration of the crusts which often matches the color of the substrate stone suggests that one element of their composition is the aggregate eroding out from the surface of the sandstone elements. The presence of crusts over dry areas suggests that water penetration was at one time present in these locations. The cause of the sanding is most probably from water and soluble salt solutions entering the stone and undergoing wet/dry cycling and large differential freeze/thaw.

Relative moisture by Protimeter™ readings

The Protimeter™ is a device designed to measure the percent of moisture in wood substrates. It can determine the percentage of water by conductivity. The device adapts to other substrates, but only gives a relative moisture reading by adjusting the conductivity measurement. The presence of salts on the surface of the sandstone in the arcade can interfere with accurate readings. Readings were

taken on the column bases, pilasters, capitol blocks and keystones of the west loggia as illustrated below.

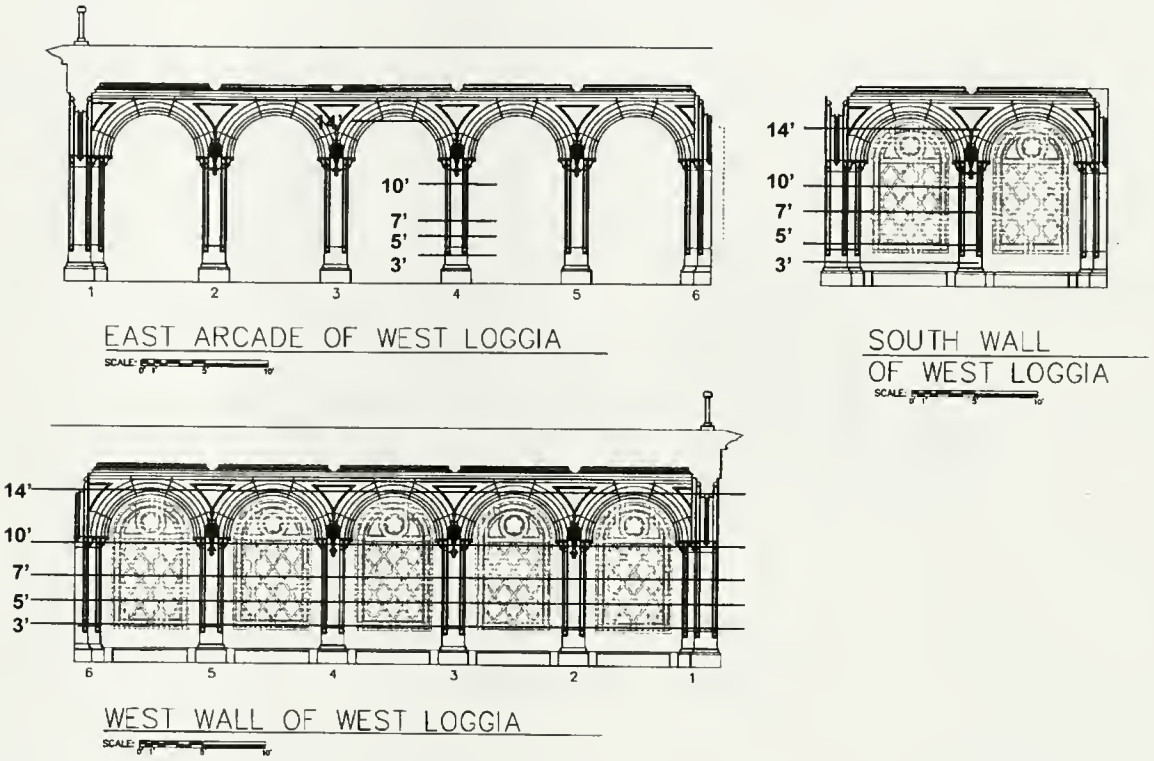


Fig. 35 - Location of Protimeter™ readings in the west loggia.

The results of the readings are graphed by column group in order from base (left) to keystone (right). Readings were taken on two different days, one relatively damp the other dry. On 3 February 1998, the temperature at 11:00 AM was approximately 50°F and the relative humidity was 39% in the arcade. It had rained within the previous week. On 7 April 1998 at 12:30 PM, the temperature in the west loggia was 60°F and the relative humidity was 25%. There had been no rain during the previous week.

TABLE 2 – RELATIVE MOISTURE VALUES ON WEST LOGGIA COLUMNS.

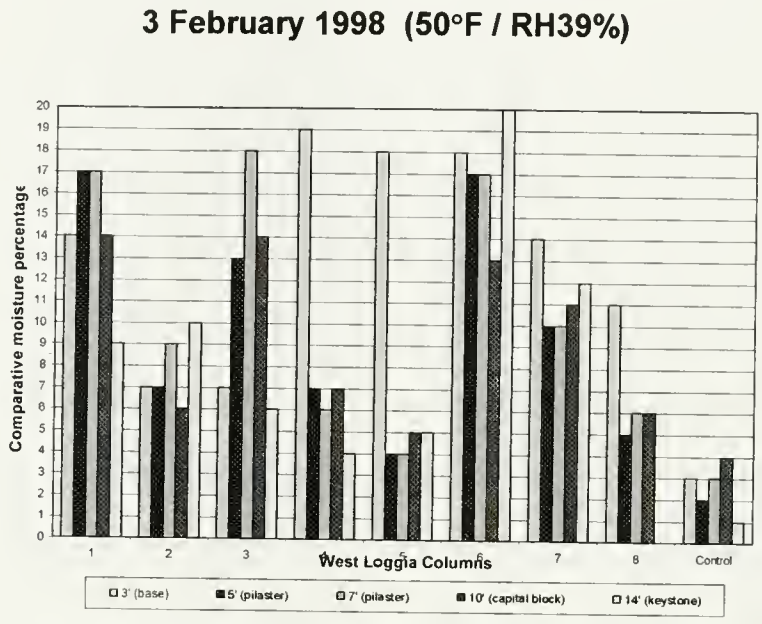
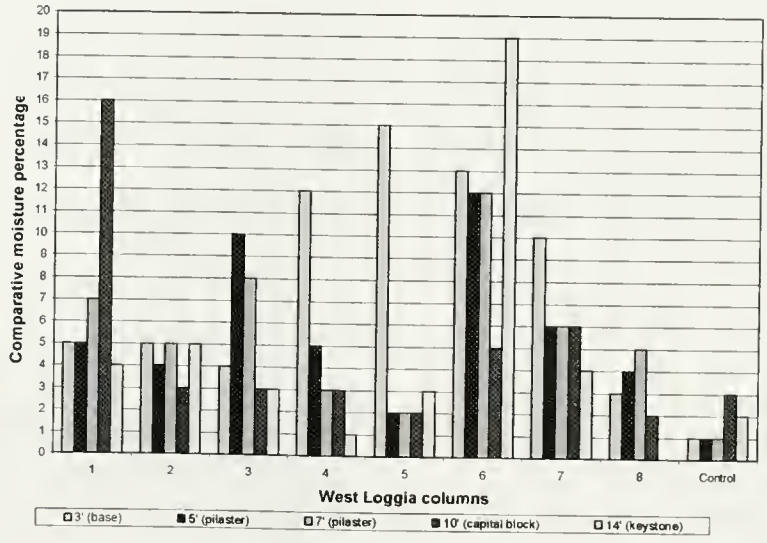


TABLE 3 – RELATIVE MOISTURE VALUES ON WEST LOGGIA COLUMNS.



The moisture readings recorded show that elevated moisture on the surface of the stone is higher on damp days and lower on dry days even when the variation in temperature and humidity is not great. This suggests that the wet/dry cycling may be very rapid when the stone is exposed to moisture. In addition, the graphs show that the stone stays wet at the column bases suggesting drainage problems at the floor level. In the corner of the west loggia, at pilaster 6, elevated moisture readings suggest the penetration of water from both the south and west subsoil. This area is also the location in the arcade that exhibits the most and severest degree of all the deterioration conditions surveyed. Efflorescence was also observed in these areas and it could have elevated these readings.

The Terrace

Preliminary observations of the conditions of the exterior sandstone show that the terrace is subject to a completely different climate and weathering phenomena than in the interior arcade. The exterior stone is more effected by its orientation on the site than the interior sandstone. The exterior stone is not affected by moisture penetration or contaminated with large quantities of de-icing salts.

The major deterioration occurs as flaking and delamination in the carved details of the terrace. This is due to moisture penetration and most likely freeze/thaw cycling in the stone in areas where water collects and does not evaporate. The

majority of the flaking of the sandstone on the terrace was either removed or consolidated in the 1980s restoration. The effects of honing and consolidation are addressed below. Theses treatments continue to protect the stone in the areas where they were applied. However in areas such as the bird panels where consolidation was determined inappropriate given its experimental application and the importance of the architectural carving, deterioration has continued.

Correlation between the causes of the delamination observed on the exterior and those on the interior show that the exterior deterioration is not directly related to salt contamination. Therefore, the sandstone used in the construction of the entire monument decays in similar patterns independent of the direct cause of the deterioration.

Further observations note the alteration of the previously applied composite patching treatments. In almost every occurrence of composite patching, a black crust formation or black stain was observed surrounding the perimeter of the patch and at times covering large areas of the patch itself. Mechanical properties of the patching material have maintained their integrity, however, the discoloration of both the patching material and the surrounding sandstone warrant further investigation.

Analysis of the Sandstone

Chemical analysis and characterization of the sandstone included laboratory experimentation, optical light, polarized light and scanning electron microscopy, and powder x-ray diffraction analysis.

Capillary Action

The porosity, pore size distribution, and the permeability of all porous building materials allow surface water to move into the material by capillarity. The system of pores operates both horizontally and vertically. Water moves in a three-dimensional way into the stone.[31] The amount of water absorbed by the material and the rate at which it moves into the material indirectly describe the relative porosity and to a certain extent the permeability of the material. The rate at which the sandstone at Bethesda Terrace absorbs water is directly related to the porosimetry, and the size, shape and quantity of the pores as capillary tubes. Determining the rate at which water is absorbed by capillary action illustrates the amount of water that can be absorbed during rain or melting snow over a given period. Additionally, it indicates the potential susceptibility to weathering and hence durability.

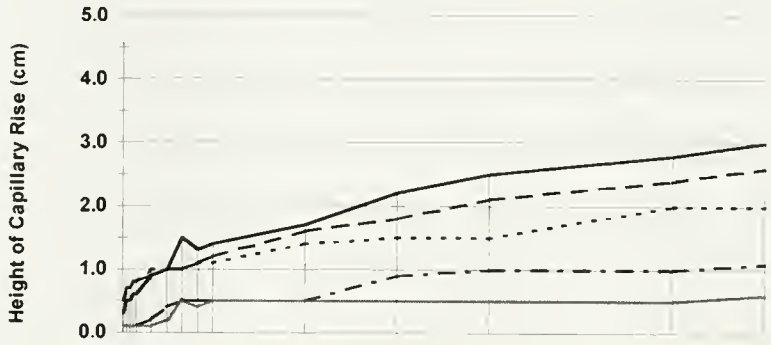
[31] Frances Gale, "Measurement of Water Absorption Techniques," *Investigative Techniques,* (Paris: RILEM, [1985?]).

Porosity in sedimentary rocks can reach up to 40%.[32] In the case of sandstone, the level of porosity varies with the size shape and distribution of the compacted grains. In unconsolidated sand beds, porosity ranges from a well-sorted 40 % to a poorly sorted 25 %. Compaction also can reduce the pore size, porosity and permeability in a material.[33]

Capillary water absorption is measured using various test methods. NORMAL 11/85 – Water Absorption by Capillary Action measures the amount of water absorbed by weight.[34] Alterations to the surface of the sandstone at Bethesda Terrace have changed the absorptive properties of the stone. The results of the following experiments show that capillary action was reduced in the consolidated stone. Water pipe absorption testing also showed that there is a differential absorption rate between treated and untreated surfaces. The following two experiments were conducted to determine to what extent this alteration occurred and to determine the vulnerability of the stone before and after treatments.

[32] Gale, p. 1.
[33] Ibid.
[34] The five unaltered core samples from Bethesda Terrace taken at Bethesda Terrace used for this experiment. Samples were washed and oven dried for 24 hours to ensure that all moisture was removed. The samples were placed on top of a layer of 3mm glass beads in Pyrex glass trays. The layer of beads ensures that complete saturation of the face of the sample is achieved. Water was added to the pans up to a height 1-cm above the bottom surface of the samples. Measurements of the height of the rising water were recorded at this time and at the time intervals shown below. One inch of stone was removed from the original surface end of the stone and the experiment was repeated.

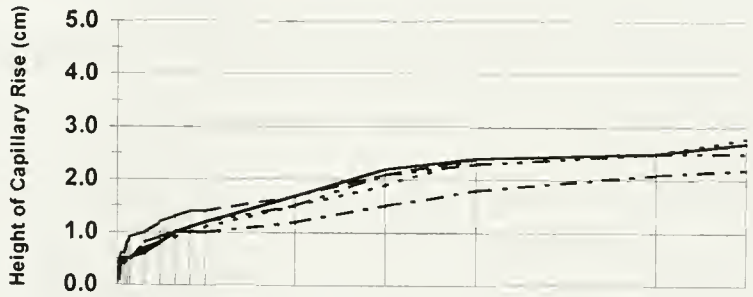
TABLE 4 – CAPILLARY RISE IN UNMODIFIED CORE SAMPLES.



	1	2	3	4	5	10	15	20	25	30	60	90	120	180	210
——— Honed	0.3	0.5	0.5	0.6	0.6	0.9	1.0	1.5	1.3	1.4	1.7	2.2	2.5	2.8	3.0
– – – Patched	0.5	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.6	1.8	2.1	2.4	2.6
- - - - - - Consolidated	0.5	0.7	0.7	0.8	0.8	1.0	1.0	1.0	1.1	1.1	1.4	1.5	1.5	2.0	2.0
– - – - Brethane	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.5	0.5	0.5	0.9	1.0	1.0	1.1
——— Wacker OH	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.6

Time (minutes)

TABLE 5 – CAPILLARY RISE IN MODIFIED CORE SAMPLES (1" OF SURFACE REMOVED).



	1	2	4	5	10	15	25	30	60	90	180	210
- - - - - - Consolidated	0.3	0.4	0.5	0.5	0.6	0.8	1.0	1.1	1.5	1.9	2.5	2.8
– – – Patched	0.4	0.6	0.8	0.9	1.0	1.2	1.4	1.4	1.7	2.1	2.5	2.7
——— Honed	0.1	0.4	0.5	0.5	0.7	0.8	1.1	1.2	1.7	2.2	2.5	2.7
– - - – Wacker OH	0.3	0.4	0.5	0.5	0.6	0.8	1.1	1.2	1.5	2.1	2.5	2.5
– - – - Brethane	0.3	0.5	0.5	0.5	0.8	0.9	1.0	1.0	1.2	1.5	2.1	2.2

Time (minutes)

The results of this experiment show that the consolidants applied to the surfaces in the areas where the core samples were taken reduced the water absorption by capillarity. Furthermore, the increase in the water absorption seen when the original surface is removed suggests that the depth of penetration of the consolidants was no greater than 1 inch.

WATER PIPE ABSORPTION

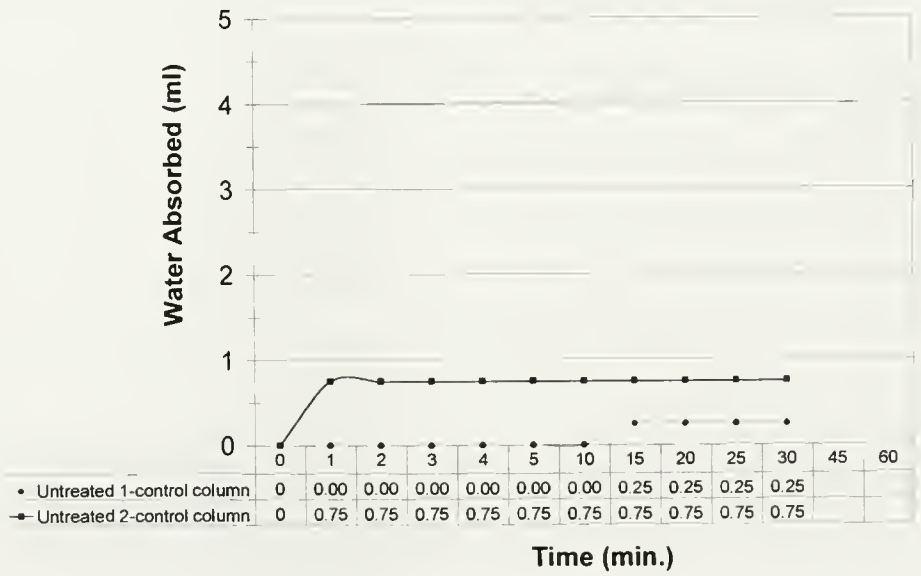
The water pipe absorption RILEM Test Method No. II.4 also quantifies the amount of water absorbed by measuring the cubic centimeters absorbed over a period of time. It is possible to conduct this method in-situ thereby reducing the need for destructive sampling therefore this method was followed.

The following data was collected from the in-situ measurements.[35] The experiment was conducted at Bethesda Terrace during spring 1998. The ambient temperature in the arcade was 60°F, relative humidity 25%. The exterior temperature was ~65°F, relative humidity 25%. The purpose of this experiment was to determine the quantity of water absorbed by the vertical surfaces of the sandstone at Bethesda Terrace during a 30-minute period. The test was performed on site on lateral surfaces of untreated, consolidated and honed areas

[35] The method of measuring the amount of water absorbed on lateral surfaces utilizes an L-shaped plastic RILEM tube cylinder. This apparatus was attached with Moretite™ window sealing putty to the sandstone piers in twelve location, three untreated areas, three consolidated areas, three honed areas, and on three composite patches. Water was added to the open end of the pipe until it reached the 0 gradations. Care was taken to ensure no air was trapped in the base of the cylinder. Measurement of the rate of absorption of water by the sandstone began at this point. Readings were taken every five minutes for 30-minute intervals.

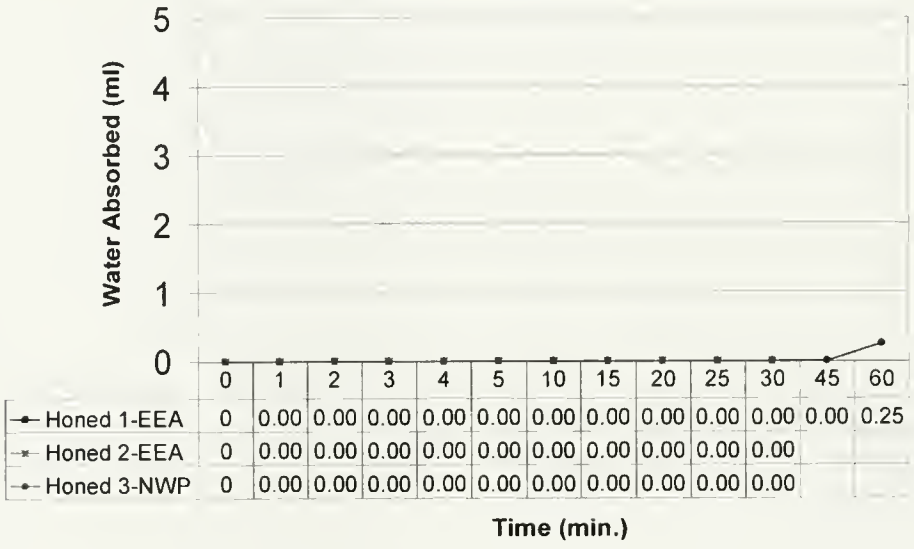
of sandstone to determine if any alterations in water absorption or porosity occurred as a result of the 1980s restoration treatments. The untreated areas tested were on the column designated as the control in the above Protimeter™ readings. The experiment was conducted on honed and consolidated areas of the pier of the east elliptical arm of the terrace from which two of the core samples were taken. The northwest pier of the middle terrace that exhibits the heaviest black staining on and around mortar patches was also tested. This mortar patch on this pier was tested along with one mortar patch on the eastern side of the same pier and one on the western side of the neighboring pier to the west.

TABLE 6 – WATER PIPE ABSORPTION CURVES – UNTREATED SANDSTONE.



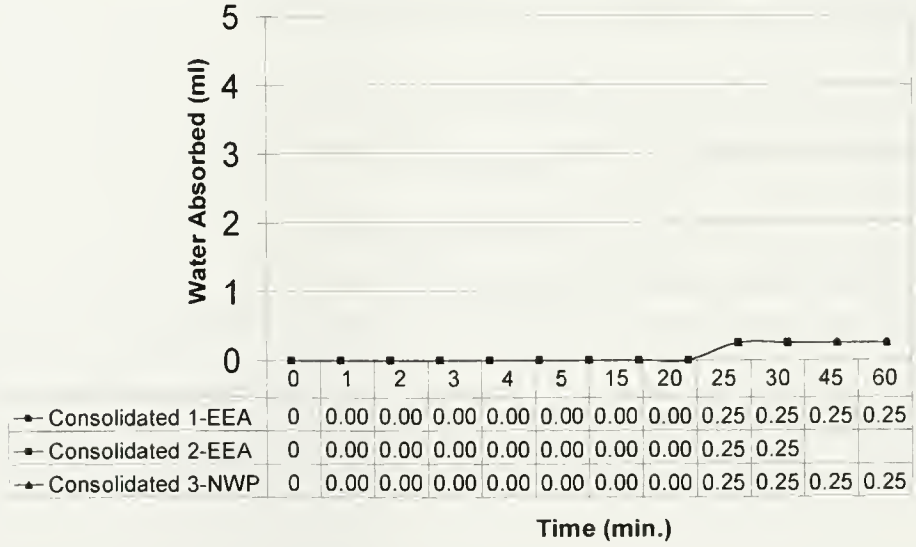
	0	1	2	3	4	5	10	15	20	25	30	45	60
Untreated 1-control column	0	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.25		
Untreated 2-control column	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75		

TABLE 7 – WATER PIPE ABSORPTION CURVES – HONED SANDSTONE.



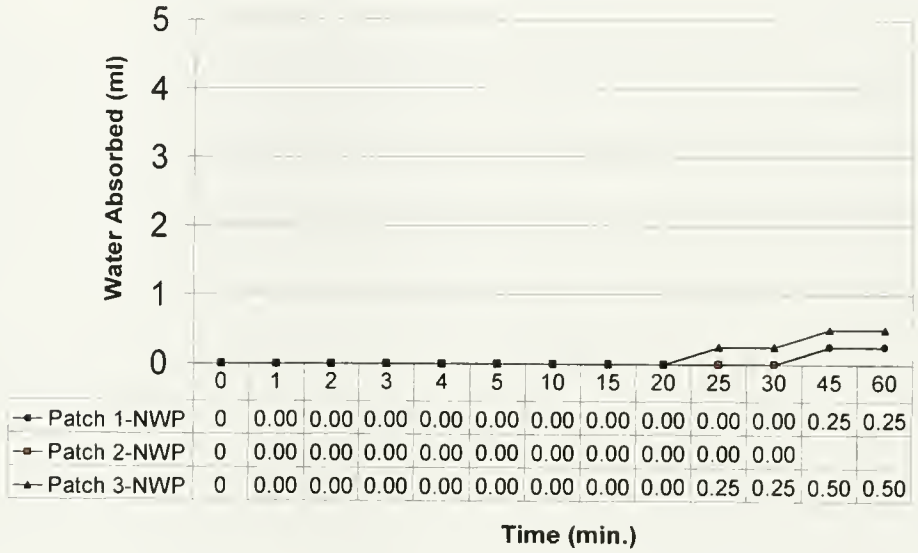
	0	1	2	3	4	5	10	15	20	25	30	45	60
Honed 1-EEA	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Honed 2-EEA	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Honed 3-NWP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

TABLE 8 – WATER PIPE ABSORPTION CURVES – CONSOLIDATED SANDSTONE.



	0	1	2	3	4	5	15	20	25	30	45	60
Consolidated 1-EEA	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.25
Consolidated 2-EEA	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25		
Consolidated 3-NWP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.25

TABLE 9 – WATER PIPE ABSORPTION CURVES – MORTAR PATCH.



	0	1	2	3	4	5	10	15	20	25	30	45	60
Patch 1-NWP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Patch 2-NWP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Patch 3-NWP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.50	0.50

The results of this experiment confirm that the sandstone at Bethesda Terrace is measurablly nonabsorptive. Comparison of the results also confirms that the untreated areas of sandstone at Bethesda Terrace absorb more water than the other test areas.[36] In addition, the water pipe tube absorption tests show that the areas of stone that were consolidated in the 1980s restoration absorb some water only after 25 minutes. Comparatively, the honed areas absorbed the least amount of water. This is possiblly due to the buildup of a layer of dust in the pores of the upper surface that effects the results of this test. This layer would

[36] Untreated sample area 3 has a high absorption curve because a leak developed in the sealant around the water pipe tube. This error gives the impression that the untreated stone absorbs a much higher amount of water very quickly. Therefore, this graph more realistically illustrates the water pipe absorption curves than a graph of the averages of each set of three sample areas plotted against each other.

have been removed during washing from the surface of the core samples that were tested for capillary rise in the laboratory experiments.

A possible margin of error in this experiment is the evaporation of water from the top of the tube. This could lead to inaccurate measurements of the amount of water absorbed, as it would lower the level of water in the tube given the low relative humidity of the days of the measurements. The relative humidity was low (~25%) and the air temperature was ~65°F on the day of the test.

WATER ABSORPTION BY TOTAL IMMERSION

This experiment followed a program of modified procedures from the ones outlined in *A Laboratory Manual for Architectural Conservators,* and NORMAL 7/81.[37, 38]

[37] The experiment was conducted in the Architectural Conservation Laboratory at the University of Pennsylvania on 2 February – 3 March 1998.

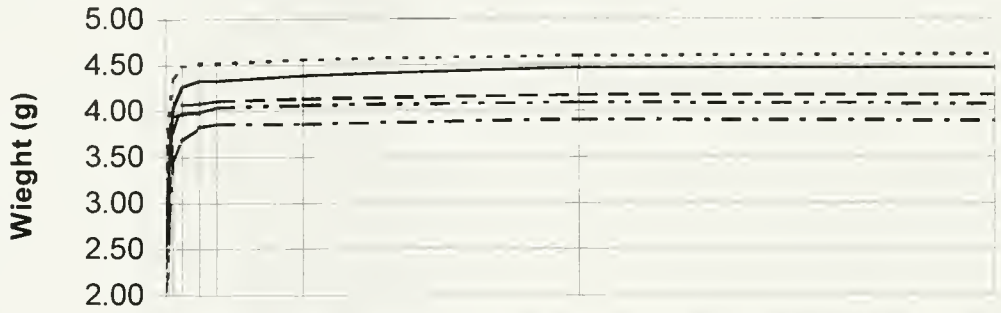
[38] The modified core samples (with 1" removed) of the Bethesda Terrace sandstone were washed with water and a plastic bristle brush. This ensured that each sample was free from previous treatment and that a comparative analysis of the sandstone itself was achieved. The samples were oven dried to a constant weight and allowed cooling in a desiccator until cooled to room temperature. Once the samples were dried and weighed, they were placed into a glass tray and supported by 3-mm glass beads. Deionized water was slowly poured over the sample until they were totally immersed. Each sample removed from the water, blotted with a dampened paper towel, and weighed at the time intervals shown in the table. Time intervals were selected based on the assumed absorption characteristics as noted in *A Laboratory Manual for Architectural Conservators.* Maximum water absorption was achieved when the weight gain of the samples was equal or less than 0.01percentage of the preceding measurement.

The measurement of water absorption is a useful laboratory test to characterize porous building materials, to evaluate the degree of deterioration and to monitor the effects of conservation treatments. This laboratory experiment presents a simple method for such measurement, which gives reliable results without sophisticated equipment. Five samples of Bethesda Terrace sandstone were tested to determine their relative porosity. The tests assist in the formulation of conclusions regarding the sandstone's behavior associated with porosity.

Absorption by total immersion is the quantity of water absorbed by materials immersed in deionized water at room temperature and pressure, expressed as a percentage of the dry mass of the sample. The water absorption capacity is the maximum quantity of water absorbed by a material under the cited conditions, again expressed as a percentage of the dry mass.[39]

[39] The quantity of water absorbed (WA) at each time interval was calculated with respect to the mass of the dry sample as follows: $\Delta M/M_o$ % = M_n - M_o/ M_o x 100 (where: M_n = weight of the wet sample at time t_n and M_o = weight of the dry sample). The mean value of the water absorption (the sum of all values for WA divided by the number of samples) as each time interval was recorded. Finally, the water absorption capacity (WAC) was calculated from the data using the following equation: WAC- M_{max} – M_d/M_d x 100 (where: M_{max} = the mass of the sample at maximum water absorption and M_d = the mass of the sample after re-drying the sample after termination of the NORMAL 29/88 experiment).

TABLE 10 – WATER ABSORPTION BY TOTAL IMMERSION.



	5	15	30	60	120	180	480	1440	2880
Sample C	3.05	3.96	4.38	4.49	4.52	4.52	4.56	4.60	4.61
Sample H	2.55	3.41	4.03	4.27	4.33	4.33	4.38	4.47	4.46
Sample P	2.31	3.10	3.78	4.07	4.08	4.11	4.13	4.17	4.17
Sample W	3.02	3.74	3.94	3.97	3.99	4.04	4.06	4.09	4.07
Sample B	2.05	2.81	3.46	3.68	3.83	3.86	3.86	3.90	3.89

Time (minutes)

The results from this experiment show that the Bethesda Terrace sandstone absorbs most of the water required to reach total saturation within the first 30 minutes of this experiment.[40] This high absorption rate confirms the small capillary tubes in the sandstone. Therefore, moisture settling on or around the stone as standing water, ground water, or penetration from the leaking roadbed above the arcade is rapidly absorbed.

[40] Possible sources of error in the experiment can result from differential drying procedures when the stone is blotted after removal from the water and weighed. Inconsistency in the blotting method was avoided, however it was noted that when the paper towel was initially wet with deionized water, it did become more saturated after blotting the samples. This may have extracted some water from the samples before weighing. This was specifically noted after total absorption was reached and weight measurements fluctuated below the previous weight measurement.

MEASUREMENT OF THE DRYING INDEX

The NORMAL 29/88 *Measurement of the Drying Index* test is designed for sound and deteriorated, treated and untreated stone materials.[41] The purpose of the experiment was to determine the amount of loss by evaporation of the water absorbed by the Bethesda Terrace sandstone after the water absorption by total immersion experiment outlined above.[42]

The Drying Index of the sandstone at Bethesda Terrace illustrates the rapidity with which water evaporates from the surface of the stone. It also indicates the amount of water remaining in the stone for longer lengths of time. This is important at Bethesda Terrace for several reasons. Retained water is critical in freeze/thaw cycling of the stone. Moreover, the amount of water and the rate of evaporation affect the amount of deterioration caused by soluble salts in the stone of the arcade. Soluble salts are transported by water in the stone. The collected data from the water absorption test and the measurement of the drying index provide information on the potential mechanisms of water and salt deterioration.

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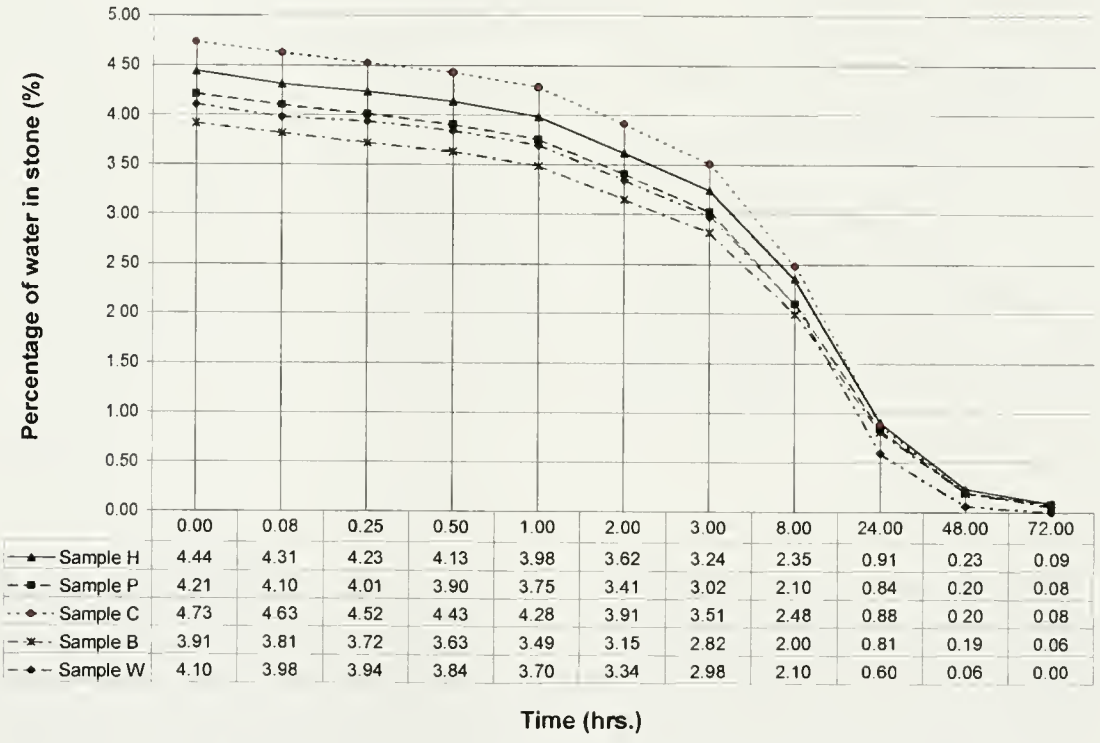
[41] This experiment was conducted at the Architectural Conservation Laboratory on 3 – 7 March 1998.

[42] The core samples from Bethesda Terrace were prepared by following the procedures in the water absorption by total immersion test NORMAL 7/81. Saturated samples were patted dry with a wet paper towel and weighed. The samples were placed on plastic coated mesh screens with 5-cm openings in a desiccator. The temperature was kept at a constant 70 degrees F with a relative humidity starting at ~60. The desiccant in the glass chamber was calcium sulfate (CaSO4) impregnated with a cobalt chloride indicator [(Dri-rite™)- the desiccant changed from blue to pink, indicating saturation at approximately two hours. The relative humidity in the desiccator increased to ~65, therefore, the desiccant was changed. This process was repeated again at eight hour (RH~50) and at 72 hours (RH~4)]. Samples were removed from the desiccator and the weight of the sample was recorded at the time intervals shown below.

The variation of water content in the material over time, at constant temperature and relative humidity, is measured and expressed as a percentage of the dry weight of the sample. The Drying Index is the ratio between the integral of the drying curve and the maximum water content multiplied by the final time, i.e., the time required for drying and taken as that reached asymptotically by the curve.[43]

TABLE 11 – RATE OF EVAPORATION IN BETHESDA TERRACE SANDSTONE.



	0.00	0.08	0.25	0.50	1.00	2.00	3.00	8.00	24.00	48.00	72.00
Sample H	4.44	4.31	4.23	4.13	3.98	3.62	3.24	2.35	0.91	0.23	0.09
Sample P	4.21	4.10	4.01	3.90	3.75	3.41	3.02	2.10	0.84	0.20	0.08
Sample C	4.73	4.63	4.52	4.43	4.28	3.91	3.51	2.48	0.88	0.20	0.08
Sample B	3.91	3.81	3.72	3.63	3.49	3.15	2.82	2.00	0.81	0.19	0.06
Sample W	4.10	3.98	3.94	3.84	3.70	3.34	2.98	2.10	0.60	0.06	0.00

The amount of water absorbed by all five samples was within 1%. The results from the evaporation experiment show the Drying Index curve is almost identical for each sample. All samples show that water begins to evaporate from the

[43] NORMAL, "NORMAL Test 29/88: Measurement of the Drying Index," trans. A. E. Charola (1998): 1.

sandstone more rapidly after three hours of isolation in a desiccator. The stone is completely dried after 72 hours. Within 24 hours, the amount of water in the sandstone is below 1%. This rapid evaporation rate confirms that wet/dry cycling is a major factor in the deterioration of the stone.

WATER VAPOR TRANSMISSION

The vapor transmission property of the Bethesda Terrace sandstone was determined by following the procedure outlined in the NORMAL 21/85 *Water Vapor Permeability* test.[44] This information provides a base characterization of the permeance of the stone. It will also prove beneficial in future studies for consolidation. Water vapor permeability is the amount of water vapor, per unit time and surface area, that flows through a material of parallel surfaces and a given thickness due to a water vapor pressure difference between the two surfaces.[45]

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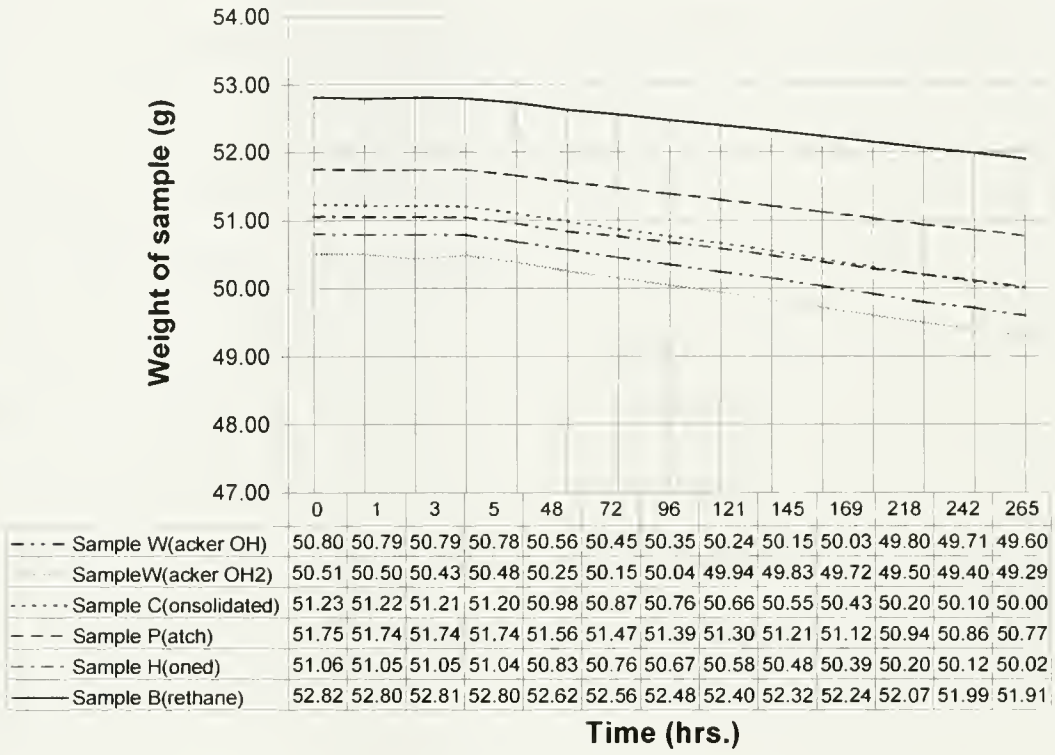
[44] Samples were prepared from the Bethesda Terrace core samples. Discs of approximately 11-mm thickness were cut from the core samples. One disc was cut from each core sample in order to ensure a representative sampling and conserve as much of the original cores a possible for future testing. The samples were washed to remove all dust created during sawing and then oven dried at 105°C to a constant weight. Samples were sealed with wax into 15-dram vials containing 25-ml of deionized water and cotton and weighed (M_1). The assemblies were placed in a 70°F/RH ~50 desiccator containing Dri-rite™. Assemblies were weighed at the intervals shown in the table below until a stationary state determined by the following formula was achieved: $[(\Delta M_i - \Delta M_{i-1})/\Delta M_i] \times 100 \leq 5\%$ (where: $\Delta M_i = M_{t=1} - M_{t=i-1}$ and $\Delta M_{i-1} = M_{t=1-1} - M_{t=1-2}$. Conducted at the Architectural Conservation Laboratory at the University of Pennsylvania on 30 March – 7 April 1998.

[45] NORMAL, "NORMAL 21/85: Water Vapour Permeability," trans. A. E. Charola (1998). The permeability of a given sample is calculated from the mean value of the weight variations at observed intervals of time and averaged from at least two points during the steady state phase of the test. The DM is then divided by the surface (m2) of the sample though which the water vapor diffused. The calculated water vapor permeability is expresses in g/m2.24h (ANSI-ASTM 355-64) and must be referred to 20°C. Therefore, in the case in which the measurements were carried out at room temperature t_x different from 20°C, the experimental value has to be corrected accordingly.

TABLE 12 – WATER VAPOR TRANSMISSION CURVES FOR BETHESDA TERRACE SANDSTONE.



	0	1	3	5	48	72	96	121	145	169	218	242	265
Sample W(acker OH)	50.80	50.79	50.79	50.78	50.56	50.45	50.35	50.24	50.15	50.03	49.80	49.71	49.60
SampleW(acker OH2)	50.51	50.50	50.43	50.48	50.25	50.15	50.04	49.94	49.83	49.72	49.50	49.40	49.29
Sample C(onsolidated)	51.23	51.22	51.21	51.20	50.98	50.87	50.76	50.66	50.55	50.43	50.20	50.10	50.00
Sample P(atch)	51.75	51.74	51.74	51.74	51.56	51.47	51.39	51.30	51.21	51.12	50.94	50.86	50.77
Sample H(oned)	51.06	51.05	51.05	51.04	50.83	50.76	50.67	50.58	50.48	50.39	50.20	50.12	50.02
Sample B(rethane)	52.82	52.80	52.81	52.80	52.62	52.56	52.48	52.40	52.32	52.24	52.07	51.99	51.91

The results from the water vapor transmission test for each sample are almost identical reflecting the fact that no consolidants penetrated more than 1" into the stone In the case of the previously treated samples. The water vapor permeability was calculated and it was 9.02 g/m^2.hr.

TABLE 13 – WATER VAPOR PERMEABILITY OF BETHESDA TERRACE SANDSTONE.

Mean value of the weight variations		**Permeability**	**Corrected Permeability**
	(g)	**(g/m^2.24h)**	**(g/m^2.24h)**
Sample W	0.11	11.94	9.94
Sample W2	0.11	11.94	9.94
Sample C	0.11	11.94	9.94
Sample P	0.09	9.72	8.09
Sample H	0.09	10.28	8.55
Sample B	0.08	9.17	7.63
Mean Permeability		**10.83**	**9.02**

Scanning Electron Microscopy

Samples of the Bethesda Terrace stone were observed under a JEOL scanning electron microscope to detect visible characteristics of the stone and previous consolidation treatments. The samples required a 10-nm carbon coating due to their non-metallic nature. The samples were bombarded in a vacuum with a high-energy scanning electron beam and the reflected electrons were focused through special lenses and captured by an electron multiplier detector that converts their energy into a visible signal. This process produces an image of the secondary electrons reflected from the sample allowing the examination of the surface morphology. Quartz crystals with clay minerals can be observed in (figure 36).

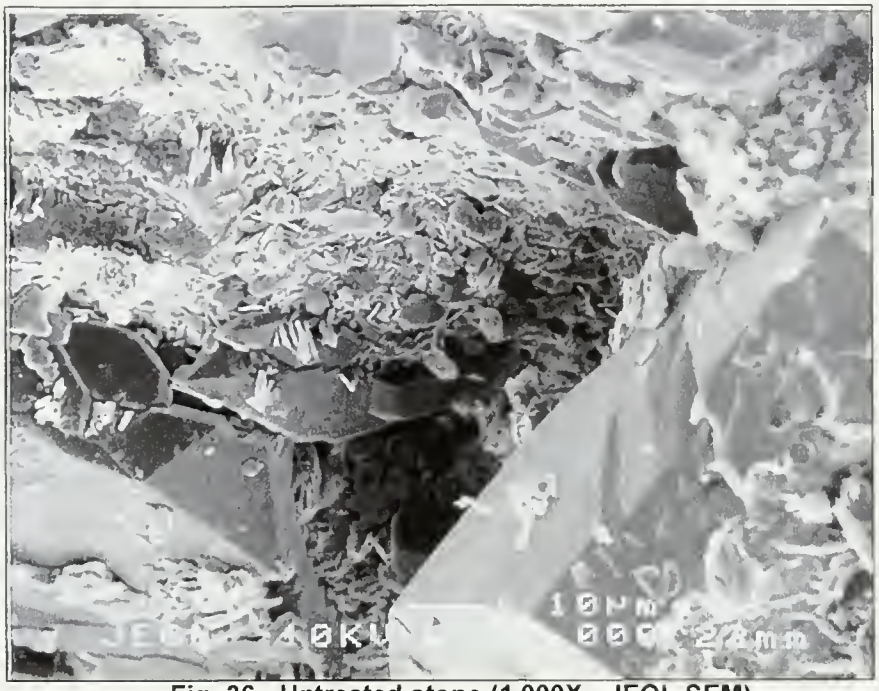


Fig. 36 - Untreated stone (1,000X - JEOL SEM).
Note the unaltered surfaces of the quartz crystals and the fine clay particles between.

POWDER X-RAY DIFFRACTION

Powder x-ray diffraction is an analytical technique that measures the amount and type of x-rays reflected from a material when bombarded by x-rays. This technique is capable of matching unknown x-ray diffraction patterns with known patterns logged in a database. A sample from the interior section of an untreated sandstone core (sample H) was powdered and mounted on orange cellophane tape. The sample was scanned at 1°/min. from 3° to 40°. The tape accounts for the high interference pattern at the lower angles of the recorded x-ray pattern. The pattern illustrated below indicates the majority of the sample is α quartz as

expected. It is possible to identify other compounds by matching the pattern of silicon oxide and removing those peaks from the graphic pattern. Other trace compounds were tentatively identified as albite, possibly from disintegrating plagioclase feldspars.

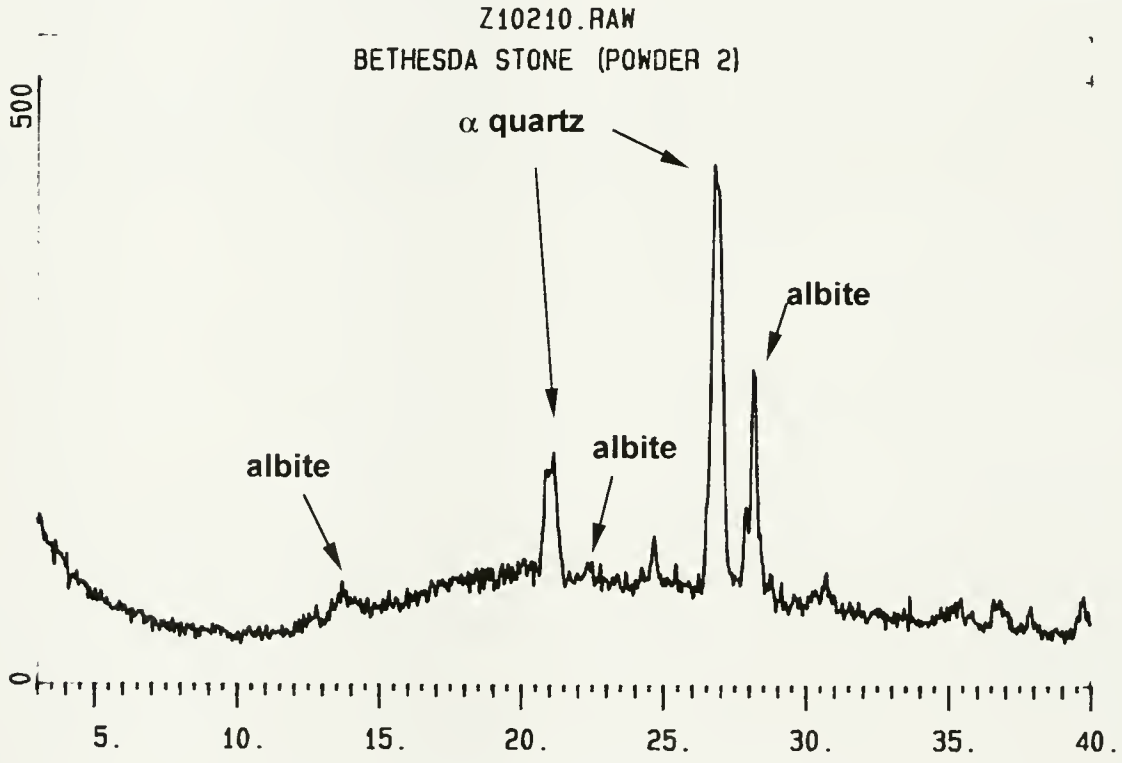


Fig. 37 - XRD for Bethesda Terrace Sandstone.

IDENTIFICATION OF SOLUBLE SALTS

Qualitative analysis of soluble salts followed standard chemical procedures utilized for salt ion identification.[46] Samples were obtained from the pilasters of the west loggia of the arcade. This is the area where the heaviest efflorescence occurs at this time. The samples were lightly brushed off the surface with a palette knife. Where a large amount of crust formation was available, this was carefully removed so as not to disturb the surface below the crust. Nine samples were removed from three heights on three columns as illustrated below.

[46] Jeanne Marie Teutonico, *A Laboratory Manual for Architectural Conservators,* (Rome: ICCROM, 1988): 56. Samples were ground to a fine homogeneous powder in small mortars. Several milligrams were dissolved in test tubes with deionized water and allowed to settle. Several samples settled very slowly, therefore the soluble solutions were filtered through medium (No. 4) filter paper into clean test tubes. The insoluble parts of the samples were conserved for testing of carbonates. Analysis for the ions was conducted by precipitation. A small amount of hydrochloric acid (HCl 2N) was added to the solution followed by barium chloride to test for the presence of sulfates. Barium chloride forms white precipitate (barium sulfate) and chlorine ions in the presence of sulfates. A small amount of nitric acid (2N) was added to the solution followed by silver nitrate to determine the presence of chlorides. A whitish-blue precipitate of silver nitrate forms when chloride ions combine with silver nitrate to form silver chloride. Phosphates in the presence of silver nitrate alone will form a yellow precipitate. To test for nitrates and nitrites *Griess-Ilosvay's* reagent was used. Analysis of the insoluble parts of the samples to determine the presence of carbonates was conducted by carbonation. The insoluble samples were dissolved in concentrated hydrochloric acid. Carbon dioxide gas effervesces in the presence of carbonates.

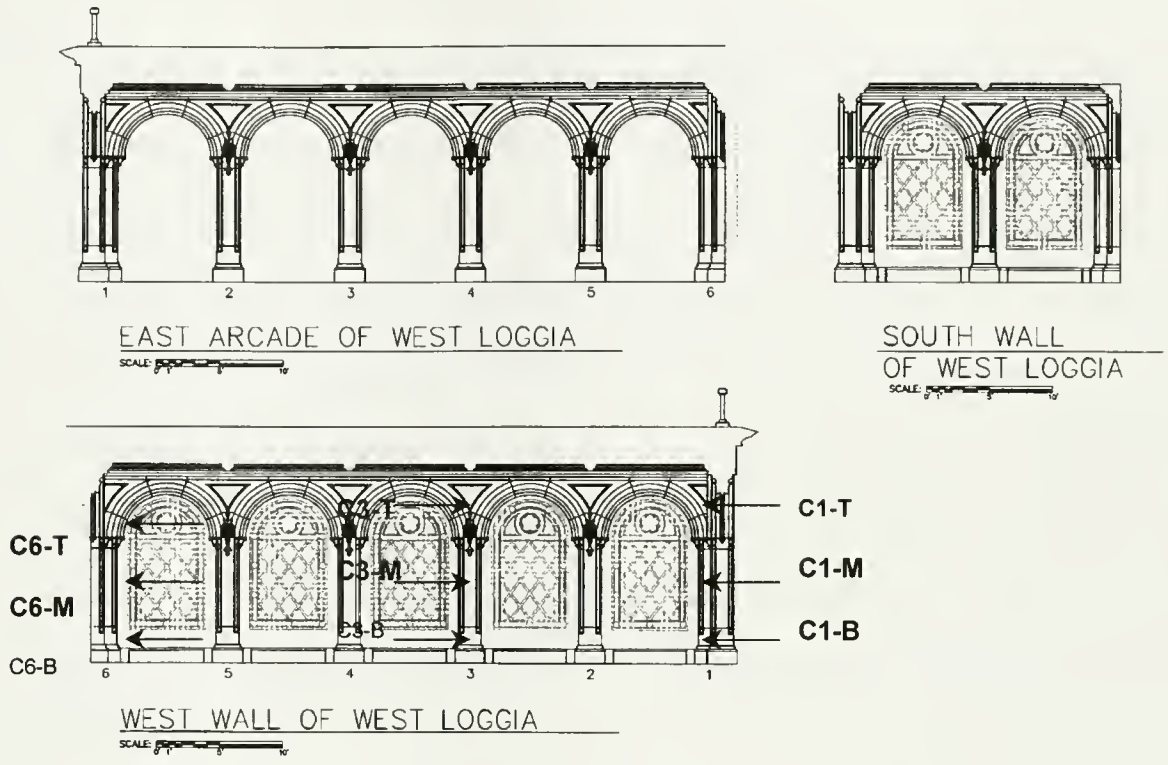


Fig. 38 - Soluble salt sample locations, west loggia.

TABLE 14 - SALT ION IDENTIFICATION.

	Sulfates ($SO_4^{=}$)	Chlorides (Cl^-)	Nitrites (NO_2^-)	Nitrates (NO_3^-)	Carbonates ($CO_3^{=}$)	Phosphates (PO_3^{-3})
C3-T	negative	perceptible	negative	negative	negative	perceptible
C3-M	perceptible	positive	negative	positive	positive	negative
C3-B	perceptible	positive	negative	negative	positive	positive
C2-T	positive	perceptible	negative	negative	negative	negative
C2-M	positive	positive	negative	negative	negative	negative
C2-B	negative	negative	negative	negative	positive	negative
C1-T	positive	positive	negative	negative	negative	negative
C1-M	positive	positive	negative	negative	negative	negative

The majority of the identifiable ions were chlorides and sulfates (see table 14). The chlorides as mentioned above are undoubtedly from sodium chloride de-icing salts used on the terrace in the past. Phosphates were identified on the northwest arcade column of the west loggia of the arcade. It is possible that these salts are deposits from water run-off from the urns above which contain fertilizers. It was suspected that nitrates or nitrites were present in the column bases of the arcade due to human and animal urine. No nitrates or nitrites were identified with this method. Some carbonates, probably from mortars, were detected. Further testing was conducted on four of the samples using x-ray diffraction.

A sample of efflorescence was removed from the southwest corner pilaster of the west loggia to attempt to determine the exact composition of the soluble salts found in this area. The sample was powdered and scanned at 5°/min. from 10° to 70°. This sample also exhibits the high interference at the lower angles from the mounting tape. The presence of α quartz from disintegrating sandstone in the sample interfered with the proper identification of the salts (see figure 39).

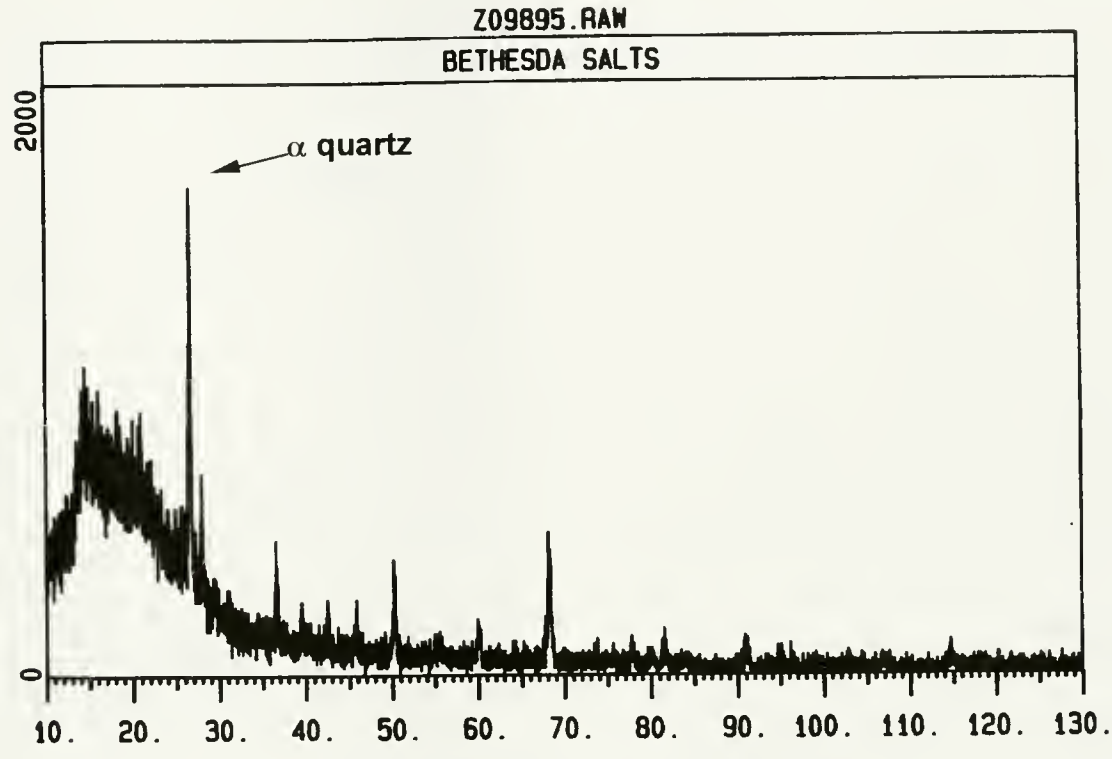


Fig. 39 - XRD sample no. 1 of arcade salts
This sample shows the presence of α quartz however, the small amounts of salts could not be detected.

An additional sample of the same salt crust was mounted with petroleum jelly in a well slide to further investigate the possibility of reducing the interference created by the tape used in the previous scans. This mounting technique reduced the interference, but the results again showed that the primary component of the sample was α quartz (see figure 40).

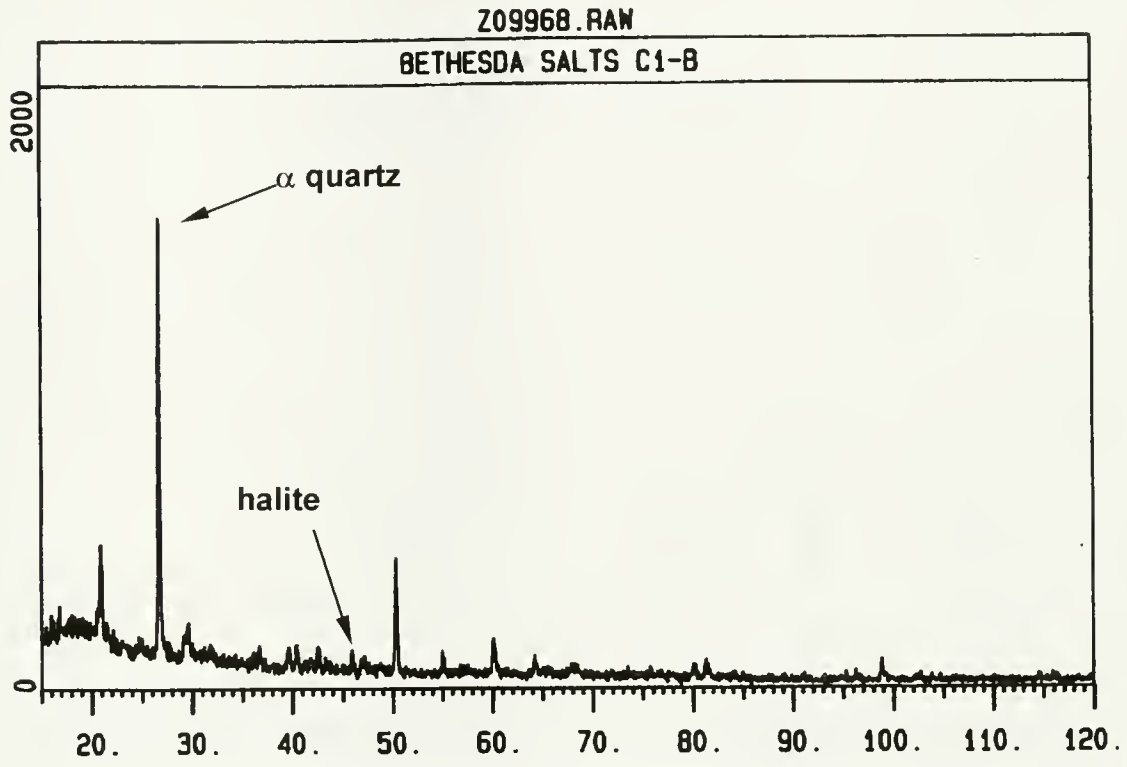


Fig. 40 - XRD sample no. 2 of arcade salts
This sample detected halite, but no other compounds.

A new sample from the arcade was taken a few weeks later when efflorescence was dense on the arcade stone. It was also mounted on a glass slide with petroleum jelly and scanned at 1°/min. from 3° to 60°. The pattern identified halite (NaCl) as the main component with trace amounts of niter (KNO_3) and nitratite ($NaNO_3$) (see figure 41).

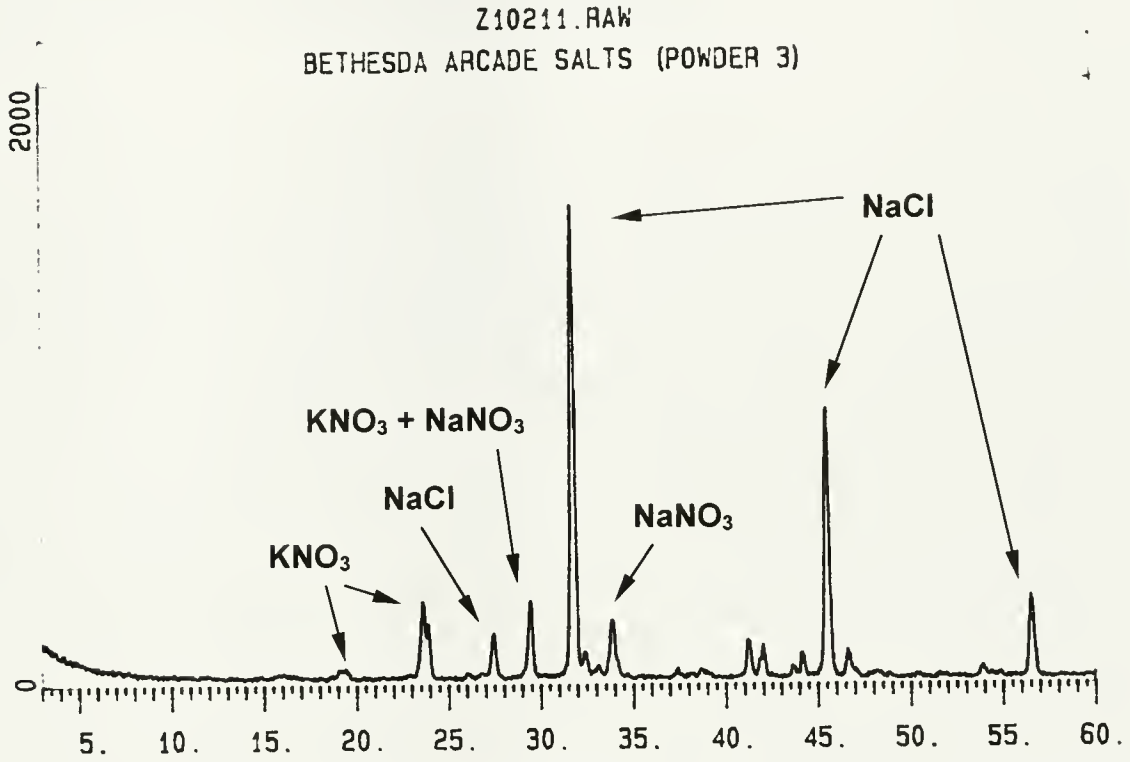


Fig. 41 - XRD sample no. 3 of arcade salts.

Sample no. 3 was mounted with petroleum jelly on a glass slide. The XRD pattern shows less interference at lower angles. The XRD pattern shows halite peaks with trace amounts of niter.

CHAPTER 7: EVALUATION OF PREVIOUS TREATMENTS

HONING

The technique of honing the surface of the sandstone at Bethesda Terrace with a rotary sander visibly altered the surface of the stone. No documents were found that explained what the existing condition at the time was that required the removal of stone surface. It is speculated that there existed surface deterioration caused by the combination of weathering and the original sawn and rubbed stone surface finishes. Localized delamination and disintegration of the stone were possibly the conditions at the time of the restoration that was treated with the honing technique. The results of the water absorption by capillary action experiments showed that the honing increased the amount of water absorbed only slightly when compared to unhoned surfaces. Water pipe absorption testing showed that the stone remained relatively non-absorptive after the process. Comparison between the results of the unaltered stone and the honed surfaces confirms that the process did not greatly alter the absorptive qualities for water on the surface of the stone.

This treatment resulted in a visual unification of the stone surface by removing unstable stone and creating a faceted surface as a function of hand variability during the honing process. Examination with plain light microscopy at 100X and with a scanning electron microscope revealed that a 100 μm thick exists at the

surface of the stone (see figure 43). This visible layer may be a build up of fine debris from either the treatment or weathering. No fractured or compacted crystals were observed in the thin sections (see figure 42).

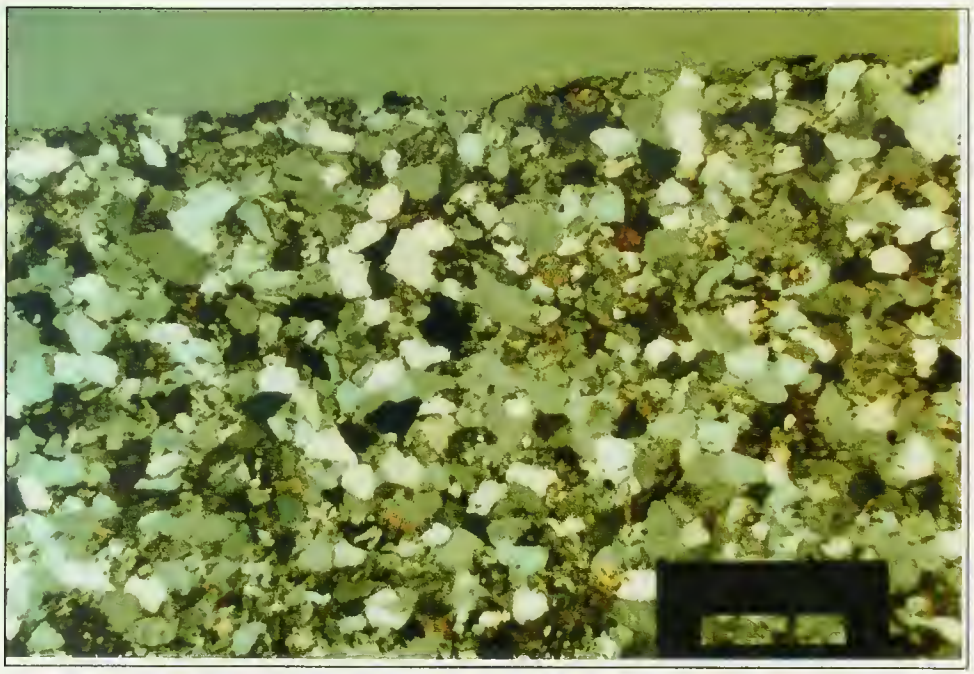


Fig. 42 - Honed Surface (50X - plane-polarized light).
Note no alteration is visible near the surface of the sample.

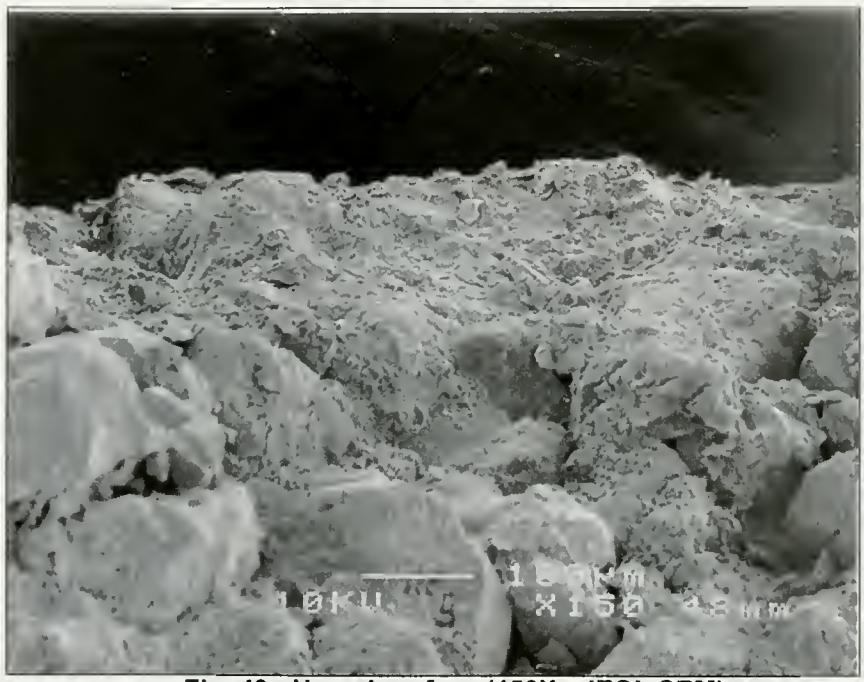


Fig. 43 - Honed surface (150X - JEOL SEM).
Visible 100-μm layer may be alteration to the surface of the sandstone from honing or it may be dirt deposit.

CONSOLIDATION

Consolidants applied as experimental treatments in the 1980s still remain in the sandstone of the exterior terrace based on scanning electron microscopy examination. Documentation of the formulation and application of these treatments is vague, however laboratory testing showed that both consolidants are still present and currently reduce capillarity in the areas tested. The application of consolidants did not alter the color of the stone.

Fig. 44 - Wacker OH™ in Bethesda Terrace sandstone (4,000X - JEOL SEM).
Characteristic gel of Wacker OH™ is visible on quartz grains.

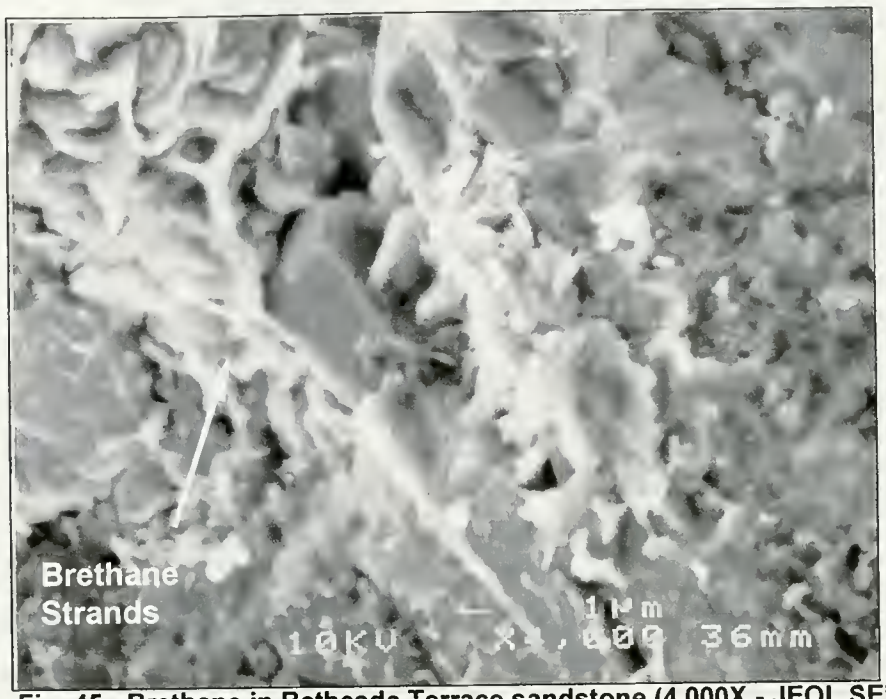


Fig. 45 - Brethane in Bethesda Terrace sandstone (4,000X - JEOL SEM).
Strands of Brethane appear stringy between crystals.

COMPENSATION

Both techniques— composite repair and stone dutchmen, for the compensation of lost stone utilized in the 1980s restoration at Bethesda Terrace have proven problematic. Compensation of missing and damaged stone is an important issue in the interior arcade since the major loss is in the detailed carving of the capital, filigree carvings and spandrel panels. Compensation for the continuing restoration of the arcade and terrace must consider the results of the previous treatments to determine an appropriate future compensation plan.

COMPOSITE PATCHING

The compensation for areas of loss of the exterior of Bethesda Terrace with composite repairs proved mechanically successful. However, the aesthetic failure of these patches is seem in a black crust formation or blackened deposit at the perimeter of almost every composite patch applied in the 1980s restoration. Discoloration of these patches was noted as early as 1986 in photographic records at the Central Park Conservancy. Testing of the black deposit material was conducted by George Wheeler at the Metropolitan Museum of art in 1986.[47] His conclusions were that the deposits were of organic composition because they were easily removed with hydrogen peroxide. Analysis of the patching material to identify any organic components was based on the fact that organic additives are commonly added to commercial composite patching materials.[48]

Plane-polarized light microscopy was used to examine the composite patch. It was discovered that the black staining existed completely throughout the matrix of the patching material and at the patch/stone interface. The quartz crystals (sand) were unaltered by the black staining (see figure 46).

[47] George Wheeler to the Central Park Conservancy, "Report on Deposits at Bethesda Terrace," 15 October 1986, Archives, The Central Park Conservancy.
[48] Kate Ottavino, personal communication. The specified composite patch formula for the 1980s restoration did not include any organic bonding agents.

Images of the patching material with SEM confirmed the addition of a non-crystalline substance (see figure 48).

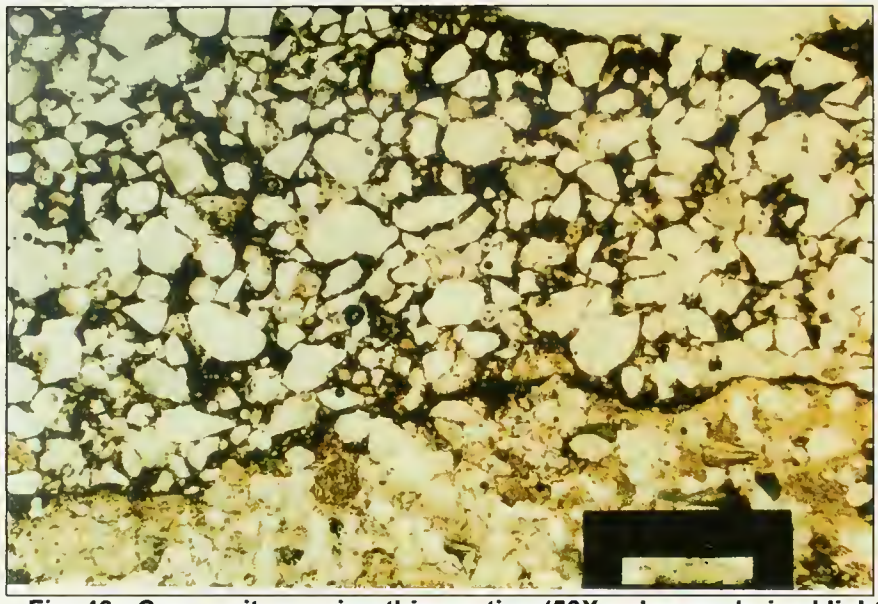


Fig. 46 - Composite repair – thin section (50X - plane-polarized light).
Black coloration is throughout the patching material (top layer) and no calcite crystals are visible in the matrix. No alteration to the sound stone beneath the patch is evident.

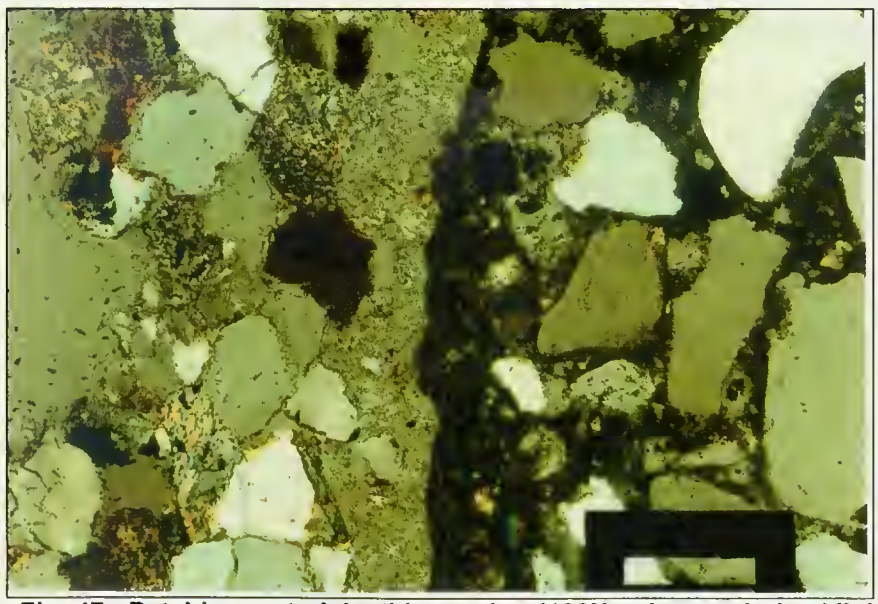


Fig. 47 - Patching material – thin section (100X - plane-polarized light).
Black layer at interface between sound stone (left) and mortar patch (right).

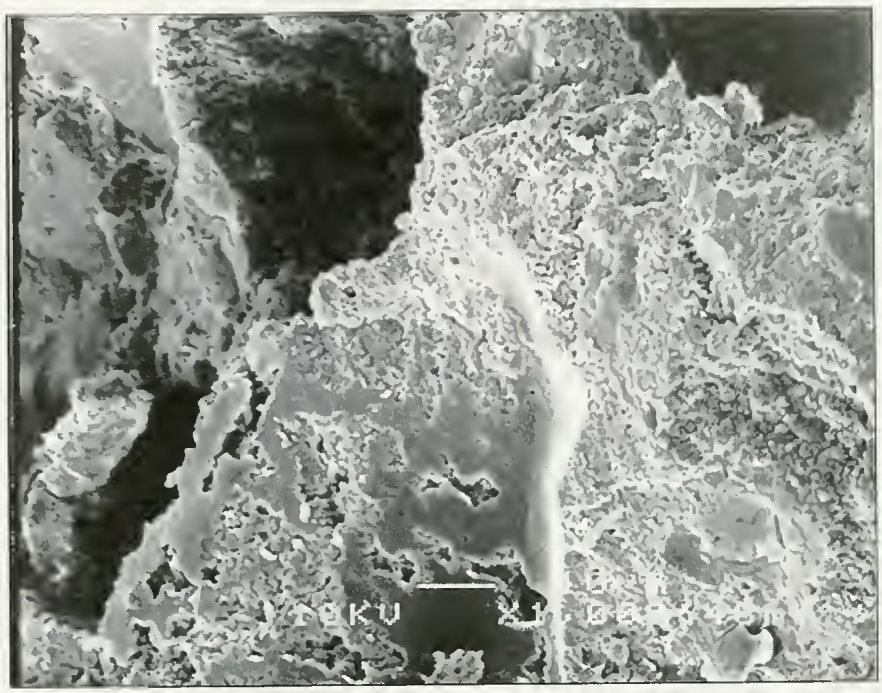


Fig. 48 - Patching material – (1,000X - JEOL SEM).
No evidence of biological growth in pores of the stone or on the glassy surfaces, attributed to the presence of an organic component, is visible.

A sample of composite patching material was removed for XRD analysis from a discolored patch on the north west balustrade of the middle terrace. This sample was flat mounted whole with sculpting putty and scanned at 5°/min. from 10° to 70°.[49] The pattern detected from this sample clearly indicates that the crystalline composed detectable with this technique is α quartz. A peak for calcite was also identified, confirming the presence of the lime binder in the patching material. This confirms previous information regarding the composition of the composite patching material used in the 1980s restoration as containing sand and lime.

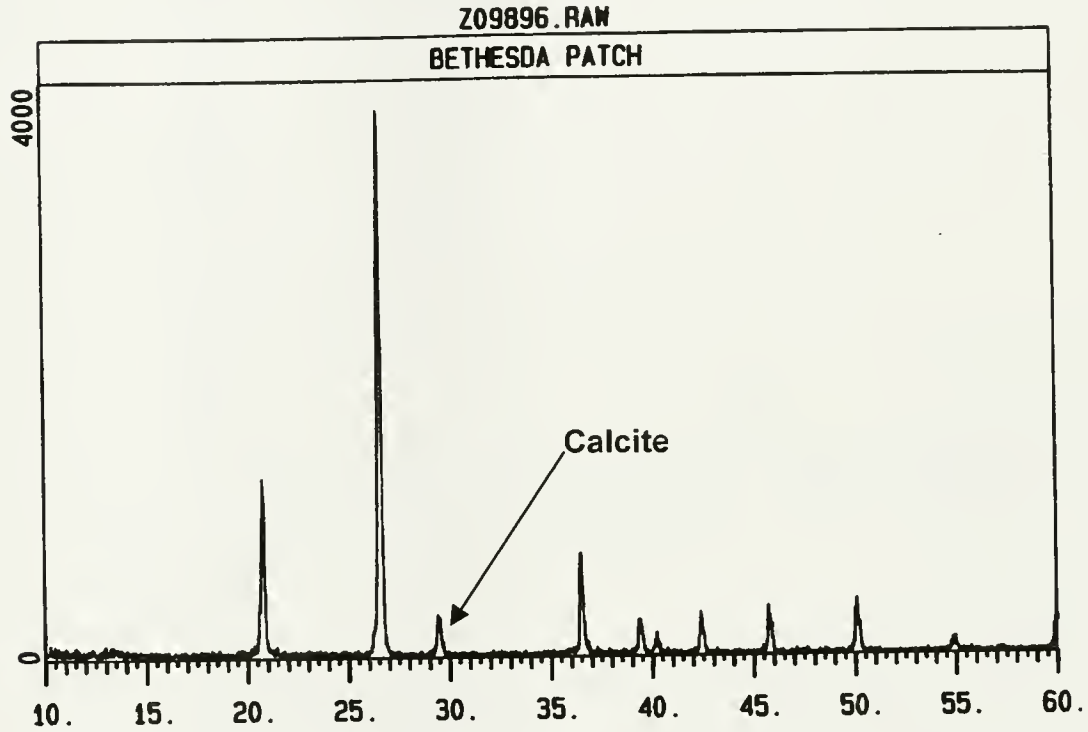


Fig. 48 - XRD Pattern for core sample – P

It was suspected that an organic additive was causing the black staining. FTIR analysis of the black crust was conducted.[50] The results showed a high concentration of hydroxides and a high carbonyl peak indicating the presence of organic materials. This peak was isolated and compared to spectra of know organic materials. The closest matches were the Acryloid™ or Rhoplex™ acrylate groups.

[49] The number of degrees per minute and angles recorded was adjusted according to Dr. A. E. Charola's advice based on previous research on the characteristics of architectural materials.
[50] FTIR analysis was conducted by Beth Price at the Conservation Laboratory, Philadelphia Museum of Art.

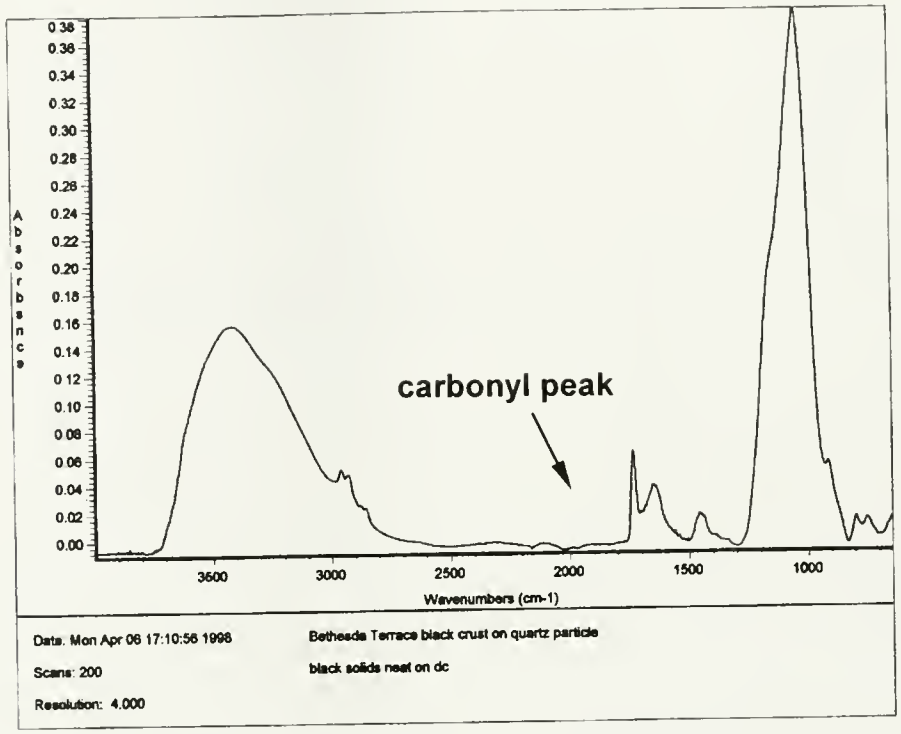


Fig. 48 - FTIR spectrum (isolated black stain).

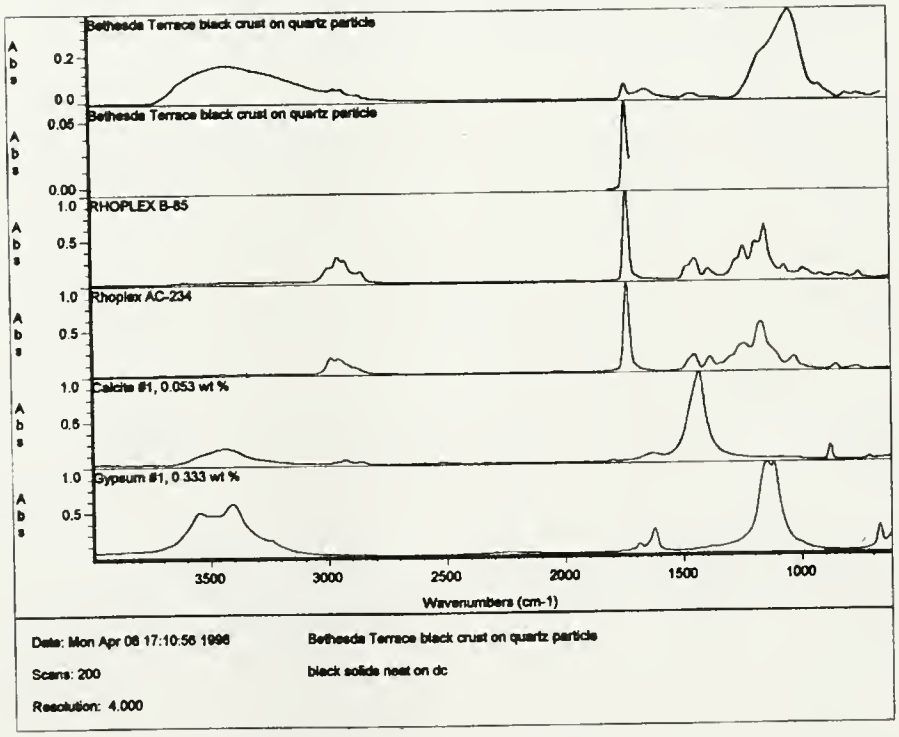


Fig. 49 - FTIR comparative spectra.

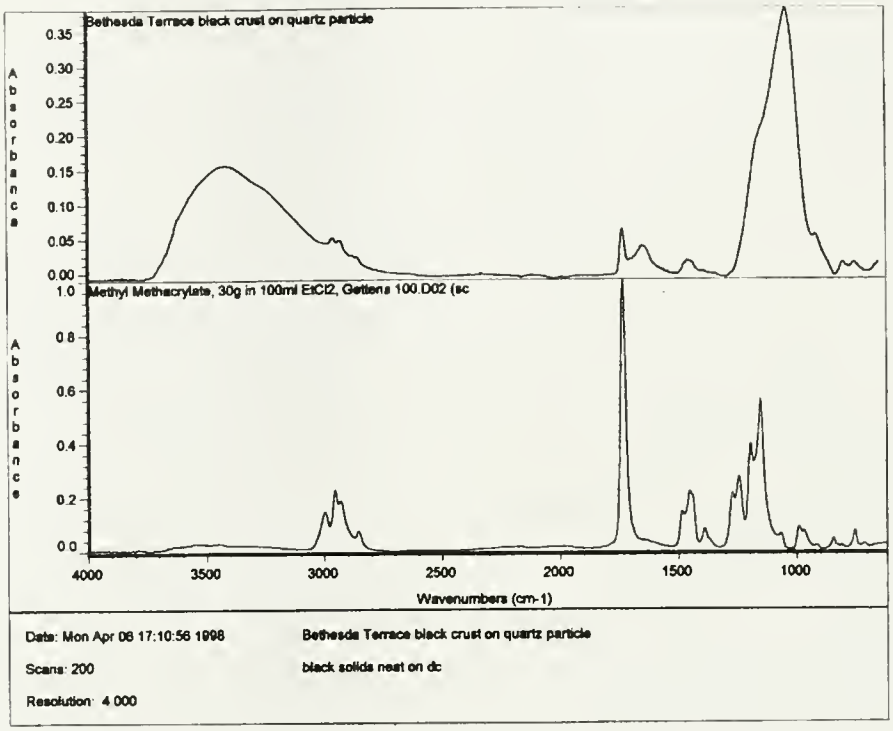


Fig. 50 - FTIR spectra comparing black stain with methyl methacrylate.

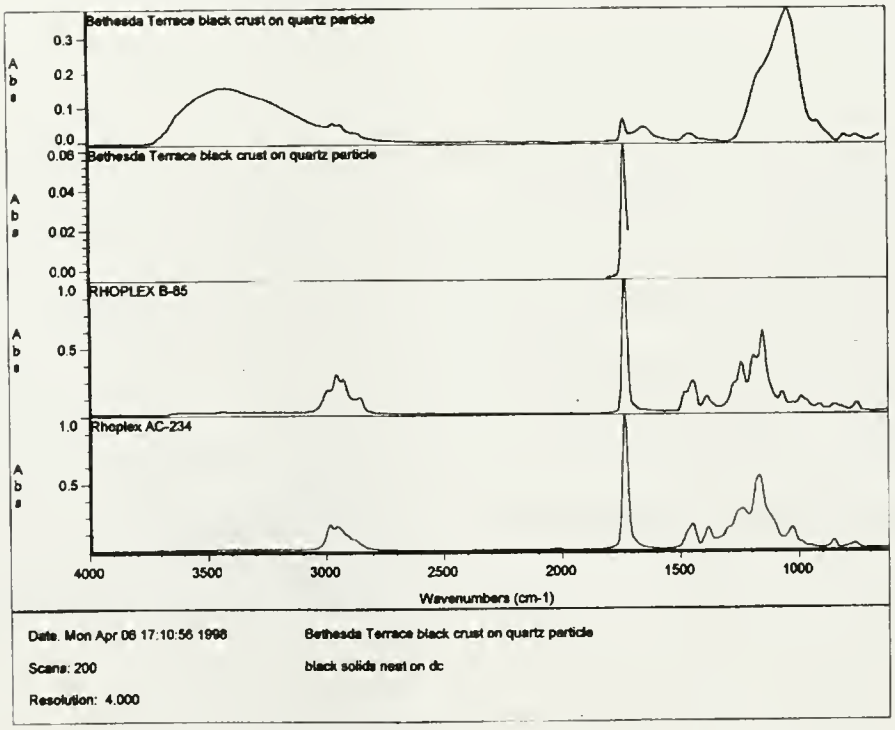


Fig. 51 - FTIR spectra for Rhoplexes.™

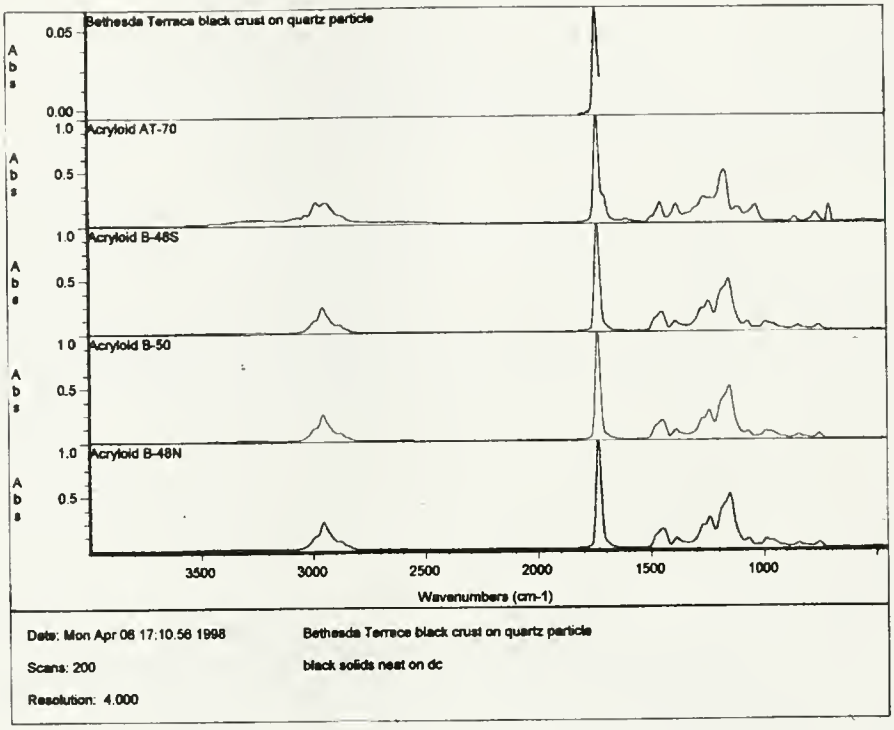


Fig. 52 - FTIR spectra for Acryloids.™

Thermal analyses in combination with mass spectrometry were also used to compliment the FTIR analysis of the organic additives in the patching mortar. Two distinct peaks were obtained in the thermal gravinometric analysis (TGA) and were compared to a sample of methyl methacrylate analyzed with the same methods. One of the peaks resembled the methyl methacrylate, however the second did not. This suggests that the acrylic admixture in the patching material was a combination of two substances.

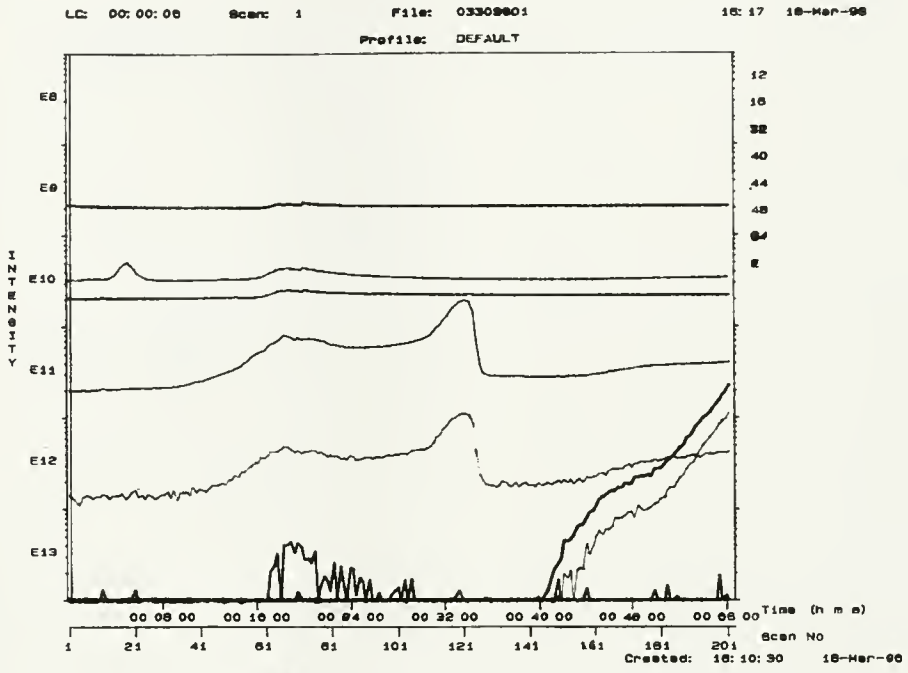


Fig. 53 - MS analysis of powdered patching mortar.

SPECTRUM AT MAX. OF ORGANIC EVOLUTION

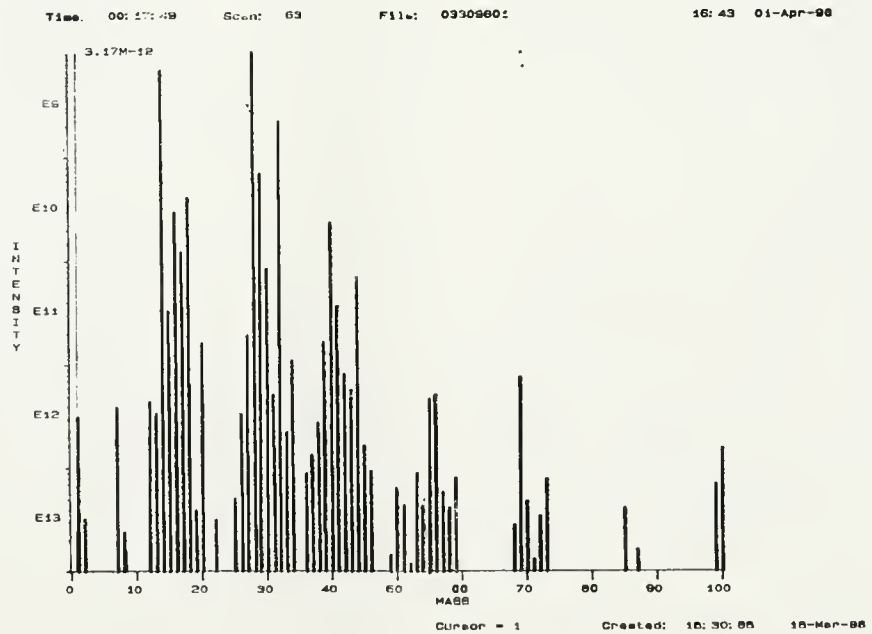


Fig. 54 - Spectrum at maximum of organic evolution.

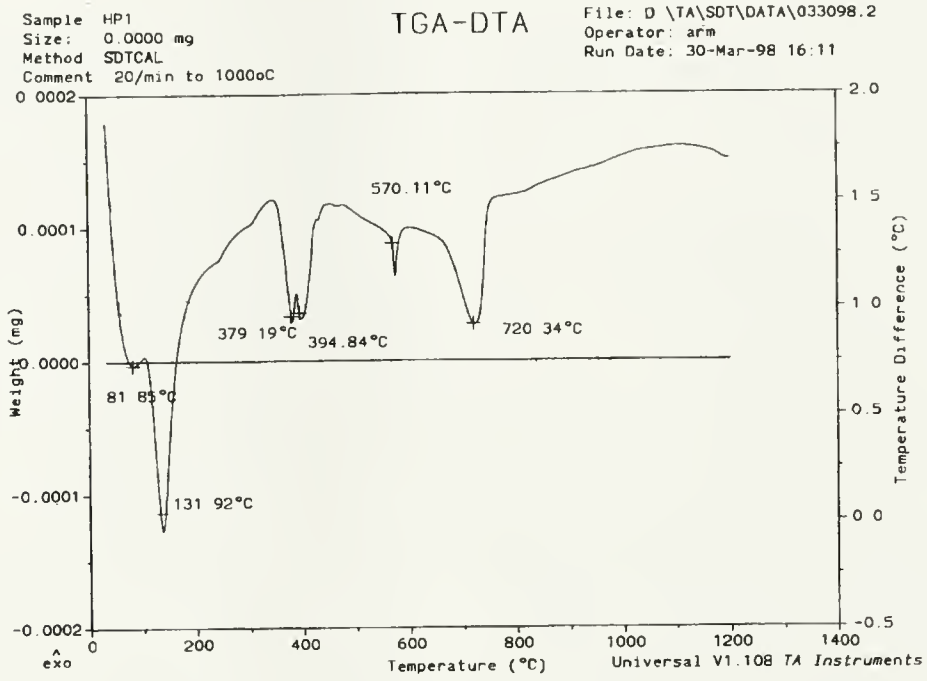


Fig. 55 - DTA analysis of patching mortar.

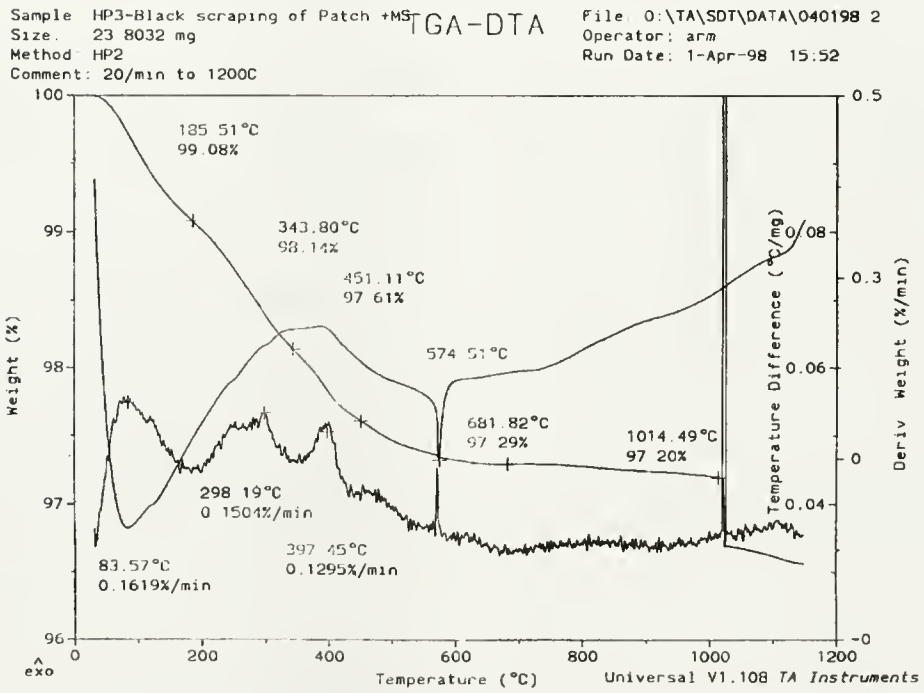


Fig. 56 - TGA-DTA analysis of freshly powdered patching mortar.

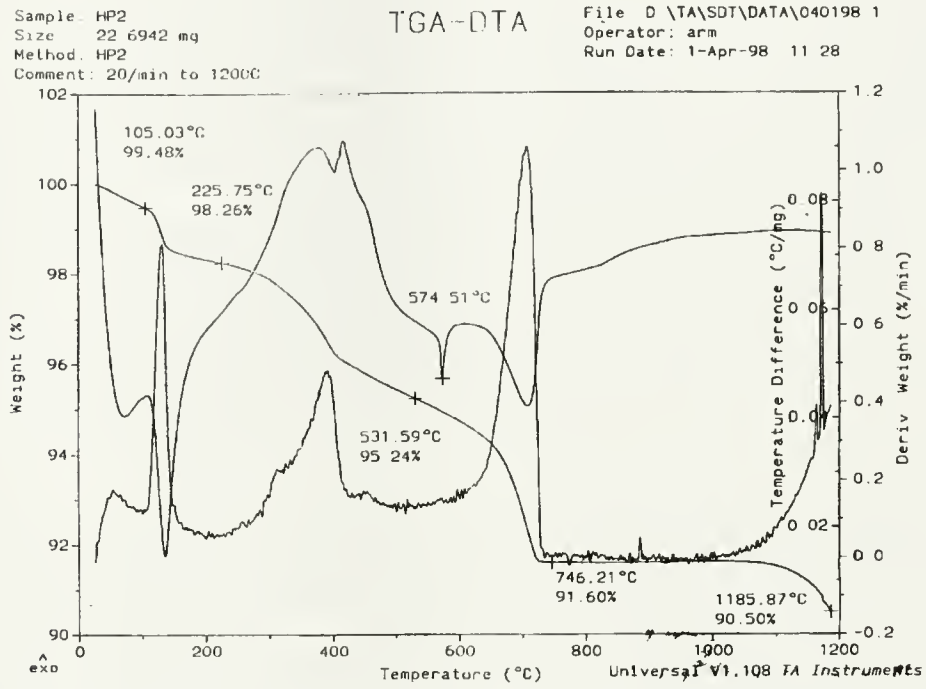


Fig. 57 - TGA-DTA analysis of powdered patch after 2 days exposure to air.

A hypothesis was developed to explain the formation of the black color found on and around the 1980s patching material based on the analyses carried out. Acrylic emulsions in mortar patches have been used for many years in architectural conservation without any major alterations to the surrounding stone substrates reported. In the case of Bethesda Terrace however, it is possible that the acrylic admixture, the environment or a combination of both have created a microenvironment for a unique phenomenon. Because some acrylic resins

breakdown to form compounds which turn black[51], the acrylics in the composite patches at Bethesda Terrace may also be experiencing a similar decomposition and discoloration. However, further analysis is required. Thermal analysis of the black crust from the northwest pier of the middle terrace showed reduced amounts of carbonates compared with the sample from the inside of the same patch. This confirms a loss of binder due to weathering or possible attack from the breakdown of the acrylics into an acidic compound.

The second hypothesis is that the acrylics in the patching material provide nutrients for a micro-flora or bacterial growth, however no evidence of this type of phenomenon was found with the analytical techniques utilized. Whatever the mechanism responsible for the black staining on and around the 1983-85 mortar repairs, it is clear from the field observations that the phenomenon is associated with the patching mortar and not the stone. Moreover, despite the reported absence of organics in the original mortar formulations, an acrylic admixture was nevertheless detected.

REPLACEMENT IN KIND

Replacement in kind with stone at Bethesda Terrace was executed primarily in the balustrade screening elements on the exterior terrace elliptical arms and the

[51] According to Andrew McGhie at the Laboratory for the Research on Structural Matter, methyl methacrylate can decompose into both an acidic compound, possibly methacrylic acid, and polyacetylene of which the latter will discolor when exposed to acidic environments.

perimeter balustrades of the middle terrace. The replacement of trefoils and entire carved screens was conducted where the original stone was either completely lost or deteriorated beyond a condition that would benefit from honing or patching. This treatment proved effective mechanically and sculpturally, however the color match to the original stone is no longer satisfactory. In addition at least two campaigns were observed in areas where double layers of adhesive and stone of slightly different color exist. The availability of sandstone from New Brunswick, Canada is in short supply even today. Therefore, to replace the stone at Bethesda Terrace with the exact same sandstone was impossible in the 1980s restoration. Since that time, another quarry was re-opened and it produces a stone similar in color to the original sandstone used at Bethesda Terrace. Currently, a supply of this sandstone is used by the Central Park Conservancy for carving replacement pieces for the decorative bird panels and other elements throughout the terrace.

Conservation philosophy argues that repairs to original fabric be compatible yet distinguishable without disrupting visual or aesthetic unity. The slight differences in color of the replacement stone at Bethesda Terrace are therefore not a major problem although the stone now used for repair offers a closer visual match. The poor quality of the earlier dutchmen installations, characterized by misalignments and excess adhesive visible at the joins, which has begun to discolor is of great concern.

Conclusions

The conditions survey of the interior arcade and representative areas of the exterior terrace at Bethesda Terrace well illustrates the various factors, deterioration conditions and decay mechanisms present. Analyses of the major treatments applied over ten years ago suggest that their interventions addressed the major sandstone deterioration conditions observed. The treatments afforded both immediate and long-term results— some anticipated and perhaps beneficial and others unanticipated and failures. The above information shows that a slightly different approach to the restoration of the previously untreated areas of the arcade will be required to ensure compatibility with the microenvironment of the interior arcade. Furthermore, alternative treatments are required on the interior stone where salt contamination and moisture penetration are major sources of active deterioration.

Research of current treatment methods may offer new techniques and materials not available in the 1980s. The experimental applications of consolidants to the sandstone of Bethesda Terrace are still extant and have proven effective in retaining the cohesion of the stone, minimally decreasing the permeability, and leaving the original color unaltered. Developments in the understanding of stone consolidant performance will ensure the appropriate choice of pre-consolidants

and consolidants and their use in conjunction with desalination processes. Alternate formulae for composite repair of lost and damaged sandstone elements at Bethesda Terrace require testing to ensure no discoloration occurs. Further research is needed to determine the cause of the black staining and the role of the organic additives in this condition. Compensation for lost stone elements with new stone dutchmen remains a viable choice with the advantage of a new supply of appropriate stone. Honing, although only superficially altering the stone, needs to be rethought as a viable means of correcting surface crusting and flaking as the visual result is not successful as previously executed.

The assessment of the exterior treatments with regard to their reapplication to the interior arcades is only the first step in the process of developing this alternate restoration plan. Further analysis of the untreated interior and treated exterior stone will be required after stabilization of the arcade. A study of the microenvironment of the arcade after structural stabilization, waterproofing and the replacement of the Minton tile ceiling will provide a basis for determining the ambient climate that differs from the exterior terrace.

Most importantly, a unifying preservation philosophy must be established prior to the implementation of any structural or cosmetic stone treatments. This is critical for the entire project as Bethesda Terrace was conceived of as a whole. It will be especially critical for the arcade interior as the differences in conditions between

undamaged and damaged stonework is great and the techniques of visual reconciliation will be more difficult without the overall unity of a weathered surface.

RECOMMENDATIONS

Diagnostic assessment of the interior sandstone conditions was based on a number of factors believed to affect stone performance and future treatment:

- Stone type, structure and composition
- Orientation
- Finish and tooling of original surface
- Location
- Exposure
- Previous maintenance and treatment of the stone

These factors, in conjunction with a comparative analysis between the interior and exterior sandstone conditions and an evaluation of previous treatments, were the focus and objective of this study. It is clear that the interior arcade has always been a different microenvironment from the exterior terrace based on the extensive conditions survey of the interior arcade and selective exterior survey. This was determined using information such as current ambient temperature, moisture penetration and relative humidity, as well as a comparison of existing conditions to those on the exterior terrace. The contamination of the arcade sandstone with salts from the 72nd Street Transverse Road has significantly added to the differential deterioration of the arcade sandstone compared to the exterior stone. The difference in the type and extent of deterioration mechanisms will require the modification of any treatment already used on the exterior and considered successful for interior use.

Preliminary recommendations for the interior arcade include the waterproofing of the envelope of the terrace to eliminate moisture penetration and control salt contamination. Ultimately, after waterproofing the arcade, the stone and brick vaults must be dried out completely. This is essential for long-term preservation of the masonry and especially during the conservation treatment process. Emergency stabilization may be necessary during this process.

After the arcade is stabilized, pre-consolidation of the decaying sandstone can be considered. This will ensure that as much historic fabric as possible is retained during subsequent conservation processes. Cleaning is a consideration especially in areas where heavy graffiti has marked the sandstone and requires removal. The overall removal of efflorescence and salt crusting also falls under the category of cleaning. Desalination of the sandstone in the arcade is possible only after the envelope is waterproofed. Several methods of salt extraction exist for historic masonry. Further testing is necessary to determine the most effective method of salt removal from the Bethesda Terrace arcade sandstone. Options may include water washing and/or poulticing with various media such as inert earth or paper pulp.

Once the arcade is cleaned and desalinated, reattachment of delaminating elements and displaced architectural elements can occur. Further research into

appropriate methods of reattachment is required before work is begun. Honing of the interior sandstone surfaces is probably inappropriate given the nature and level of deterioration in the interior and the difficulty in achieving a planer surface on broad flat areas. Compensation for lost elements will be required in the arcade at Bethesda Terrace. Exploration of the options, which include composite patching and replacement in kind with dutchmen is essential to provide compatible patches and replacement elements. Clearly defined levels of acceptable loss and compensation must be established before any repairs occur.

Research into the effects and performance of consolidants to be tested or applied on the friable deteriorated sandstone of the interior arcade at Bethesda Terrace are needed if consolidation is to be considered as a preservation treatment. This research must include further analysis of the stone to determine the quantity, type and source of soluble salts that remain in the stone after drying occurs. Careful examination of the effects of test samples or patches on the arcade stone will provide essential information as to the effectiveness of the consolidants currently on the market. The application of ethyl silicates such as Consevare OH™ is a possible consideration. Applications of consolidants require caution due to the high concentration of soluble salts in the stone that could prove destructive if their passage to the surface form the interior is inhibited. Brethane is not currently used in the US, but is being reevaluated in

the UK as a consolidation treatment and new research on its effects is still possible, as are similar products.

Finally, after completion of the restoration, it is necessary to set-up a program of maintenance and inspection that will be carried out to insure the success of the treatments and provide additional treatment should unexpected alterations or failures occur. It is important that a maintenance plan is created, followed and documented to ensure the long-term success of the Bethesda Terrace arcade. Furthermore treatments need to be monitored after 1, 5, and 10 years. To that end, the conditions survey from 1997 will provide useful baseline information for to the ongoing preservation of Bethesda Terrace.

APPENDIX A: INTERVIEWS

Interviews with people involved in the 1980s restoration of Bethesda Terrace as well as people knowledgeable in the performance, decay and restoration of sandstone were conducted this summer. The following people provided valuable information to aid in the analysis of previous sandstone restoration techniques.

Frank G. Matero, Chair and Associate Professor, Department of Historic Preservation, University of Pennsylvania and Project Director, provided overall guidance throughout the project including the scope of the project as well as acquiring funding. He aided in the determination of the initial categories of decay mechanisms and the areas of importance to be surveyed for analysis. Formation of the key questions this project addresses and an outline of possible mechanical and chemical tests were developed in interviews with Matero.

A. E. Charola, conservation scientist and project consultant, provided information concerning the development of the condition survey. Charola discussed, on site in June, and over the telephone and internet throughout June, July and August, the decay mechanisms occurring at Bethesda Terrace. With her assistance and input conditions categories were developed and arranged utilizing previous research in the field. Charola also guided the selection of the survey areas and served as Project Advisor for the material analysis of the previous conservation treatments at Bethesda Terrace during Phase II.

Mark Rabinowitz, Historic Preservationist, oversaw the work performed this summer and provided names of people involved in the 1980s restoration project. Rabinowitz also made available his knowledge of the past restoration and the field of architectural conservation.

Peter Champe, Monuments Conservator, Central Park Conservancy oversaw the administrative aspects of this project and provided his knowledge of monuments conservation and the decay of sandstone elements at Bethesda Terrace. He offered daily support in organizing the logistics of the conditions survey and also will continue to oversee the project through Spring 1998.

Kate Ottavino, architect, visited the sight in June and provide information on the 1980s restoration project. Ottavino was the project architect for Ehrenkrantz Architects, the firm overseeing the restoration of Bethesda Terrace and its surrounding landscape. Ottavino outlined the past project and located areas where specific conservation treatments were conducted. Ottavino initially developed the system of documenting the restoration process in the 1980s, however the dossiers created under her guidance could not be located in the archives in summer 1997.

Martin Stecklow, conservator, oversaw the participation of Thomason Industries in the 1980s restoration of Bethesda Terrace. Stecklow was contacted by telephone in June and provided information confirming that no waterproofing of the sandstone at Bethesda Terrace was conducted in the restoration. He also confirmed that consolidation was performed in certain areas. Stecklow suggested contacting Fleur Palau, the sculptor overseeing the honing of the stone elements as she may have documents regarding the testing, determination, execution and effectiveness of the treatments conducted at Bethesda Terrace. According to Stecklow, Thomason Industries kept no records concerning the restoration project.

Ivan Meyjer, Director of Conservation, Society for the Preservation of New England Antiquities, provided information at a conference in Boston this past May on the use and treatment of sandstone in architecture. Over the telephone in

June, Meyjer suggested some possible resources concerning the restoration of Canadian sandstone and conservation treatments for stone materials. He also furnished Hans Durstling's contact information. Durstling is writing a book documenting the use of Canadian sandstone that includes New Brunswick sandstone and its use in the eastern United Stares and Canada.

Several other contacts were made this summer. Many people offered assistance in locating missing documentation. To this date, the Ehrenkrantz dossiers of Bethesda Terrace are still unfound. Continued contact with the following people may someday uncover this resource.

New York City Municipal Archives; Kenneth Cobb
Ehrenkrantz Architects; Loren Stall, Johnny Mack
Eileen Brown; Columbia University Graduate
George Wheeler; Metropolitan Museum of Art
Norman Weiss; Graduate Program in Historic Preservation, Columbia University
Phieffer Architects; Jean Parker Phieffer
Thomason Industries; William Stecklow
Manhattan Construction; David Goldstone
New York City Department of Parks, Department of Construction, Pat Lombardi
New York City Art Commission; Lynne Baudner
Tim Marshall, previously Central Park Conservancy
John Freeman, previously New York City Department of Parks

APPENDIX B:

AUTOCAD DRAWINGS OF THE CONDITIONS SURVEY OF THE ARCADE AT BETHESDA TERRACE, SUMMER 1997.

PREVIOUS LONG-TERM LOSS

Drawing 1-CA	Central arcade, 148
Drawing 1-CA	East loggia, 149
Drawing 1-CA	North and south arcades, 150
Drawing 1-CA	West loggia, 151

SURFACE DEPOSITS

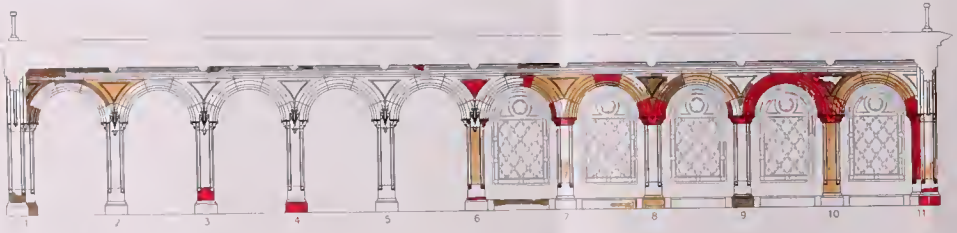
Drawing 2-CA	Central arcade, 152
Drawing 2-CA	East loggia, 153
Drawing 2-CA	North and south arcades, 154
Drawing 2-CA	West loggia, 155

RECENT ACTIVE DETERIORATION

Drawing 3-CA	Central arcade, 156
Drawing 3-CA	East loggia, 157
Drawing 3-CA	North and south arcades, 158
Drawing 3-CA	West loggia, 159

MOISTURE PENETRATION

Drawing 4-CA	Central arcade, 160
Drawing 4-CA	East loggia, 161
Drawing 4-CA	North and south arcades, 162
Drawing 4-CA	West loggia, 163



EAST WALL OF CENTRAL ARCADE

SCALE

WEST WALL OF CENTRAL ARCADE

SCALE

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

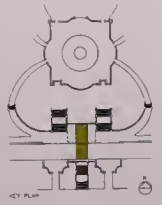
PREVIOUS LONG-TERM LOSS:

ROUNDING OUT OF STONE SURFACE

ROUGHENING/PITTING

DIFFERENTIAL EROSION

LOCATION
CENTRAL ARCADE



SURVEYED BY
C. J. GEMBINSKI

SURVEY DATE
AUGUST 1997

DRAWING NO
1-CA

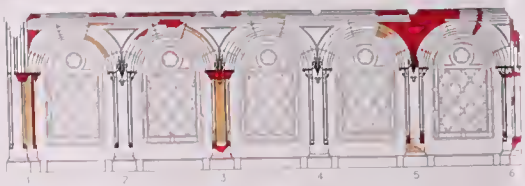
BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

PREVIOUS LONG-TERM LOSS

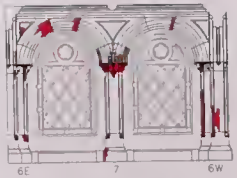
ROUTING OUT OF STONE SURFACE

ROUGHENING/PITTING

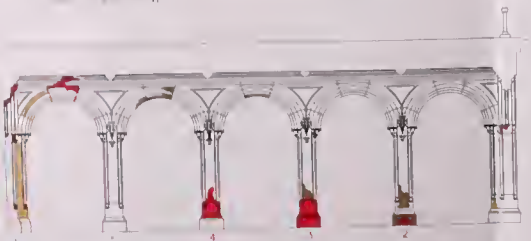
DIFFERENTIAL EROSION



EAST WALL OF EAST LOGGIA

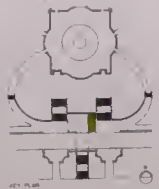


SOUTH WALL OF EAST LOGGIA



NORTH WALL OF EAST LOGGIA

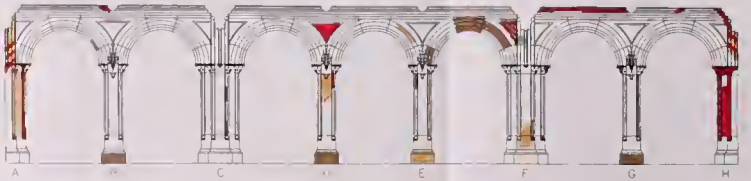
LOCATION
EAST LOGGIA



SURVEYED BY
C. GEMBINSKI

SURVEY DATE
AUGUST 1997

DRAWING NO.
11-EL



NORTH ARCADE

SCALE

SOUTH ARCADE

SCALE

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

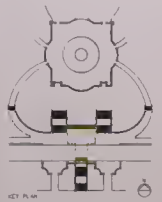
PREVIOUS LONG-TERM LOSS

ROUNDING OUT OF STONE SURFACE

ROUGHENING/PITTING

DIFFERENTIAL EROSION

LOCATION
NORTH AND SOUTH ARCADES



SURVEYED BY
C. J. GEMBINSKI

SURVEY DATE
AUGUST 1997

DRAWING NO
1-NS

EAST ARCADE OF WEST LOGGIA

SCALE 0 5 10

SOUTH WALL
OF WEST LOGGIA

SCALE 0 5 10

WEST WALL OF WEST LOGGIA

SCALE 0 5 10

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

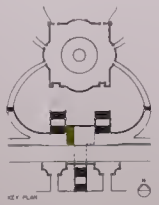
PREVIOUS LONG-TERM LOSS

ROUNDING OUT OF STONE SURFACE

ROUGHENING/PITTING

DIFFERENTIAL EROSION

LOCATION
WEST LOGGIA



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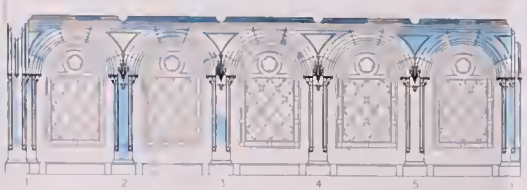
C. J. GEMBINSKI

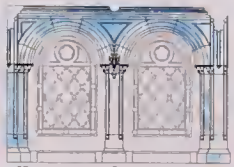
SURVEY DATE
AUGUST 1997

DRAWING NO
1-WL



EAST WALL OF EAST LOGGIA

SCALE



SOUTH WALL
OF EAST LOGGIA

SCALE

WEST ARCADE OF EAST LOGGIA

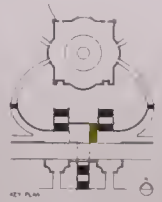
SCALE

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

SURFACE DEPOSITS

EFFLORESCENCE AND CRUSTS

LOCATION
EAST LOGGIA



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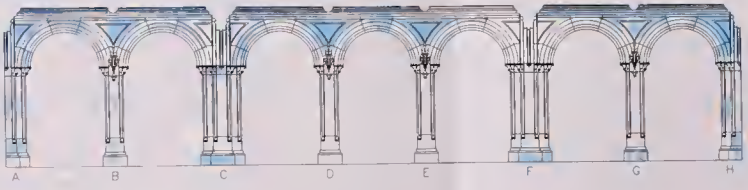
C. J. GEMBINSKI
SURVEY DATE
AUGUST 1997

DRAWING NO.
2-EL

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

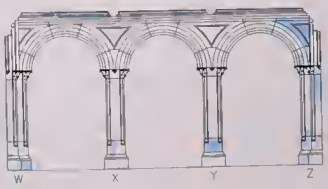
SURFACE DEPOSITS.

EFFLORESCENCE AND CRUSTS



NORTH ARCADE

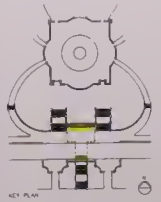
SCALE



SOUTH ARCADE

SCALE

LOCATION
NORTH AND SOUTH ARCADES



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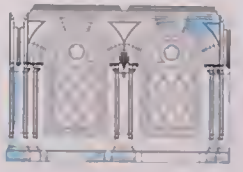
C. J. GEMBINSKI
SURVEY DATE
AUGUST 1997

DRAWING NO.
2-NS



BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

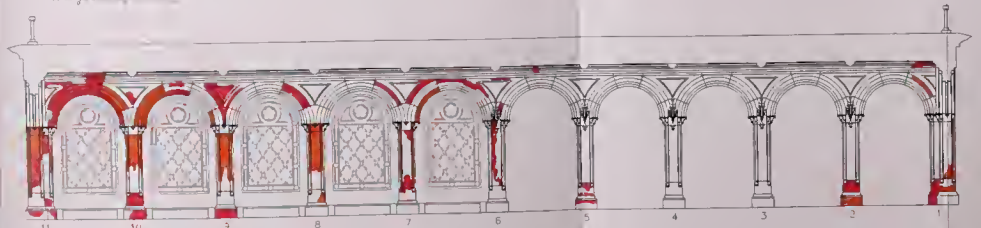
RECENT ACTIVE
DETERIORATION.

GRANULAR DISINTEGRATION

FLAKING AND DELAMINATION

EAST WALL OF CENTRAL ARCADE

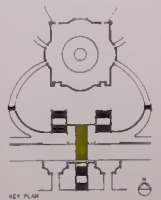
SCALE



WEST WALL OF CENTRAL ARCADE

SCALE

LOCATION
CENTRAL ARCADE



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C. J. GEMBINSKI

SURVEY DATE
AUGUST 1997

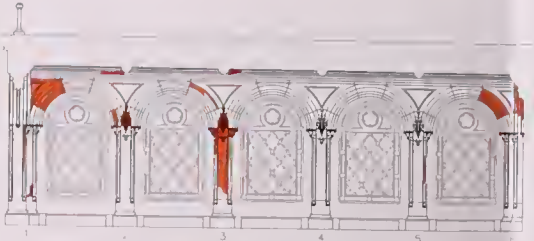
DRAWING NO.
3-CA

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

RECENT ACTIVE
DETERIORATION

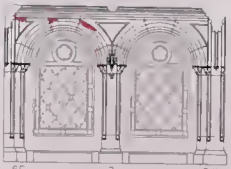
GRANULAR DISINTEGRATION

FLAKING AND DELAMINATION



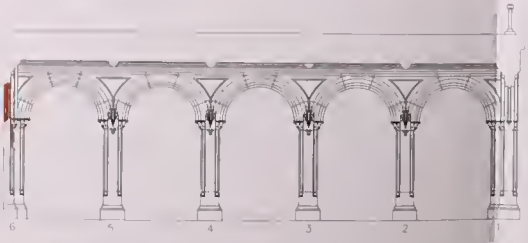
EAST WALL OF EAST LOGGIA

SCALE



SOUTH WALL
OF EAST LOGGIA

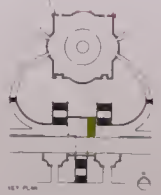
SCALE



WEST ARCADE OF EAST LOGGIA

SCALE

LOCATION
EAST LOGGIA



KEY PLAN

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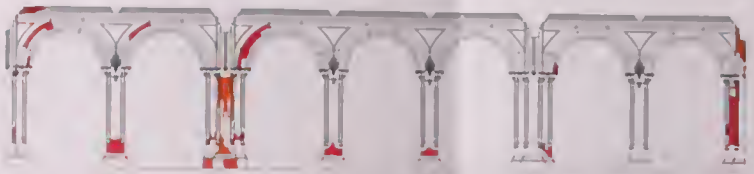
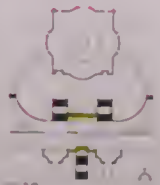




EAST ARCADE OF WEST LOGGIA

SCALE 0 5 10

SOUTH WALL
OF WEST LOGGIA

SCALE 0 5

WEST WALL OF WEST LOGGIA

SCALE 0 5 10

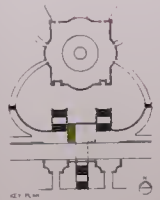
BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

RECENT ACTIVE
DETERIORATION

GRANULAR DISINTEGRATION

FLAKING AND DELAMINATION

LOCATION
WEST LOGGIA



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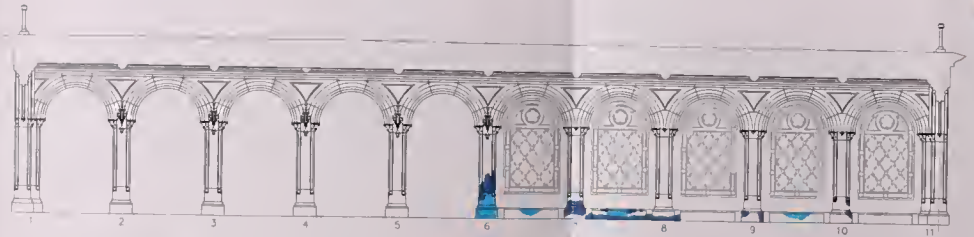
SURVEY DATE
AUGUST 1997

DRAWING NO. 3-WL



EAST WALL OF CENTRAL ARCADE

SCALE

WEST WALL OF CENTRAL ARCADE

SCALE

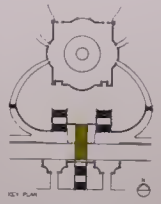
BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

MOISTURE PENETRATION

RISING/FALLING DAMP

PENETRATION DURING RAIN

LOCATION
CENTRAL ARCADE



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C. J. GEMBINSKI
SURVEY DATE
AUGUST 1997

DRAWING NO
4-CA

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

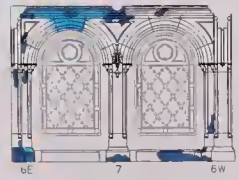
MOISTURE PENETRATION.

RISING/FALLING DAMP

PENETRATION DURING RAIN

EAST WALL OF EAST LOGGIA

SCALE 0 1 2 10



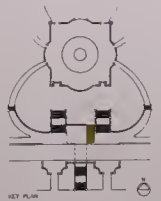
SOUTH WALL
OF EAST LOGGIA

SCALE 0 1 10

WEST ARCADE OF EAST LOGGIA

SCALE 0 1 10

LOCATION
EAST LOGGIA



SURVEYED BY
C J GEMBINSKI

SURVEY DATE
AUGUST 1997

DRAWING NO. 4-EL

BETHESDA TERRACE ARCADE
CONDITIONS SURVEY

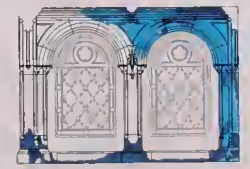
MOISTURE PENETRATION:

RISING/FALLING DAMP

PENETRATION DURING RAIN

EAST ARCADE OF WEST LOGGIA

SCALE 0 1 2



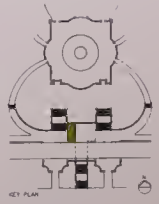
SOUTH WALL
OF WEST LOGGIA

SCALE 0 1 2

WEST WALL OF WEST LOGGIA

SCALE 0 1 2

LOCATION
WEST LOGGIA



SURVEYED BY
C. J. GEMBINSKI

SURVEY DATE
AUGUST 1997

DRAWING NO.
4-WL

FUTURE FORMATTING OF CONDITIONS SURVEY IN AUTOCAD

The process of digitizing the conditions survey began the third week of August at the University. Final documentation format is currently under development. The level of detail in the final presentation design must clearly convey the needed information to a general audience. Currently, the overlay system contains a large amount of complicated information reliant on a detailed key. Reformatting of these pages may remove the need for complex legends in the final document.

Future formatting of the AutoCAD drawings will clearly illustrate the conditions present at Bethesda Terrace. Drawings will be plotted at a scale large enough to read important details of areas for comparative analysis and determination of necessary conservation treatment. The example drawings that follow illustrate the sandstone decay mechanisms of the interior arcade for the areas of surface loss, surface deposits and coloration and active deterioration. They record these categories specific to the sandstone at Bethesda Terrace. These drawings enable quantification of the overall categories and illustrate areas in need of immediate attention based on alteration activity.

Final drawings separating specific conditions into layers will clearly denote specific conditions on the sandstone and will allow for various combinations of recorded symptoms as a means of diagnosing cause/effect relationships. The digitized survey consequently becomes both a fixed record and an active diagnosis process. Level II and Level III drawings will also aid in the selection of analytical test/sample areas and selection of appropriate conservation treatment.

Appendix C: Scanning electron photomicrographs

Fig. 58 - Honed Bethesda Terrace sandstone (200X – JEOL SEM).
Honed surface covered by 100µm layer of dust.

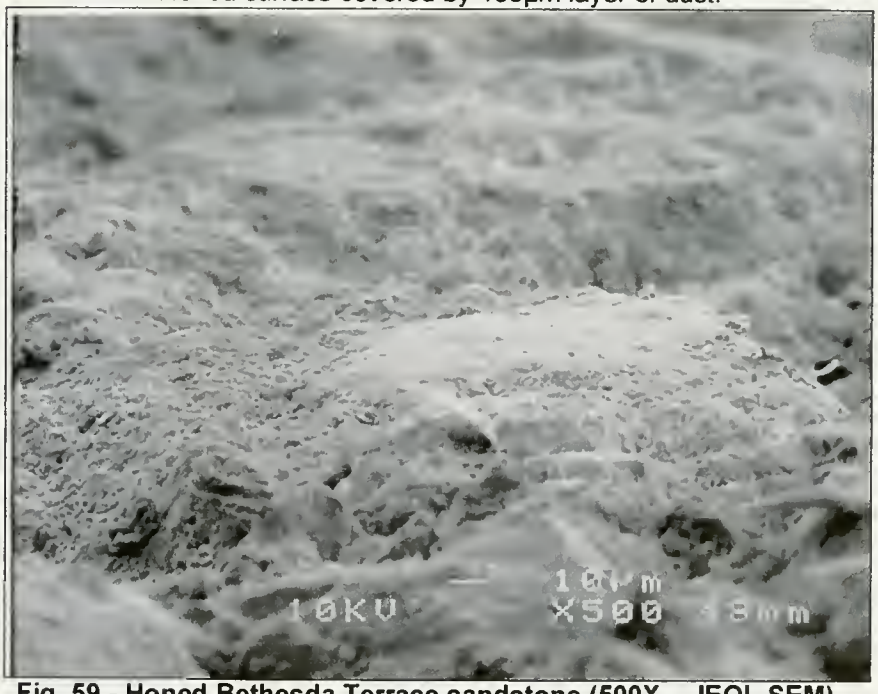


Fig. 59 - Honed Bethesda Terrace sandstone (500X – JEOL SEM).
Dust layer completely covers sandstone grains.

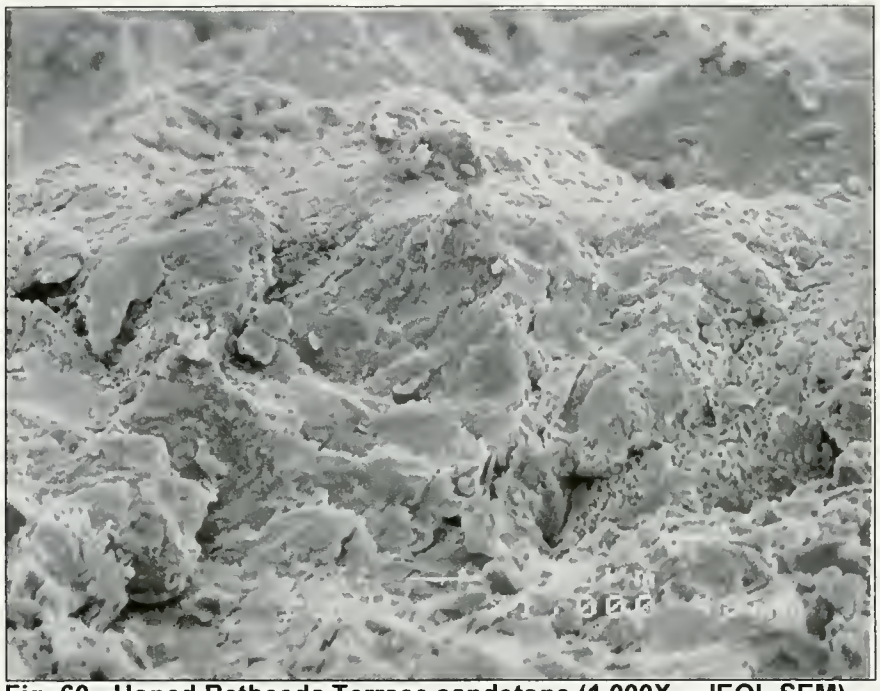


Fig. 60 - Honed Bethesda Terrace sandstone (1,000X – JEOL SEM).
Higher magnification shows smooth flaking surfaces in the 100µm layer on the surface

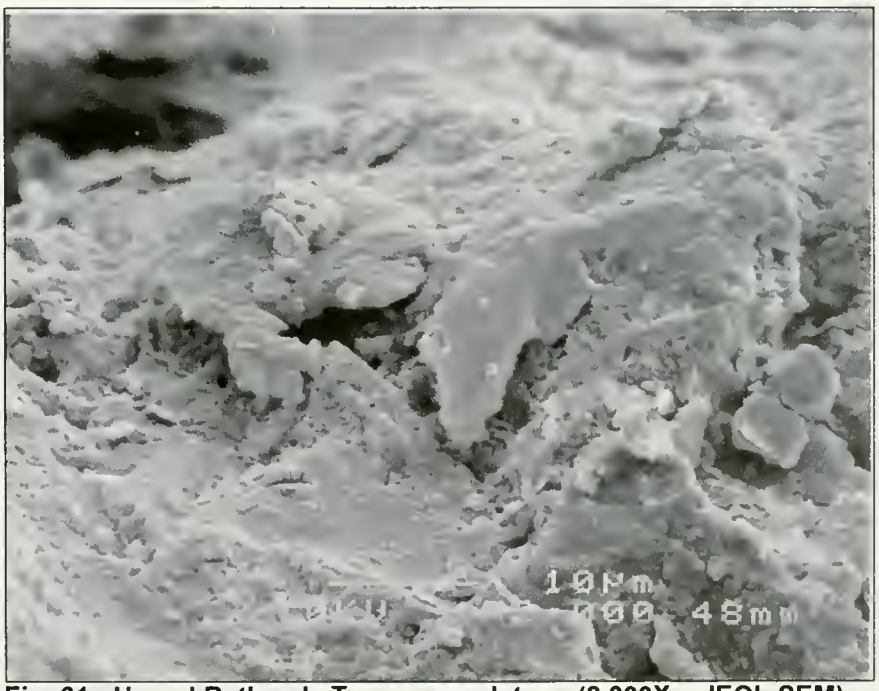


Fig. 61 - Honed Bethesda Terrace sandstone (2,000X – JEOL SEM).
Smooth flakes on honed surface.

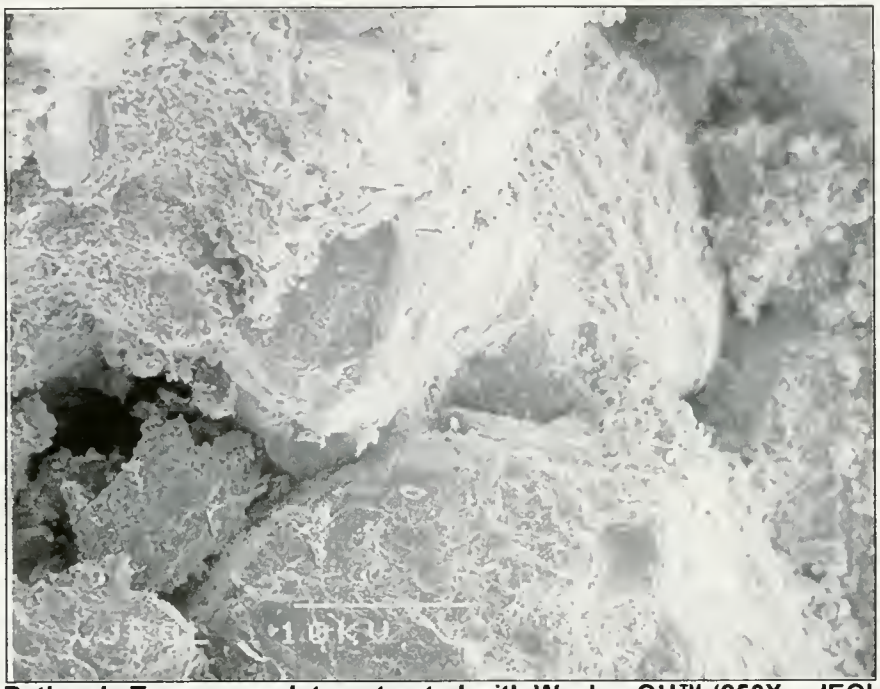


Fig. 62 - Bethesda Terrace sandstone treated with Wacker OH™ (250X – JEOL SEM). Wacker OH™ appears as a film on the quartz grains of the Bethesda Terrace sandstone

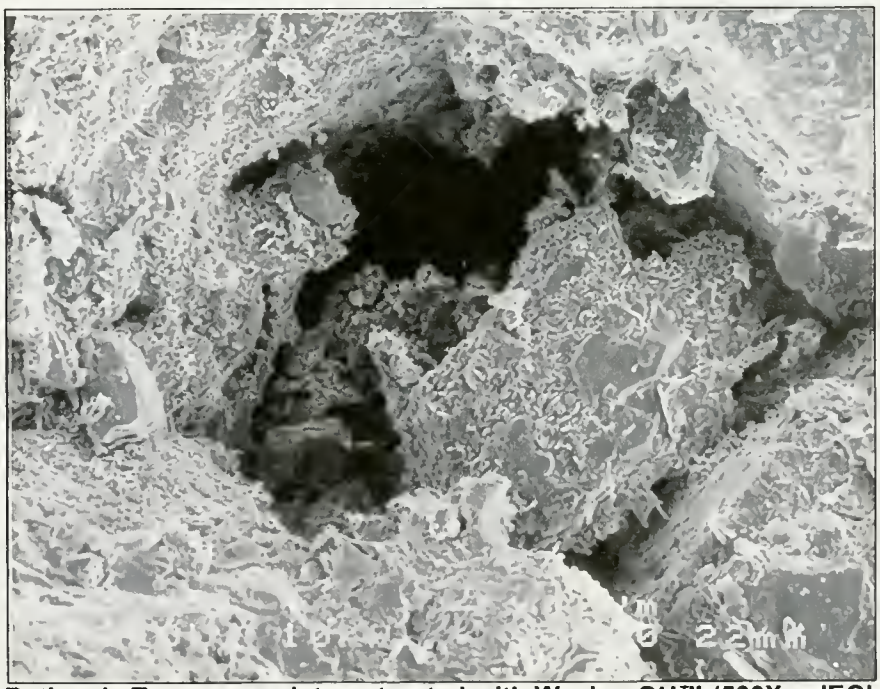


Fig. 63 - Bethesda Terrace sandstone treated with Wacker OH™ (500X – JEOL SEM). Wacker OH™ is observed in the pores of the Bethesda Terrace sandstone.

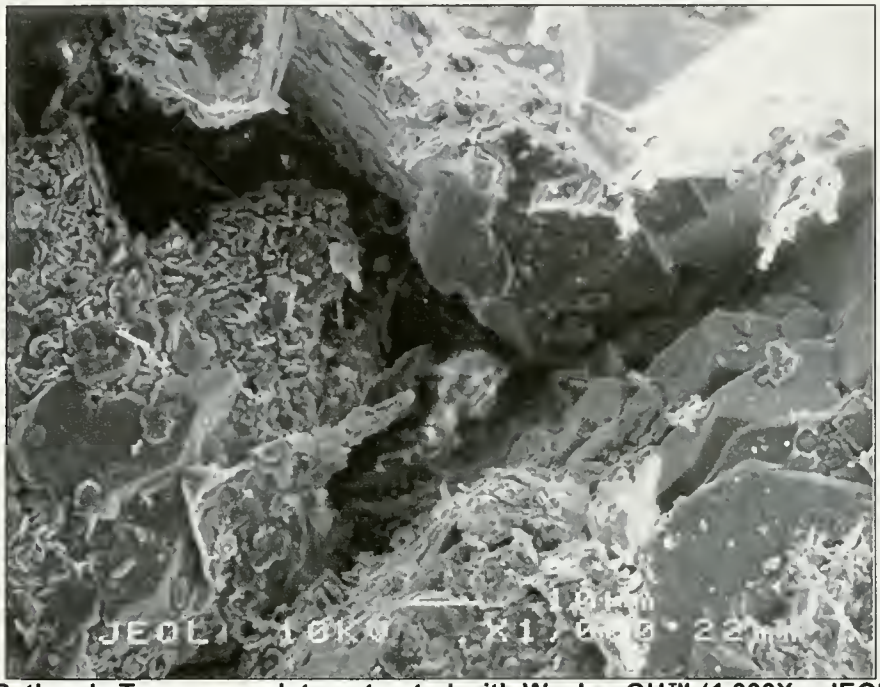


Fig. 64 - Bethesda Terrace sandstone treated with Wacker OH™ (1,000X – JEOL SEM).
Clay particles are coated with Wacker OH.™

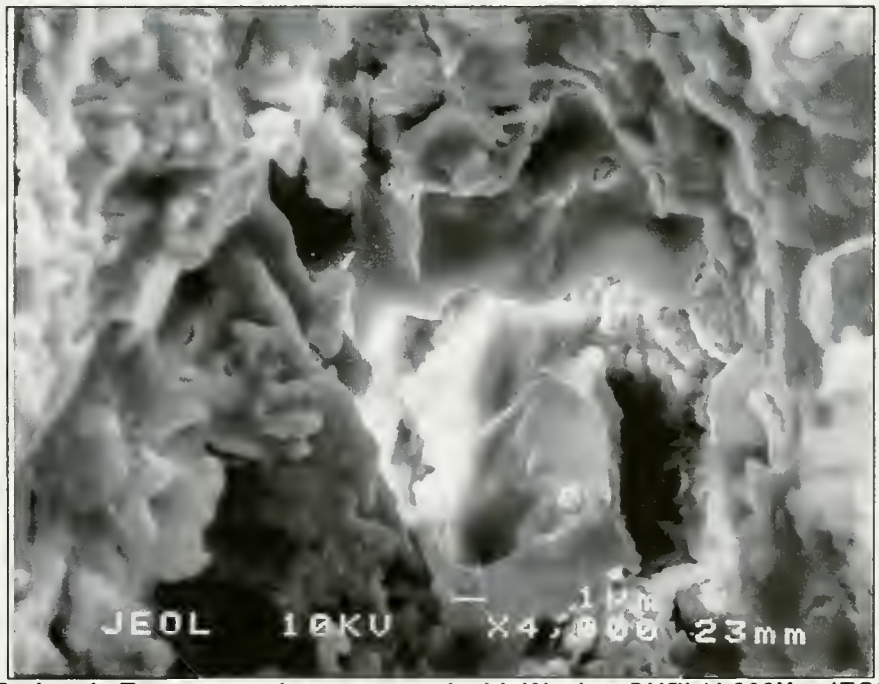


Fig. 65 - Bethesda Terrace sandstone treated with Wacker OH™ (4,000X – JEOL SEM).
Wacker OH™ is observed as a gel coating the surface of the Bethesda Terrace sandstone grains.

Fig. 66 - Bethesda Terrace sandstone treated with Brethane (250X – JEOL SEM).
Brethane observed as a rough coating over the grains of the Bethesda Terrace sandstone.

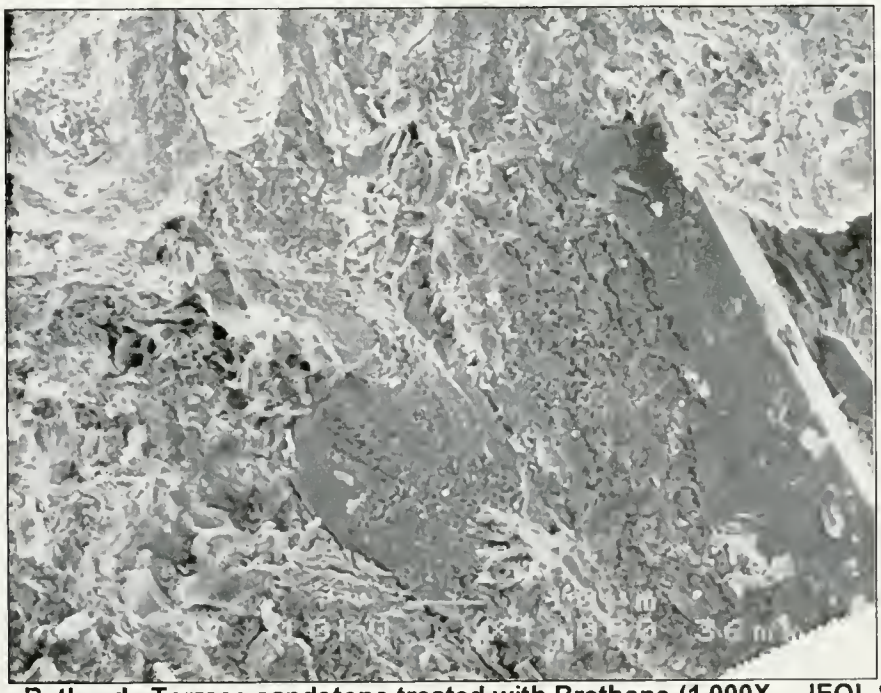


Fig. 67 - Bethesda Terrace sandstone treated with Brethane (1,000X – JEOL SEM).
Brethane is observed as stringy masses adhering to the Bethesda Terrace sandstone grains.

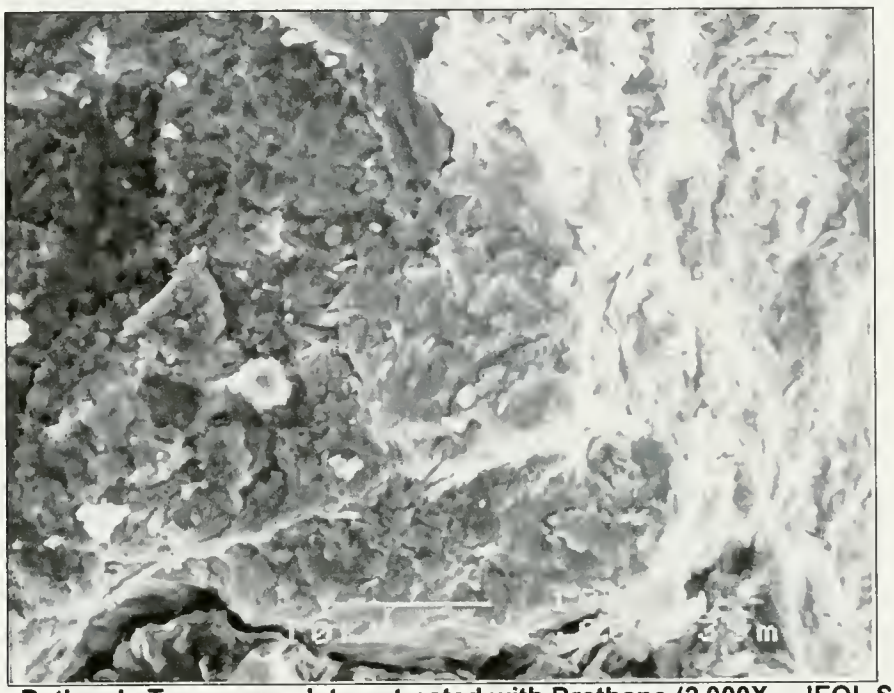


Fig. 68 - Bethesda Terrace sandstone treated with Brethane (2,000X – JEOL SEM).
Rough, stringy appearance of Brethane in the Bethesda Terrace sandstone.

Fig. 69 - Composite Patching material from Bethesda Terrace (150X – JEOL SEM).
Composite patching material showing glassy consistency of mortar matrix.

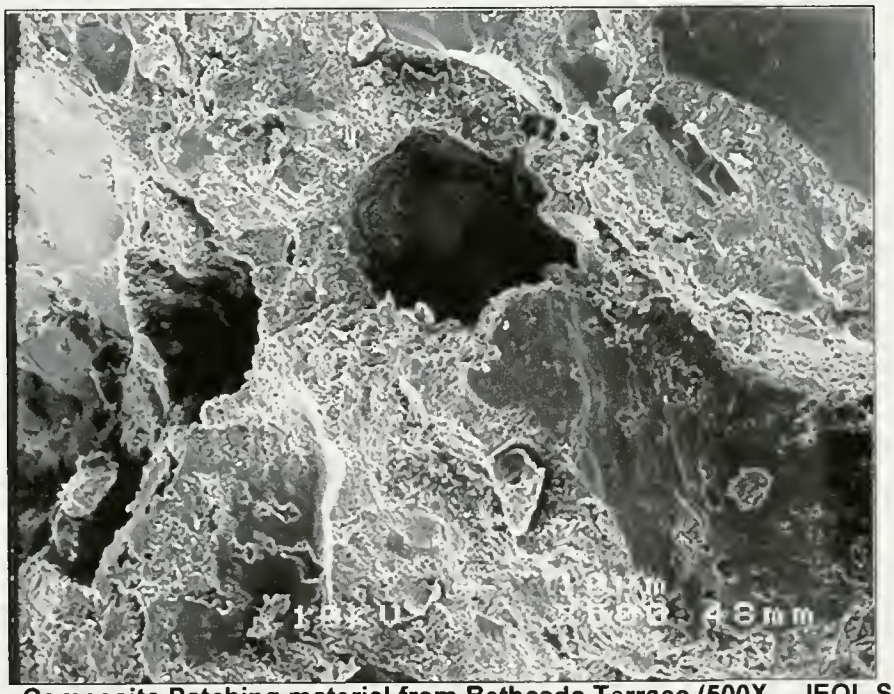


Fig. 70 - Composite Patching material from Bethesda Terrace (500X – JEOL SEM).
Matrix of composite patching material contains low amounts mineral components. The smooth, glassy texture of the matrix appears to be an organic admixture.

BIBLIOGRAPHY

Documents were gathered from the following offices and organizations:

Central Park Conservancy
Office of Capital Projects at Central Park, New York
New York Historical Society
New York City Archives
Fisher Fine Arts Library, University of Pennsylvania
Avery Architectural Library, Columbia University
Ehrenkrantz Architects, New York City
New York City Art Commission
Manhattan Construction Archives
New York City Department of Parks and Recreation
Frederick Law Olmsted Archives, Brookline, MA

Bethesda Terrace History and Previous Restoration Bibliography

Board of Commissioners of the Central Park. *Ninth Annual Report for the Year Ending December 31, 1865.* New York: William C. Bryant and Co., 1866.

Brown, Eileen Grand Pre. "A Conservation Study of the Bethesda Terrace, Central Park." Masters Thesis, Graduate School of Architecture, Planning and Preservation, Columbia University, 1991.

———. Eileen G. P. Brown to Thomas F. Giordano. "RE: Proposal to Remove Staining at Bethesda Terrace." 17 April 1991. Archive of the Central Park Conservancy.

Cedar-Miller, Sarah. Central Park Conservancy Slide Archive. Central Park Conservancy, New York.

Central Park Conservancy, New York. Historic Preservation Archives. Bethesda Terrace Archives. Various dates.

———. Office of Capital Projects Archives. Bethesda Terrace Archives. Various dates.

Deitz, Paula. "Central Park's Bethesda terrace and its restoration." *Antiques Magazine.* 133, no. 4 (1988): 88.

Dietsch, Deborah K. "Saving Sandstone: Bethesda Terrace Restoration, Central Park, New York City." *Architectural Record.* 174, no. 6 (1986): 130-37.

Ehrenkrantz Group. "The Rehabilitation of Bethesda Terrace including the Terrace Bridge and Steps Located North of the Mall on the 72nd Street Transverse Road in Central Park, Borough of Manhattan Contract Known as: M - 10 - 240." Outline Specifications, 1983.

Frederick, Sharon. "The Restoration of Bethesda Terrace Arcade Ceiling: Central Park, New York." Masters Thesis, Graduate School of Architecture, Planning and Preservation, Columbia University, 1994.

Historical Society of New York, New York. Photographic Collections.

Kuhn, Denis G. "Controlling the Cost of Preservation." *Architecture.* 83 no. 11 (November 1994): 137 - 141.

Municipal Archives of New York City, New York. Olmstead Catalogue of Central Park Drawings and Images.

National Oceanic and Atmospheric Administration. "Local Climatological Data: Annual Summary with Comparative Data, New York, Central Park, New York." Ashville, NC: NOAA, 1986.

Palmer, Kathy, ed. *Bethesda Terrace in Central Park.* New York: Central Park Conservancy, 1987.

Singer, Martha. "The Making of the Ornamental Friezes at Bethesda Terrace: Central Park." Qualifying Paper, submitted to Richard Stone, May 1995.

Wheeler, George. George Wheeler to the Central Park Conservancy. "Report on Deposits at Bethesda Terrace." 15 October 1986.

Sandstone and Sandstone Treatment Bibliography

Ashurst, Nicola. *Cleaning Historic Buildings.* Vol. 2. London: Donhead, 1994.

Bee Stone Company. "Brownstone Bits." *Journal of the Bee Stone Co., Inc.* 1, no. 1 (Fall/Winter 1991).

Carosino, C., et al. *Historic Masonry Deterioration and Repair Techniques: An Annotated Bibliography.* Washington DC: US Department of the Interior, National Park Service, 1993.

Clifton, James R. *Cleaning Stone and Masonry.* Philadelphia: ASTM Special Technical Publication #935, National Bureau of Standards, 1986.

Douglas, R. J. W. *Geology and Economic Minerals of Canada.* Ottawa: Department of Mines, 1970.

Gale, Frances. "Measurement of Water Absorption Techniques." *Investigative Techniques.* Paris: RILEM [1985?].

Gannett, Henry, ed. *Report on the Building Stones of the United States and Statistics of the Quarry Industry for 1880.* (Report of the Tenth Census). Washington DC, 1883.

Goldberger, Paul. "The Dakota." *Antiques.* 126, no. 4 (October1984): 842-851.

Historical Society of Pennsylvania, Philadelphia. Geological Survey of Canada. Annual Reports and Index. Ottawa, 1897-1906.

Houseknecht, David (editor), et al. *Origin, Diagenesis, and Petrophysics of Clay Materials in Sandstones.* Special Publication no. 47. Society for Sedimentary Geology, 1992.

Julien, Alexis A. "The Decay of the Building Stones of New York City." January, 29. *New York: Transactions of the New York Academy of Science,* 1883. p. 67-138.

Knight, John and J. Ross McLean. *Shelf Sands and Sandstones.* Calgary: Canadian Society of Petroleum Geologists, 1986.

Martin, Gwen L. "For Love of Stone." *Miscellaneous Report.* 1, no. 8. Nova Scotia: New Brunswick Department of Natural Resources, and Energy, Mineral Resources Division, 1996.

Matero, Frank G. and Jeanne M. Teutonico. "The Use of Architectural Sandstone in New York City in the 19th Century." *Bulletin of the Association for Preservation Technology,* 14, no. 2 (1982): 11-17.

Merrill, George Perkins. *Stones for Building and Decoration.* New York: John Wiley, 1910.

Miller, Charles. "From Boulders to Building Blocks: How a traditional stonemason quarries and dresses sandstone." Photocopy. N.p., n.d.

Myjer, Ivan. "Restoring Brownstone Structures." *Stoneworld: Preservation Techniques.* (January 1994).

Parks, William A. *Report on the Building and Ornamental Stones of Canada.* Vol. 1. Ottawa: Governments Print Bureau, 1914.

———. *Report on the Building and Ornamental Stones of Canada.* Vol. 2. Ottawa: Governments Print Bureau, 1914.

———. "Report on the Building and Ornamental Stones of Canada." Vol. 2. Maritime Provinces: Canada Department of Mines, Mines Branch, No. 203, 1914.

Pettijohn, F. J., et al. *Sand and Sandstones.* 2nd ed. New York: Springer-Verlag, 1972.

Pellerin, Fred. Personal communication. Bee Stone Company, Inc. Dieppe, New Brunswick, Canada, 1997.

Price, C. A. *Stone Conservation: An Overview of Current Research.* Santa Monica, CA: Getty Conservation Institute, 1996.

Stubbs, M. Stephanie. "Preserving Historic Materials." *Architecture.* 75, no. 11 (November 1986): 108.

Smock, John C. *Bulletin of the New York State Museum of Natural History.* No. 3. Albany: Charles Van Benthuysen and Sons, 1888.

———. *Bulletin of the New York State Museum.* Vol. 2, no. 10. Albany: University of the State of New York, 1890.

Teutonico, J. M. *A Laboratory Manual for Architectural Conservators.* Rome: ICCROM, 1988.

Torraca, G. *Porous Material Building: Material Science for Architectural Conservation.* 3rd ed. Rome: ICCROM, 1988.

Wheeler, George. "Report on Deposits at Bethesda Terrace." New York, 15 October 1986. Archives, The Central Park Conservancy.

Conditions Survey Bibliography

Brown, Eileen Grand Pre. "A Conservation Study of the Bethesda Terrace, Central Park." Masters Thesis, Graduate School of Architecture, Planning and Preservation, Columbia University, 1991.

Ehrenkrantz Group. "The Rehabilitation of Bethesda Terrace including the Terrace Bridge and Steps Located North of the Mall on the 72nd Street Transverse Road in Central Park, Borough of Manhattan Contract Known as: M - 10 - 240." Outline Specifications, 1983.

Fitzner, B., et al. *Weathering Forms at Natural Stone Memorials - classification, mapping and evaluation.* Aachen, Germany: International Zeitschrift fur Bauinstandsetzen, 1997.

———. *Verwitterungsformen - Klassifizierung und Kartierung (Weathering Forms - Classification and Mapping).* Berlin, Germany: Verlag, Ernst and Sohn, 1995.

Grimmer, Anne E. *A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments.* Washington DC: Department of the Interior, National Park Service, Preservation Assistance Division, 1984.

Matero, F. G., et al. *Preservation of the Lincoln and Jefferson Memorials Stone Conservation Program: Phase I, Conservation Treatments: Research and Design.* 1-2. Philadelphia, PA: University of Pennsylvania, 1996.

NORMAL. *NORMAL 1/88* - C. N. R. Centri di Dtudio di Milano e Roma sulle cause di deperimento e sui metodi di conservazione delle opere d'arte and Istituto Centrale per il Restoration, Rome, 1988.

Prescott, Einhorn Yaffee. *Jefferson Memorial: Stone and Joint Survey.* Washington DC: Department of the Interior, National Park Service, 1992.

World Monuments Fund. *Survey of the State of Conservation of the Tower of Belem.* Lisbon, Portugal: World Monuments Fund, 1994.

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