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The Ohio State Pavilion at Philadelphia's 1876 Centennial Exhibition: Identification, Survey and Evaluation of 20 Types of Ohio Stone

Elizabeth H. Seyfert
University of Pennsylvania

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements of the Degree of Master of Science in Historic Preservation 2006.
Advisor: A. Elena Charola

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EXHIBITION: IDENTIFICATION, SURVEY,
AND EVALUATION OF 20 TYPES OF OHIO STONE

Elizabeth Hunter Seyfert

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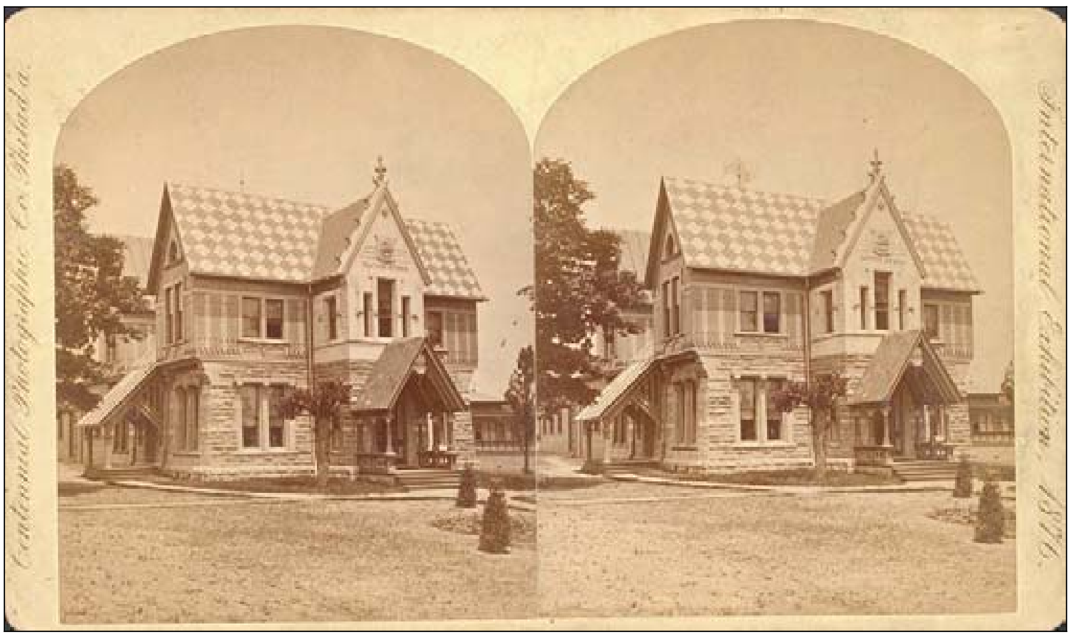
Advisor
A. Elena Charola
Lecturer in Historic Preservation

Reader
Frank G. Matero
Professor of Architecture

Program Chair
Frank G. Matero
Professor of Architecture



Stereoscopic photograph of the Ohio House taken circa 1876 (Print and Picture Department, Free Library of Philadelphia).

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INTRODUCTION

Thousands of commuters pass by the Ohio House in Fairmount Park every day without realizing it is a rare architectural treasure surviving from the 1876 Centennial Exhibition. It is one of only two structures from the Exhibition still standing in their original location and plays a significant role in defining the historic landscape of West Fairmount Park in Philadelphia. The significance of the building lies not only in its relation to the Exhibition, but also in its impressive collection of 19th century American building stone.

The following study documents the 20 different types of Ohio stone employed in the building, for the first time, in a thorough stone-by stone identification and condition survey. This thesis takes advantage of the unique opportunity presented by the Ohio House to analyze the deterioration and performance of 20 types of Ohio sandstone and limestone in the same building. The research will have broad reaching applications, as Ohio sandstone and limestone were and still are some of the most popular building stones in the United States.

It is the author's hope that this document will also prove especially useful to the Fairmount Park Historic Preservation Trust. The organization is currently developing an adaptive use program for the Ohio House, planning to lease the first floor as a cafe and the second floor as office space.[1] The renovation and restoration efforts associated with the adaptive use plan are tentatively scheduled to take place in the summer of 2006. The following study will provide the organization with critical information for the future preservation of the historic building and, more specifically, serve as a basis for developing a treatment plan to extend the life of the irreplaceable stone.

The objective of this thesis is to identify and effectively document the stone, to survey the present condition and critical properties of the stone, and through the use of Geographic Information System (GIS) software, to evaluate decay mechanisms to determine those stones which are at high risk. For this purpose the project methodology can be broken down into three major phases: research, field work, and evaluation.

1. Research Phase

The research phase involved a thorough review of existing archival resources for the Ohio House and a general review of resources regarding the 1876 Centennial Exhibition. Archives at the Fairmount Park Commission proved particularly helpful in obtaining the construction and alteration history of the building and the Free Library of Philadelphia provided excellent images. Chapter 1 provides a brief history of the Exhibition and a more extensive description of the historical background surrounding the Ohio House. A literature review of current trends in measuring stone decay in situ is presented in chapter

[1] Stephen Salisbury, "Fairmount Park Trust is Facing an Uncertain Future" *Philadelphia Inquirer* 15 Nov. 2005: B1.

2. Although the techniques described will not be performed on the Ohio House at this time due to time and funding restraints, the research is included because quantifying the decay would greatly assist in determine rates of deterioration in the future and it is important to understand the options available. The research phase includes geologic data presented in Chapter 3. There is an immense amount of historic and contemporary literature regarding the petrology and mineralogy of Ohio building stone. The most informative sources found during the review include the *10^th Census of the United States*, the various U.S. Geological Surveys of Ohio, and the works George Merrill and J. A. Bownocker. Chapter 3 also contains a contemporary literature review highlighting critical properties and decay mechanisms of building stone.

2. Field Work Phase

In preparation for the field work phase of the project, a review of current literature addressing various systems and techniques being used to map stone condition was conducted. Information to be collected in the field was divided into a conditions survey and a critical property survey. Prior to the work in the field a GIS file was designed, survey forms created, and glossaries developed for both sections of the survey. Chapter 4 outlines this process in detail an illustrated glossary is included in Appendix A. In the field critical properties were obtained visually and with limited testing and then recorded onto the survey forms. The conditions were obtained visually or tactically and recoded onto CAD elevation drawings.

3. Evaluation

The evaluation phase involved compiling the critical property data and the current condition data into GIS in order to make an accurate diagnostic assessment of the stone in the Ohio House. The graphic and analytical capabilities of GIS were utilized to evaluate deterioration mechanisms based on a set of five factors affecting performance: environment, composition, tooling, water absorption and location in the building. Chapter 5 explores each condition explaining cause and effect relationships and then explores the factors affecting condition. Condition drawings are included in Appendix C and factor drawings are included in Appendix D. The evaluation in Chapter 5 ultimately identifies the high risk stones and ranks the influence of the factors affecting performance.

HISTORIC BACKGROUND

> *It is certain that as a nation we have gathered a rich harvest of culture and of material benefits, and that through the influence of the Exhibition abroad we have acquired a recognition, never before afforded us, as a county of the most diversified and active industries, and the highest civilization.*[2]
>
> *James D. McCabe 1876*

After six months of operation, the Centennial Exhibition officially closed on November 10th 1876, marking a significant place in American history and in the landscape of Philadelphia. The Exhibition is inextricably linked to the advances and growth of industry toward the end of the 19th century and the emergence of America as a world power. Built as a temporary exhibit, the physical legacy of this important event is represented by only two buildings surviving in their original location in Philadelphia's Fairmount Park: Memorial Hall and the Ohio House. The Ohio House now stands alone on the corner of Belmont Avenue and Montgomery Avenue, a location which was once surrounded by other state pavilions and crowds of fairgoers.

[2] James D. McCabe, *Illustrated History of the Centennial Exposition* (Philadelphia: The National Publishing Co., 1876) 293.

Figure 1.1: *Historic Engraving of Ohio House circa 1876 (Illustrated History of Centennial Exposition).*

1876 Centennial Exhibition

Celebrating the 100th anniversary of the Declaration of Independence, President Ulysses S. Grant officially opened the Centennial Exhibition on May 10, 1876 in Philadelphia's Fairmount Park. The International Exhibition was the first world's fair held in the United States and a product of ten years of extensive planning.[3] Over 30,000 exhibits from fifty countries around the world showcased developments in science, industry, and culture. Reflecting the primarily industrial focus of the Expo, there were seven categories of exhibits: mining and metallurgy, manufactured products, science and education,

[3] Bruno Giberti, *Designing the Centennial: A History of the 1876 International Exhibition in Philadelphia* (Lexington: University Press of Kentucky, 2002) 12.

machinery, agriculture, fine arts, and horticulture. A description of the event in *Manufacture and Builder* reports in 1876, "A child can learn more of the physical condition, the products, and civilization of the world from a week's visit to this exposition that from a year's study of geography at school."[4]

The Centennial Committee hired a twenty-seven year old architect, Hermann J. Schwarzmann, to design the layout of the exhibition grounds. Instead of containing the entire fair in one large building, Schwarzmann's design was the first world's fair to separate the exhibitions into several large buildings surrounded by smaller pavilions.[5] This design concept was subsequently adopted for future world's fairs. In addition to the grounds, Hermann J. Schwarzman also designed Horticultural Hall, displaying a wide range of native and exotic plants and Memorial Hall, which functioned as an art gallery. Both buildings were originally intended to be permanent, but Horticultural Hall was demolished in 1955. The Memorial Hall is the only major building from the Centennial still standing. One year after the Exhibition, the Beaux-Arts building opened as an art museum for the city and developed into what is now the Philadelphia Museum of Art.

There were several other important structures. The Main Building, designed by Henry Pettit and Joseph M. Wilson, was primarily constructed with cast iron and brick and provided over 20 acres of exhibition space for foreign and domestic goods. Machinery

[4] "Opening of the American International Exhibition," *Manufacture and Builder* 8 (1876): 121-122.
[5] Giberti 36.

Hall, also designed by Pettit and Wilson, displayed the latest technological developments including the telephone, the telegraph, typewriters, and steam engines. The other main buildings included Agricultural Hall, the Woman's Pavilion, and the Government Building.

Surrounding these massive exhibit halls were twenty-four pavilions constructed by various states. Primarily modest buildings with a temporary quality, the state pavilions were mostly located in the northwest portion of the fairgrounds along States Avenue. The state pavilions functioned as club houses, where exhibition visitors from the particular states could meet, gather, relax, socialize, and view exhibits related to the state. They also served as offices or headquarters for the state Centennial Commissioners. The concept for the state buildings can be linked to Kansas's early application to create its own separate display of native resources, which ignited a competitive spark between the states and resulted in the construction of 24 state buildings.[6]

Architecturally, the buildings of the Centennial Expo received mixed reviews. Some praised the Beaux-Arts Memorial Hall and others described it as "the oddest collection of structures that had ever been assembled in America, and assembled in that rather careless way which was still a convention in landscape architecture, with winding paths and unexpected openings. Here a Swiss chalet rose above its shrubbery and turned out to be

[6] McCabe 221.

the New York State Building."[7] Lewis Mumford states in *The Brown Decades*, "It is hard to conceive anything lower than the architecture of the Centennial Exposition."[8]

After six months and ten million visitors, the Centennial Exhibition officially closed in October of 1876. During this time the United States successfully displayed to the rest of the world their impressive progress since their poor representation at the 1851 Crystal Palace Exhibition. From the remarkable industrial, commercial, and cultural growth displayed during the Exhibition, Americans gained a sense of patriotic pride in their own progress and a sense that the country was moving beyond the troubled times of the reconstruction era. The first world fair held in the United States proved to have a lasting impact on the economy, foreign relations, and American culture. The 1876 Centennial Exhibition had a large impact on the City of Philadelphia. The high standard set by Philadelphia elevated the city into a more respectable and recognizable position and ushered in an era of great change in regard to industry and culture.

Ohio House: Architectural Description and Construction History

"…the most elegant and substantial of all the state edifices…"[9]

The Ohio House stands alone on the corner of Belmont Avenue and Montgomery Avenue in Fairmount Park, not only as the sole surviving state pavilion, but along with Memorial

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[7] Oliver W. Larkin, *Art and Life in America*, (New York: Rinehart and Winston, 1949), page 113.
[8] Lewis Mumford, *The Brown Decades: A Study of the Arts in America, 1865-1895* (New York: Harcourt Brace, 1931) 61.
[9] McCabe 89.

Hall as one of only two buildings surviving in situ from the 1876 Centennial Grounds. As the majority of pavilions were wooden frame buildings, its survival can be attributed to its masonry construction. In his history of the Exhibition Robert Post provides the following description of the Ohio House, "Built of stone rather than framed, the Ohio Building has an air of permanence. Probably this quality, more than any aesthetic judgment, led to its survival after the Centennial closed."[10]

The Ohio House is an interesting combination of architectural elements and can be described as Victorian Gothic Revival, Carpenter Gothic and Eastlake or Stick style. Many of the architectural critics at the time found the state buildings undistinguished, but the Ohio House was one of the few state buildings considered architecturally and structurally noteworthy.

The architects of the Victorian Gothic Revival cottage, Heard & Sons, were from Cleveland, Ohio, and a local Philadelphia building company, Aaron Doan and Co., was responsible for the construction. The Ohio state commissioners for the Exhibition were appointed in 1871 and were subsequently in charge of planning and financing the building. Construction of many of the state buildings did not begin until a few months before the scheduled opening. The original design intent for the Ohio House called for a

[10] Robert C. Post, *A Centennial Exhibition* (Washington: Smithsonian Institute, 1976) 190.

completely masonry building, however, due to the time restraints and a lack of resources the second floor of the building was constructed with wood clapboards.[11]

Original plans of the building display a 40 foot square simple footprint, with four rooms somewhat symmetrical around a central hall and stair.[12] Rooms included offices of the States Commission, reception rooms, and reading rooms. The original plans also indicate a large *40' x 60'* annex off the North elevation indented as a public meeting space and as exhibition space for Ohio resources.

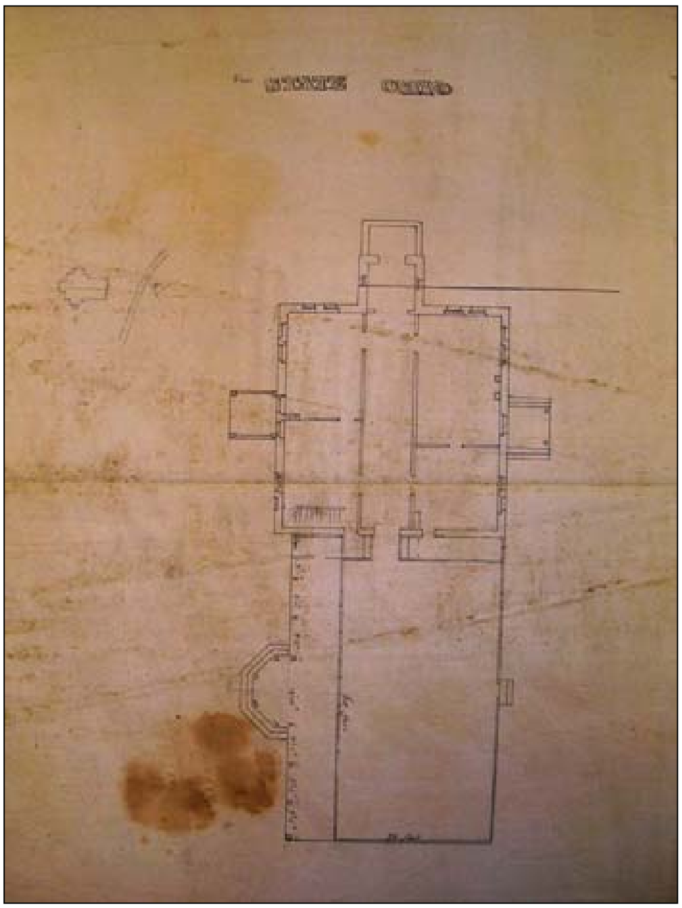

Figure 1.2: *1876 plan of Ohio House with exhibition annex off north elevation (Fairmount Park Commission).*

The Ohio House rises two and a half floors high and each façade, excluding the North façade, is marked with a central porch entry and flanking windows. The structure terminates in a

[11] *Fifth Agricultural Record and Centennial Report of State Mangers* (Topeka, Kansas: Geo. W. Marton, Kansas Publishing House, 1877).
[12] Original 1876 plans courtesy of Fairmount Park Commission.

steep gable roof with projecting second-story dormers. The south elevation is the predominant façade, articulated with a projecting central bay and a gable roof porch over a double door entrance. The veranda on the east façade is supported without columns and the veranda to the west is supported with a columned porch. Although there is a tripartite window above the main entrance, the majority of windows are double windows and have double hung wood sashes and frames with masonry surrounds.

Structurally, the building is supported by a timber frame. The stone is keyed into wood framing members with an inner wall of brick masonry. The specific masonry installation techniques utilized at the Ohio House, such as metallic ties and connectors, are unknown due to inaccessibility.

An exhibition in itself, the Ohio House was constructed with a variety of building materials, all of which were native to Ohio, provided by citizens of the state, and used to showcase the natural resources of the state. The first floor walls and projecting front bay in the south façade are various types of building stones from Ohio and the second story was sheathed in Ohio timber. The original vertical wood siding was scalloped at the lower edge, and painted in a polychrome scheme with grey and green trim. The original roof was flat seam metal roof, most likely tern plate, and strikingly laid out in either a diagonal pattern or stripes.[13] The metallic crockets and pinnacle (Ohio asparagus) at the roof apex were originally hammered tin, but are now fiberglass reproductions. Glass for the Ohio House was made from ground Massillon stone from a quarry near Ravenna, Ohio.[14] During the 1876 Exhibition, judges often commented on the tasteful manner in which the resources of the state were exhibited by the building.

The most impressive feature of the Ohio House is without question the vast display of nineteenth century building stone from Ohio. Sandstone and limestone from 20 historic quarries is showcased in the building, often with the name and location of the quarry, the trade name of the stone, the distributor, or the mason carved into the ashlar. These carvings were advertisements for the stone companies. Examples include: the Berea Stone Company; Euclid Quarry, Cleveland; Marcus Bossler, contractors, and William Huffman, dealer in Dayton stone. (See Appendix A2 for carving locations.) Each of the twenty-one courses of stone comprising the first floor are a particular type of stone and wrap around the west, south and east elevations. The masonry window surrounds are also various types of stone and incorporate ornamental carving in the lintels and brackets. In the first floor of the south façade and in the two projecting courses above the ground level the stone is rusticated. The stones on the east and west elevations lay flush and are

[13] *Ohio House Stereoscopic Photograph*, (Free Library of Philadelphia, Print and Picture Department: circa 1876).
[14] *Kansas Centennial Report,* 37.

each tooled differently, displaying a full range of finishing techniques. The stone types and their critical properties will be expanded upon in Chapter 3.

Throughout the 130 years its existence, the Ohio House has been altered several times. The wooden pavilion attached to the North side of the building was removed in the 1950s. The building served intermittently as residence throughout the first half of the 20th century, but in preparation for the 1976 Bicentennial celebration, it underwent a major restoration campaign and was converted into a Park Information Center. The Ohio House interiors have been reconfigured several times, but most significantly in the 1970s conversion of the house into the information center for Fairmount Park. At the time, the exterior wood clapboards were replaced, the stone was cleaned and re-pointed where necessary, and sealant added where stone abuts wood.[15] The original metallic roof has been replaced by slate and there have been several campaigns to improve the water conduction system, most recently involving copper flashing repairs.

The building was listed on the local Philadelphia Register of Historic Places in1963 and listed as a contributing building in the Fairmount Park National Register Historic District in 1972. There are current plans to reuse the Ohio House as a cafe on the ground floor and rent out the upper floors as office space.[16]

[15] National Heritage Corporation, *Meeting Minutes from Architect to Client*, June 1976.
[16] Stephen Salisbury, "Fairmount Park Trust is Facing an Uncertain Future" *Philadelphia Inquirer* 15 Nov. 2005: B1.

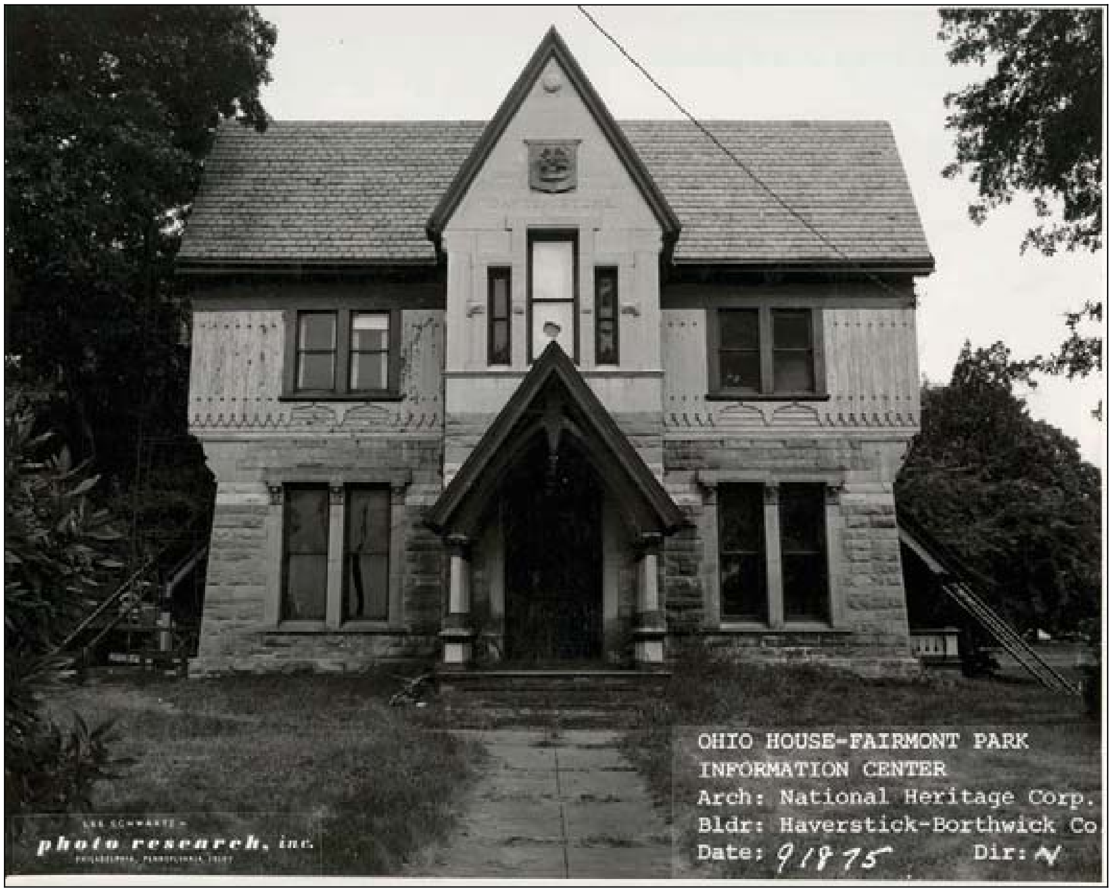

Figure 1.3: *South elevation of Ohio House during Bicentennial restoration effort, 9-18-75 (Fairmount Park Commission).*

Figure 1.4: *South elevation of Ohio House after Bicentennial restoration efforts 1976, note absence of pyrite staining in "DAYTON STONE" limestone in projection gable (Fairmount Park Commission.).*

LITERATURE REVIEW: MEASURING STONE DECAY IN SITU

One of the primary goals of the subsequent chapters of this study (Chapters 4 and 5) is to create an accurate analytical assessment of the various types of stones used in the Ohio House to assist future conservation efforts of the fabric. Stone decay can be complex and certain conditions are often the result of several degradation mechanisms acting together. The analysis of conditions found at the Ohio House will be explored in Chapter 3. In addition to the description and mapping of conditions, a quantitative measurement of decay in its severity is an important aspect of making an analytic assessment of the fabric. The techniques designed to measure stone decay in situ will be explored in this chapter.

The methods discussed will not be performed on the Ohio House due to time and funding restraints. However, the following exploration is included in this study because quantifying the decay at the Ohio House would greatly assist in determine rates of decay in the future and it is important to understand the options available. In addition, examining degradation mechanisms from a different perspective as described by the following techniques would be extremely valuable in detangling all the complex degradation mechanisms at work on the building stone. Should further study be made possible, several of the following techniques would be a valuable contribution to the assessment of the stone.

An overview of the current literature regarding quantifying decay and the rate of decay in situ reveals significant progress in related technologies, but further developments are needed in terms of practical cost-value benefit. There is a wide range of literature on the subject of measuring stone decay in situ which often emerges from other fields such as geology, archaeology, or object conservation. This review is divided based on techniques which measure 1) surface decay, addressing deterioration patterns such as erosion and contour scaling; and 2) subsurface techniques, addressing conditions such as internal inconsistencies or incipient spalling.

SURFACE

Profilometry

Stylus profilometry is a technique utilizing a metal needle or stylus which moves across the stone surface and values are obtained by a transducer receiving electrical signals from the position of the stylus. Powerful stylus profilometers used for laboratory research can be expensive. However, there are also field model instruments which are less expensive but may not be as effective in measuring extremely rough stones. Stylus profilometry is commonly used with metals, but there is less research in the literature regarding its effectiveness for measuring stone surfaces. In the article *Measuring Surface Roughness* *on Stone: Back to Basics* stylus profilometry is one of three techniques used to measure the effects of abrasive cleaning on various stones.[17] The authors explored the many drawbacks of the stylus profilometery technique for stone including replica preparation, the limited vertical range of measurement, and the inability to measure highly irregular surfaces such as tooling. The article concludes that tactile, and visual to a lesser extent, evaluation was the most effective method in evaluating roughness in a range of stone surfaces, especially if standards are provided. It should be noted that in most cases, roughness is not a measure of recession, as "surfaces of weathered stones are found to maintain constant roughness as grains are dislodged, although they may recede significantly."[18]

Profilometry can also be carried out using a laser, where a series of lines at 45 degree angles are superimposed onto the surface picking up varying relief measurements based on triangulation. Although increasingly expensive and time consuming, ultrasound biomicroscopy (UBM) laser profilometry more accurately reads 3D relief. There is more research in the literature on the use of laser profilometry to determine the microtopgraphy of painted surfaces and less involving the surface relief of stone monuments in situ.[19]

[17] A. E. Charola et al, "Measuring Surface Roughness on Stone: Back to Basics," *Studies in Conservation,* 45 (2000): 73-81.
[18] A. E. Charola 78.
[19] Daryl Williams and Sheila Fairbrass, "Laser surface profilometry in materials conservation," *Preprints of the 11th triennial meeting* (Edinburgh: ICOM Committee for Conservation, 1996) 978-980.

The article *Profilometry and Image Analysis Applications to In Situ Study of Monuments Stone Decay Phenomena*, describes the application of line profilometry in situ.[20]

Microerosion Meter

Microerosion meter measurements (MEM) of stone surface relief can be obtained with a relatively straightforward tool known as a needle-point depth micrometer. Relief readings are taken relative to a set of predetermined reference points in the stone. A good example of this technique has been utilized at St. Paul's Cathedral in London to measure the surface height of the balustrade over the span of 20 years.[21] The microerosion meter yielded results reliable to two decimal places, although measurements were made to 0.0001 mm. The first 10 years resulted in a mean erosion rate of 0.045 mm and the second 10 year period indicating a rate of 0.025 mm.[22] The simple technique is effective in situ, but the reliability of data can be compromised by errors in calibrations, temperature fluctuations, deposition, unreliable data points, and erratic erosion.

Photogrammetry

Photogrammetry is the art and science of taking precise measurements from stereo-photographs, which are overlapping photographs taken from slightly different vantage

[20] Aires-Barros, Mauricio, and Figueiredo, "Profilometry and Image Analysis Applications to In Situ Study of Monuments Stone Decay Phenomena," *La conservazione dei monumenti nel bacino del Mediterraneo*, Venice, Soprintendenza ai Beni Artistici e Storici di Venezia (1994) 19-24.
[21] S. Trudgill et al, "Remeasurement of weathering rates, St Paul's Cathedral, London," *Earth Surface Processes and Landforms*, Volume 14, (1989) 175-196.
[22] S. Trudgill et al, "Twenty-year weathering remeasurements at St Paul's Cathedral, London," *Earth Surface Processes and Landforms*, Volume 26, Issue 10, (London: John Wiley & Sons, Ltd., 2001) 1131.

points from metric cameras eliminating distortion.[23] When viewed in stereo, the pairs allow one to see relief. Actual depth or height measurements may be calculated by comparing grid points of the photogrammetric images on the computer or with tools such as an Abrams Heightfinder which is accurate to 0.02mm.[24]

Using a plaster cast from 1862, photogrammerty was used in 1990 to determine the surface recession rate of certain areas of Trajan's Column.[25] Conti's article explores several reliable approaches to expressing surface loss and describes applicability to other sites. Photogrammetry techniques also provided rates of deterioration for the marble of the Merchants Exchange Building in Philadelphia.[26] Stereoscopic photographs taken in 1987 and 1991 at several locations were plotted, analyzed, and stored for future comparison. The data from the exterior weathered marble was compared to erosion at an interior location and the degradation rates were determined; for example, the long-term degradation rates were 0.1 mm/yr for Pennsylvania Marble on the east side.

Photogrammetry is increasing being used in the field of stone conservation and is providing accurate relief information at a much lower cost than laser scanning.

[23] English Heritage*, Measured and Drawn: Techniques and practice for the Metric Survey of Historic Building* (English Heritage 2003) 12.
[24] Erhard M. Winkler, "The Measurement of Weathering Rates of Stone Structures, A Geologist's View," *APT Bulletin,* Volume 18, Number 4, (1986): 65.
[25] Walter Conti, "A method for the evaluation of material loss from bas-reliefs due to air pollution," *Materiali e strutture*, Number 1 (1990) 12-26.
[26] Jeffery A. Coe et al, "Measuring stone decay with close range photogrammetry," *Proceedings of the 7th International Congress on Deterioration and Conservation of Stone, Lisbon, Portugal* (1992) 917-926.

Laser Interferometry

There have been significant developments in the use of laser interferometry to detect surface erosion since the 1970s. The advanced technology uses TV holographic interferometers with fibre-optic illumination based on the random interference of scattered waves from illuminated surfaces.[27] This is known as the speckle effect, and the method is referred to as electron speckle pattern interferometry (ESPI). Much of the literature on the technique regards its application to examining painted surfaces, specifically frescos based on the versatile portable capabilities of the technology.

However, the technique is increasingly being used to detect masonry surface topography and to monitor loss of stone monuments. Paoletti has used laser interferometry to measure surface erosion depths of marble monuments in Abruzzo and used a contouring technique for other buildings.[28] The method has the ability to detect deformations at 0.5um and has also had success in monitoring the effectiveness of conservation treatments over time.[29]

[27] Domenica Paoletti and Schirripa Spagnolo, "The Potential of Portable TV Holography for Examining Frescos In Situ," *Studies in Conservation* 40 (1995) 127-132.
[28] Domenica Paoletti et al, "Electronic speckle pattern interferometry for marble erosion measurements," *The conservation of monuments in the Mediterranean Basin: proceedings of the 2nd international symposium* (1992) 247-253.
[29] C.A. Price, *Stone conservation: an overview of current research* (The Getty Conservation Institute, 1996) 3.

SUBSURFACE

Ultrasonic Tomography

There is a significant amount of recent literature on the use of ultrasonic tomography in building stone conservation. A variety of ultrasonic methods are available, but in general the technique involves the using the velocity of sound as a measurement for consistency within the rock fabric. The waves are transmitted from a fixed transmission point on one side of the stone and a receiver on the opposite side of the stone measures the velocity based on the distance. Ultrasonic tomography can be used in a specific location to detect cracks, crevices, pores, joints, added mortar, and steel reinforcement.[30]

There are several laboratory case studies that used ultrasonic tomography which are yielding interesting results. For example, the weathering behavior of Carrara marble was determined from the ultrasonic velocity distribution based on the orientation of calcite crystals in the marble.[31]

Ultrasonic tomography was utilized on a marble column at the Marmorpalais in Germany in which data from the synthetic tomogram model was used in conjunction with a

[30] Siegfried Siegesmund, Thomas Weiss, and Joerg Ruedrich, "Using ultrasonic diagnosis to monitor damage: the Marble Palace in Potsdam as an example," *Restauro: Zeitschrift für Kunsttechniken, Restaurierung und Museumsfragen* 110, no. 2, (2004) 98-105.
[31] Florije Sheremeti-Kabashi and Rolf Snethlage, "Determination of structural anisotropy of Carrara marble with ultrasonic measurements," *Proceedings of the 9th International Congress on Deterioration and Conservation of Stone, Venice, 2000*, Fassina Vasco eds (Elsevier Science Publishing Co.: 2000), 247-253.

detailed visual mapping of the conditions.[32] Another example involves the use of ultrasonic tomography in situ to assist in developing a conservation treatment for several limestone blocks in Egypt, dating to 1900-1400 BCE. In this case the technology was also used to determine the distribution of the consolidant treatment.[33]

As ultrasonic tomography is used more frequently in the conservation field, it is becoming clear that accurate data interpretation is critical and can require a high skill level. More research in this area is needed to establish standards and higher quality results.

Ground Probing Radar

Similar to ultrasonic tomography, ground probing radar (GPR) also utilizes electromagnetic waves, however, GPR uses radar as opposed to ultrasonic waves. Not surprisingly, much of the research on ground probing radar comes from the archaeology field, but the technique is now being applied to buildings more frequently. It can provide vital information on the internal structure of historic buildings and is considered more practical and accessible then some of the other non destructive test methods for sub

[32] Siegesmund, Siegfried et al., "Deterioration characteristics of columns from the Marmorpalais Potsdam (Germany) by ultrasonic-tomography," *Proceedings of the 9th International Congress on Deterioration and Conservation of Stone, Venice, 2000*, Fassina Vasco ed. (Elsevier Science Publishing Co.: 2000) 145-153.

[33] Stefan Simon and Anne-Marie Lind, "Decay of limestone blocks in the block fields of Karnak Temple (Egypt): non-destructive damage analysis and control of consolidation treatments," *12th triennial meeting, Lyon, 29 August-3 September 1999: preprints (ICOM Committee for Conservation)*, Janet Bridgland ed., (James & James: 1999), 743-749.

surface conditions. By measuring the intensity of reflections the system can provide 3D data of the subsurface stratigraphy displaying voids, cracks, layers, and tie locations.[34]

In their 1996 review of nondestructive test methods, Nappi and Cote suggest that the best results are obtained by combining two or more test methods such as sonic tests and radar.[35]

X-Ray Tomography

Recent developments have been made involving the use of X-Ray computed microtomography for detecting sub-surface conditions in stone conservation. The resulting scans can display a variety of important information including petrophysical properties, internal structure, and pore size distribution.[36] The advanced technology can provide 3-D data with a resolution of up to 12 μm. X-Ray tomography has been used to determine natural weathering patterns of building masonry as well as the effectiveness of certain treatments.

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[34] A. Nappi and P. Côte, "Nondestructive test methods applicable to historic stone structures," *Saving our architectural heritage: the conservation of historic stone structures: report of the Dahlem workshop on Saving our Architectural Heritage, the Conservation of Historic Stone Structures, Berlin, March 3-8, 1996* N.S Baer and R. Snethlage, eds. (Wiley & Sons Ltd: 1997) 152.
[35] A. Nappi and S. Côte 163.
[36] V. Cnudde and P. Jacobs, "Preliminary results of the use of x-ray computed microtomography as a new technique in stone conservation and restoration," *Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage 2-6 June 2002, Congress Centre Elzenveld, Antwerp, Belgium: proceedings* (University of Antwerp: 2002).

Infrared Thermography

Infrared themography generates visible images from thermal patterns and can produce a thermal map of moisture movement through building stone. By examining water evaporation cycles in a porous material such as stone, information on the patterns of degradation become apparent. Infrared themography can be used as tool to assess the microclimate variations and the impact of environmental factors contributing to material failure.[37]

A thermographic survey was utilized at the National Bank of Greece historic buildings in Athens to investigate the temperature variations regarding the physicochemical incompatibility of the marble and plaster surfaces.[38] Another example includes the use of infrared themography at a the Medieval city of Rhodes where the data was managed in a Geographic Information System (GIS) along with other information such environmental, functional, material, structural, and social data. Through GIS the information was used in conjunction to determine movement of salt solutions and the

[37] A. I. Moropoulou, "NDT as a tool for materials characterization, environmental impact assessment, conservation, evaluation and strategical planning regarding the protection of cultural heritage," *Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage: 2-6 June 2002, Congress Centre Elzenveld, Antwerp, Belgium: proceedings* (University of Antwerp: 2002).

[38] A. I. Moropoulou, E. T. Delegou, and N. P. Avdelidis, "NDT planning methodology of conservation interventions on historic buildings," *Art 2002: 7th International Conference on Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage: 2-6 June 2002, Congress Centre Elzenveld, Antwerp, Belgium: proceedings* (University of Antwerp: 2002).

crystallization of salts within the pores of the masonry.[39] Infrared themography has also been used to monitor failing areas of historic buildings to determine the appropriate time for intervention.[40]

Conclusion

There has been a great deal of progress made in the ability to measure stone decay non destructively in situ. The technology is complicated and can be prohibitively expensive, but advances are increasing accessibility and lowering costs. It is worthwhile to note that throughout the literature many authors stressed the importance of skilled technicians and the interpretation of data. In his review of the current state of stone conservation, C. Price suggests, "In order to make real progress, we need to put numbers on decay."[41] Ideally, the Fairmount Park Historic Preservation Trust will be able to utilize one or more of the methods discussed in this chapter to take measurements over time and determine a rate of change.

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[39] A. I. Moropoulou, M. Koui, and N. P. Avdelidis, "Innovative strategies for the preservation of historic cities by ND monitoring techniques and GIS management of data regarding environmental impact on historic materials and structures," *Proceedings of the 9th International Congress on Deterioration and Conservation of Stone, Venice, 2000*, Fassina Vasco ed. (Elsevier Science Publishing Co.: 2000) 119-127.
[40] Doina Frumušelu, "IR thermography applied to assess the deterioration degree of historic and art monuments," *6th International Conference on "Non-Destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage": Rome, May 17th-20th 1999: proceedings*, Maurizio Marabelli and Concetto Parisi, eds. (Italian Society for Nondestructive Testing, 1999), 271-282.
[41] Price 2.

CHAPTER 3: GEOLOGICAL DATA

The collection of building stone employed at the Ohio House is a tangible lecture in field geology, sedimentary rock, and stone identification. The following chapter examines each of the 20 types of stone in their distinct courses or window surrounds. General geological data on Ohio sandstones and Ohio limestones is presented, including the locations of formations in Ohio, mineralogy, critical properties, and typical weathering processes. Appendix A contains a geologic map of Ohio with specific quarry locations as identified through the historic literature, an elevation of the building displaying the location of each type of stone, and the location of the carvings.

All of the building stone utilized in the Ohio House is sedimentary rock, formed as either sandstone or limestone. In order to accurately differentiate between their sometimes subtle variations, a thorough understanding of the petrology and mineralogy of these materials is needed.

Petrology is defined as the field of science which studies the genesis and classification of rocks, describing them systematically with regard to their appearance, composition, structure, and fabric. Petrology explains the sedimentary formation processes for both sandstone and limestone. Sedimentary rocks are formed by the hardening of loose rock material that accumulates on the earth's surface. This happens through rock weathering; transport, sorting, and decomposition; and diagenesis and lithification. The three major classes of sedimentary rocks include: 1. detrital, clastic, or alluvial (sandstone), 2. chemical and bio-organo (limestones), 3. and mixed alluvial and chemical.

Mineralogy is defined as the study of naturally occurring inorganic solid compounds with fairly definite physical properties and chemical composition. Minerals are classified by their crystallography and chemical composition. Crystal systems are based on their external symmetry and internal atomic arrangement. The 6 systems are: isometric (cubic), hexagonal, tetragonal, orthorhombic, monoclinic, and triclinic. Chemical classes are based on the ion or ion group of the minerals. The 8 groups include: native elements, carbonates, halides, oxides, phosphates, silicates, sulfides, and sulfates.

Sandstones

Sandstones are consolidated sand in which the dominant mineral grain is quartz. The lithofication process converts sediment deposits into solid stone or rock with various interstitial cementing materials, including silica, iron oxides, calcite, or clay.[42] As sandstone is formed the cementing material is deposited on the grains, filling voids either partially or completely. The rock strength depends on the degree of cementing and can

[42] Robert R. Compton, *Geology in the Field* (New York: John Wiley & Sons, 1985) 56.

be described as contact cement, pore cement, and basal cement.[43] Sandstones fall into the detrital or clastic (alluvial) class of sedimentary rocks and are identified by particle size. The rocks included in the clastic group are: the conglomerates which are formed from gravel or "rudites" (clasts 2-4 mm), sandstones which are formed from sands or "arenites" (clasts 2-1/16 mm), siltstones which are formed from silts or "lutites" (1/16 – 1/256 mm), and shales which are formed from clays or "argillites."

The state of Ohio is famous for its production of sandstones in many varieties and muted shades. Of the five lithologic providences in the United States Ohio is included in the Central-Interior Sedimentary Basin, generally composed of flat lying sedimentary rocks from the Paleozoic, Mesozoic, and Cenozoic eras.[44] The detrital sandstone formations in Ohio were created during the Paleozoic era near the ancient shorelines of the enormous inland sea of this period.

The collection of sandstones used in the Ohio House were taken from quarries throughout the state. Table 3.1 identifies the geologic period of the sandstone formations in the particular quarry locations of stone used for the Ohio House.[45] The majority of sandstones are from the Pennsylvanian Period, 286-248 million years ago, or the

[43] E. M. Winkler, *Stone: Properties, Durability in Man's Environment* (New York: Sprunger-Verlag, 1975) 11.
[44] Norman Herz, "Geological Sources of Building Stone," *Conservation of Historic Stone, Buildings, and Monuments* (Washington, D.C.: National Academy Press, 1982) 57.
[45] *Ohio Geologic Map of 1926*, map (Ohio Department of Natural Resources, 1926).

Mississippian Period, 360 – 325 million years ago. The Pennsylvanian bedrock formations are located in the eastern portions of the state and the formations include sandstone, conglomerate, shale, clay, limestone, coal, flint, and ironstone. The Mississippian formations are primarily in north-central Ohio and are comprised of sandstone, siltstone, conglomerate, shale, and limestone.[46]

GEOLOGIC AGE	GEOLOGIC PERIOD	LOCATIONS OF SANDSTONE QUARRIES
PALEOZOIC (540 – 248 Million)	Permian (286-248 Million)	
	Pennsylvanian or Upper Carboniferous (325-286 Million)	Massillion, Ohio Youngtown, Ohio Coshocton, Ohio (or Mississippian)
	Mississippian or Lower Carboniferous (360-325 Million)	Berea, Ohio Amherst, Ohio Cleveland, Ohio (or Devonian) Euclid, Ohio (or Devonian)
	Devonian (408-360 Million)	Columbus, Ohio
	Silurian (440-408 Million)	
	Ordovician (505-440 Million)	Cincinnati, Ohio

Table 3.1: *Geologic Age and Period of Sandstone Quarry Locations.*

The Ohio Geological Survey identifies the most important formation in regard to the building stone industry as the Waverly group of the Mississippian or sub-Carboniferous period.[47] The Waverly group, including the Logan group, Cuyahoga Shale, Berea Shale,

[46] Ohio Department of Natural Resources, *Geologic History of Ohio, GeoFacts, No 23,* Apr. 2006 <www.ohiodnr.com/geosurvey/geo_fact/geo_f23.htm>.
[47] *Geological Survey of Ohio, Volume 5* (Columbus, Ohio: Nevins & Meyers, 1884) 578.

Berea grit, and Bedford shale, is quarried throughout north-central Ohio.[48] (See image 3.3) The buff or gray Berea grit is an evenly bedded sandstone and is used in several courses in the Ohio House. The outcrop runs from the northeast corner of Ohio in Astabula County to north-central Erie County and then turns directly south to Adams County.

The Geological Survey of Ohio of 1873 is an invaluable resource in its detailed descriptions of the Waverly formation and the Berea grit. The following description is useful in differentiating between certain areas of the formation:

> Below the Cuyahoga shale lies a well known stratum, which from the locality that has rendered it most famous, I have called the Berea Grit. This is a bed of sandstone something like 60 feet in thickness, varying much in character in different localities, but possessing qualities that render it one of the most valuable formations in our entire geological series. Compared with the conglomerate, the Berea stone is much finer and more homogenous in texture. It very rarely contains any pebbles in this section of the state, though further south it is sometimes in part a coarse Conglomerate…The color of the grit differs in different localities. At Berea some of the layers are nearly white, and the prevailing tint is grey. At Independence, Chargrin Falls, and Amherst, it is a light buff or drab. At Berea the stone is quarried below drainage where it is covered by a portion of the Cuyahoga shale and by Drift clay; while at Independence, Bedford, and Chargin Falls, as at Amherst, it lies higher and is more thoroughly drained. In the latter localities atmospheric water has been for ages freely passing through the rock, and has thoroughly oxidized whatever iron it contains; whereas at Berea it is buried or submerged; oxygen is excluded and the iron contained by the grit is in the condition of protoxide or sulphide.[49]

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[48] George Merrill, *Stones for Building and Decoration*, *3d ed.* (New York: John Wiley & Sons, 1910) 155.
[49] *Geological Survey of Ohio, Volume 1* 186.

The industry which emerged based on the Berea grit formation plays a major role in the early economic history of Ohio. The quarries in Cuyahoga and Lorain County employed hundreds of men and exported stone for various purposes all over the country. The Geological Survey of Ohio reports, "In New England, the Berea grindstones compete successfully with those from Nova Scotia, while the building stone is being extensively used, and for some of the most expensive and beautiful structures in all the cities of the northern states."[50]

The predominant mineral in sandstone is quartz, but there are often a variety of other minerals included in the consolidated stone such as feldspar, mica, aluminum, calcite, silica, pyrite, clays and iron oxides. Pure sandstone is comprised of quartz grains and silica cement, but sandstones are rarely pure and can be classified based on additional grains or the cementing materials. Sandstone containing a significant amount of feldspar is known as arkose sandstones or significant amounts of mica yield a micaceous sandstone. Sandstones containing clayey material are known as argillaceous sandstones. Classifying based on cementing material primarily results in four types of sandstones: siliceous, calcareous, ferruginous, or argillaceous.[51] The cementing agent in sandstone is often the most important variable of the mineral composition in regard to performance.

[50] *Geological Survey of Ohio, Volume 1* 187.
[51] George P. Merrill, *Rocks, Rock- Weathering, and Soils* (New York: The MacMillan Company, 1897) 114.

Powder X-Ray Diffraction was preformed on three samples of previously detached stone from the Ohio House to obtain specific chemical compositions of the various sandstones. This test identifies the crystalline structure and the composition of the stone; it is semi quantitative. The testing was preformed at the University of Pennsylvania by an experienced technician at LRSM. [52] The results obtained are displayed in Table 3.2.

Powder X-Ray Diffraction		
1) Coshockton Stone Co. Coshockton, Ohio 87% Silicon Oxide/Quartz, 5% Kaolinite, Aluminum Silicate Hydroxide, 8% Muscovite (Mica flakes), Potassium Aluminum Silicate Hydroxide	**2) Independence Stone, J.R. Hurst Cleveland Ohio** 98% Silicon Oxide/ Quartz, 2% Aluminum Silicate Hydroxide/ Kaolinite	**3) W. Fish and Co. Columbus, Ohio** 86% Silicon Oxide/ Quartz, 8.5% Iron Oxide Hydroxide/ Goethite 1.8% Aluminum Silicate Hydroxide/ Dickite, 3% Sodium Calcium Aluminum Silicate Hydrate/ Garronite

Table 3.2: *Powder XRD results at the LRSM University of Pennsylvania.*

The results of the powder XRD reveal the Coshocton stone to have significant amounts of kaolinite and muscovite indicating an argillaceous or micaceous sandstone. The Independence stone is very close to a pure sandstone with quartz grains and silica cement, but a small amount of kaolinite was also found. The Columbus sandstone from the W. Fish and Co., indicates high levels of iron oxides which account for its deep brown color and indicates a ferruginous binder. It is also possible to obtain proposed mineral compositions from a literature review. Many of the mineral compositions

[52] Powder XRD analysis was conducted by Bill Romanov at the Laboratory for Research on the Structure of Matter (LRSM), University of Pennsylvania, Nov. 1 2005.

recorded in table 4.1 and Appendix D4 were found in the following sources: Bownocker's *Building Stones of Ohio* (1915), Merrills's *Stones for Building and Decoration* (1910), and the 10th Census (1880).

The texture, fabric, and structure of sandstones can vary considerably. Texture is a function of the size, shape, and distribution or sorting of individual grains; whereas fabric is an overall result of texture in regard to the arrangement and orientation of grains. In general, the majority of sedimentary rock is well sorted because of the sorting action defined by Stokes Law. Structure describes differences in the main body of the stone such as bedding or ripple effects.[53] Sandstones can be extremely homogenous as displayed in the Berea stone, or they can have significant stratification formed by the deposition of the particles in layers or beds.

Although there is a huge range in the characteristics displayed by sandstones, there are several critical properties which remain relatively constant. As in most rock, iron is the predominant determination of color in sandstone. Color in sandstone is determined by the presence of iron in various states. Red and brown is due to iron in the anhydrous sesquioxide state; yellow, the hydrous sesquioxide state; and blue and gray tints are a result of protoxide carbonates of iron (sometimes due to disseminated iron pyrites).[54] Ohio sandstones were particularly popular for use as building stone partially based on the

[53] Compton 48-51.
[54] Merrill, *Stones for Building and Decoration* 126.

wide range of muted colors offered. The subtle variations in color are a result of concentration and degree of iron oxidation to ferric oxides.[55]

One of the most striking features of the Ohio House is the stone used in the window surrounds in the projecting front bay. (See Figure 3.1) These stones display scalloped bands of ochre, buff, brown, and red rings in concentric bands. The bands are known as liesegang rings in sandstones, in which ferric hydroxide has formed rings of diffusion.[56] Liesegang rings or bands are caused by rhythmic precipitation within a fluid saturated rock.[57]

[55] Winkler 102.
[56] Winkler 115.
[57] Paul Stutzman, Email Interview, 23 Mar 2006.

Figure 3.1: *Liesegang rings in sandstone in window surrounds in front bay.*

Porosity, the ratio of pore space volume to the total volume, is well-know to be a critical property of building stones. Porosity in clastic sediments is particularly dependent on particle size and sorting and general porosities of are estimated at 25-40% for uncemented and 15-30% for cemented.[58] Another class of important properties to consider when characterizing sandstones are the thermal properties. For example,

[58] Winkler, 33.

expansion and contraction due to temperature moisture can have dramatic repercussions. The moisture expansion of sandstone from Amherst, OH is 0.013%.[59]

Due to their formation processes, sandstones are already a product of disintegration and decomposition and by nature will undergo less chemical change than carbonate sedimentary rock.[60] The weathering and deterioration characteristics of sandstones tend to be more physical and determined by the parent rock and the cementing material. Durability depends on the type and degree of cementing which determines how closely the grains are bound together and determines porosity properties. Although many of the deterioration mechanisms of sandstone are mechanical, there are still many chemical processes that can be very damaging and accelerate physical deterioration.

Sandstones cemented with silica are frequently light colored and very hard. Ferruginous cementing material contains iron oxides and are usually brown or red with good carving properties. Carbonate cement is light colored or gray and easily worked, but the carbonate makes it susceptible to acid rain. Sandstones cemented with clayey material leave the stone more liable to injury by frost because their tendency to absorb water.[61] Many sandstones contain little cement, such as the Berea grit and the Euclid bluestone, but are very durable based on pressure at the time of formation.

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[59] Winkler 51.
[60] Merrill, *Rocks, Rock- Weathering, and Soils* 213.
[61] Merrill, *Stones for Building and Decoration* 126.

Texture plays a role in the weathering process in that a coarser sandstone will weather more quickly than a finely grained sandstone and the cementing material will decompose first. As the cementing material disintegrates, the silica grains are often left projecting. As previously discussed, grain size and shape contribute to porosity properties. In addition, well sorted subrounded grains yield high porosities and poorly sorted angular grains yield sandstones with lower porosities.

Porosity is an indicator of durability. There is great variety among sandstone porosities, but some can have high surface permeability due to complex capillary properties which can leave the sandstone susceptible to the damaging effects of moisture and salts.

Typical decay conditions resulting from complex processes associated with the effects of moisture and salts on sandstone involve case hardening, flaking, granular disintegration and spalling. As soluble salts move through the stone and evaporate they leave behind harmful salt crystals, depending on the maximum moisture content, either at the surface or below the surface.[62] The damaging effects of water can also be linked to moisture in the pH range of 2 – 8 (and especially above 11) which can dissolve silica, SiO_2, as a function of temperature.[63] Other sandstone decay mechanisms result from laying the

[62] A. Elena Charloa, "Salts in Porous Materials," *Journal of the American Institute of Conservation* 39 (2000): 3.
[63] Winkler 193.

stone with the bedding planes perpendicular to the ground (face-bedding). Sandstone is the most durable installed in its natural bed.

Limestones

Limestones can be generally categorized as carbonate rocks. They can be classified of organic, chemical or detrital and clastic origin. In the first two classes, limestones are formed by precipitation out of seawater and can include the shells of marine organisms. These are called autochthonous limestones. The latter class is formed by deposition of detritus, both of marine organisms as well as other limestones and these are called allochthonous limestones. The collection of limestones in the Ohio House is not as extensive as the sandstones, however there are three types used and the entire upper portion of the front bay is entirely Dayton limestone.

The flat lying sedimentary rock of the Central-Interior Sedimentary Basin is one of the most significant sources of limestone used for building stone. In the shallow seas that covered Ohio during the Paleozoic age, carbonate limestone precipitated away from the shore lines where sandstone was deposited.[64] The majority of Ohio limestone was formed during the Devonian period, 417 to 354 million years ago, which also produced dolomite, shale, and sandstone.

[64] Herz 57.

The predominant outcrops of limestone are located through the central Ohio and along the shore of Lake Erie. This formation includes the Columbus limestone utilized in the Ohio House. The Geological Survey of Ohio specifically mentions the Stitt and Price (or Smith and Price) Columbus limestone quarry, "the cutting stone of the quarries ends with this course. It will be observed that ten layers of stone here, or double the number that is reported at Smith and Prices."[65]

There are however other significant limestone formations from the Silurian and Ordovician periods located in the south-west portions of the state which produced the Dayton Stone and the stone from Springfield used in the Ohio House. (See Table 3.3.)

GEOLOGIC AGE	GEOLOGIC PERIOD	LOCATIONS OF LIMESTONE QUARRIES
PALEOZOIC (540 – 248 Million)	Devonian (408-360 Million)	Columbus, Ohio Dayton, Ohio
	Silurian (440-408 Million)	Springfield, Ohio

Table 3.3: *Geologic Age and Period of Limestone Quarry Locations.*

The textures of limestones can be fine grained, fragmentary, crystalline, or oolitic.[66] Limestone textures are a result of formation processes and can be described as fragmented, where the limestone was formed by detritus deposition, or crystalline, where the limestone texture is a result of mineral growth at the site of deposition or a result of

[65] *Geological Survey of Ohio, Volume* 5 (Columbus Ohio: Nevins & Meyers 1878) 612.
[66] Winkler 16.

diagenesis.[67] The rounded grains of calcite or aragonite in oolitic limestone are typically less than 2mm. There is great variety in limestone structure and can range from large cemented shell material to fine, uniform crystalline fabric. Other characteristics of limestone structure include bedding, stylolites, and ripple marks.

The mineralogy of limestone depends on size and shape of the calcareous particles or grains. There are four basic minerals found in limestone: calcite (rhombohedral), aragonite (orthorhombic), dolomite (rhombohedral), and magnesite (rhombohedral). Of the three limestones employed at the Ohio House two are primary calcium carbonate, but the third is a dolomitic limestone.

Many limestone properties are determined by secondary minerals and impurities; most common of which are quartz and clays. Limestones are classified according to their impurities: siliceous limestone contains silica and argillaceous limestone contains clays. Pyrite is a very common accessory mineral found in most of Ohio's limestone. The obvious effects of this can be observed as a rust colored appearance of the stone upon the oxidation of the pyrite. (See figure 3.2) Impurities such as pyrite can drastically affect the weathering properties of limestone.[68] Another important characteristic of limestone in regard to durability is its susceptibly to rain water. High levels of carbon

[67] Compton 48.
[68] Merrill, *Stones for Building and Decoration* 30-31.

dioxide as well as sulphuric and nitrous oxides as found in urban areas can be very damaging to carbonate stone.[69]

Figure 3.2: *Detail of pyrite inclusions and pitting in Dayton limestone.*

Some of the most important properties in explaining the weathering processes of limestone are its solubility properties. The susceptibility of calcium carbonate to low pH values accounts for much of the deterioration of limestone.

Fossils firmly cemented in the body of the stone can have a large impact in determining the weatherabilty of a limestone. For example, all of the Dayton stone used in the Ohio House displays severe pitting, where fossils which were a part of the original structure of

[69] Harley J. McKee, *Introduction to Early American Masonry—Stone, Brick, Mortar and Plaster* (National Trust for Historic Preservation and Columbia University, 1973) 33.

the rock formation weathered out and filled with a less stable material. (See figure 3.2) When originally quarried the variation in composition may have been undetected, but after years of exposure in an urban environment the less stable material has drastically deteriorated. This underscores the effects of secondary minerals and impurities on limestone performance.

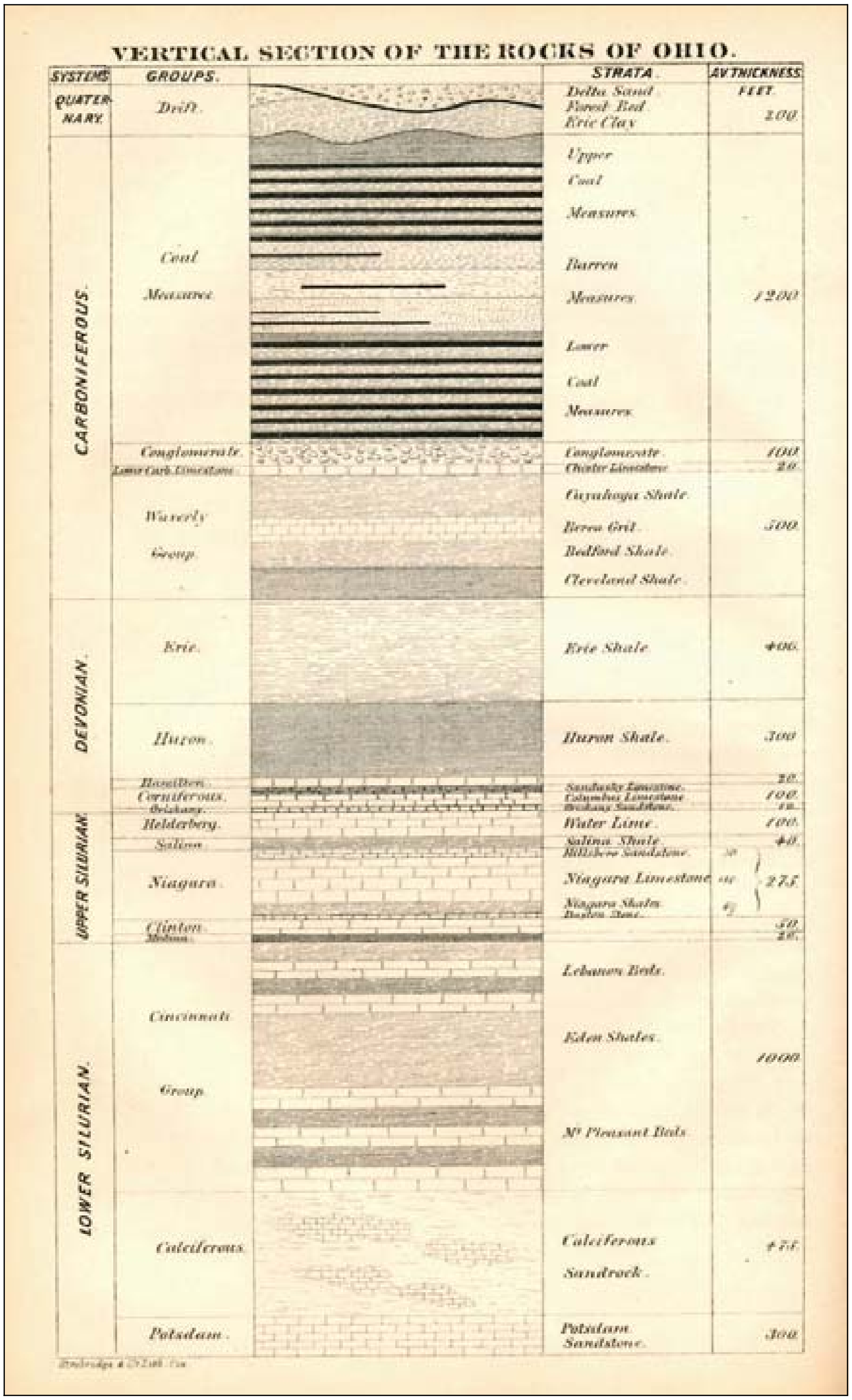

Figure 3.3: *Vertical section of rocks in Ohio from Geological Survey of Ohio 1973, Volume 1 page 88.*

CHAPTER 4: FIELD SURVEY

The field survey phase of the study was divided into two sections, the condition survey and the critical property survey. Both sections required careful pre-planning, the development of specific definitions, and significant time to record information on site. The majority of the field work was carried out between March 1st and March 13th of 2006. Information gathered from the two surveys will be linked together with Geographical Information System (GIS) software and analyzed in Chapter 5.

CONDITION SURVEY

Goal

The Ohio House condition survey was developed to serve as the basis for a comprehensive diagnostic assessment of all the historic stone used in the building. Through the recording of conditions in regard to type, location, degree and extent, various patterns are revealed which can be used to determine decay mechanisms. The condition survey is a means to understand the many etiological relationships at work when conditions are mapped across the façade of a building.[70] The survey will be used to identify which stones are at higher risk and which require intervention.

[70] Frank G. Matero et al., *The Pennsylvania Blue Project: Documentation and Conditions Survey of Exterior Marble Masonry, Second Bank of the United States* (Philadelphia: Architectural Conservation Laboratory and Research Center, University of Pennsylvania, 2004) 22.

Review/Research

A review of the current literature in the stone conservation field revealed several systems and techniques being used to map stone decay. The following classification systems were taken into consideration in the design of this survey: the Italian standard NORMAL 1/88[71] and those developed by John Ashurst[72], Bernd Fitzner[73], and the Architectural Conservation Lab at the University of Pennsylvania.[74] It was decided that Bernd Fitzner's classification system of dividing weathering forms into three categories would be used as the frame work, but that the level of detail Fitzner describes in his mapping system (over 60 individual weathering patterns) was unnecessary for the purposes of this study. Ten conditions were outlined for the Ohio House survey and they correspond to the Fitzner categories of previous loss of stone material, deposition or discoloration, and active deterioration. Condition definitions were developed specifically for the Ohio House, but were primarily guided by Fitzner's work and the survey of the Second Bank of the United States, developed by the Architectural Conservation Laboratory (ACL) at the University of Pennsylvania.

Conditions Glossary

The following glossary is expanded in Appendix B in a more extensive way. Conditions defined in the first category of previous loss are backweathering/relief, pitting, and open

[71] NORMAL, *Normal 1/88*, CRN-Centri di Dtudio di Milano e Roma sulle cause di deperimento e sui metodi di conservation delle opera d'art and Istituto Centrale per il Restoration (Rome, 1988).
[72] John Ashurst and Francis Dimes, *Conservation of Building and Decorative Stone* (London: Butterworth-Heinemann, 1990).
[73] Bernd Fitzner, et al., *Verwitterungsformen – Klassifizierung und Kartierung (Weathering Forms-Classification and Mapping)* (Berlin: Verlag, Ernst and Sohn, 1995).
[74] Matero, *The Pennsylvania Blue Project*.

joints. Discoloration and deposit is the second category and is comprised of soiling, efflorescence, biological growth, and composite repair. In the third category, active loss, conditions recorded include flaking/granular disintegration and contour scaling/detachment. The last definition "condition unique" comprises a miscellaneous final category.

CATEGORY 1: Previous Loss of Stone Material

1. **Backweathering/Relief:** This condition is based on the overall previous loss of stone material for each stone. The degree of deterioration is given a numerical value for each stone, 1 to 6, with 6 indicating the highest amount of previous loss. (Based on Fitzner definitions 1a and 1b.)

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

3. **Open Mortar Joints:** Missing, deteriorated, or detaching mortar in joints. About 20 percent of the joints in the Ohio House are faux and pointing is used to give the appearance of regular coursing. The majority of actual joints are between 3mm and 1cm and there is evidence of original mortar as well as of 2 repointing campaigns. (Based on ACL definition.)

CATEGORY 2: Discoloration/Deposit

4. **Soiling:** Includes the deposition of materials that alter the appearance of the stone surface and build up forming layers. The deposits are a result from atmospheric pollutants, ground water and rising damp, animal droppings, direct anthropogenic causes, and metallic staining. (Based on Fitzner definition 2b.)

5. **Efflorescence:** Loose salt deposits on or under the surface of the stone. (Based on Fitzner definition 2c.)

6. **Biological Growth:** The growth or presence of biological life on the surface of the stone by microbiological colonization of algae, fungus, or lichens. (Based on the Fitzner definition 2e.)

7. Composite Repair: A Portland cement mortar based system used as a surface repair for losses greater ¾ inch in width. They are primarily found on the window trim in the Ohio House. (Based on ACL definition.)

CATEGORY 3: Recent Active Deterioration

8. Flaking/Granular Disintegration: This condition combines the often interrelated flaking and granular disintegration. Granular disintegration is defined as the disintegration of the stone surface due to the loss of the matrix binding the aggregate into the stone. It can occur as powdering when the aggregate and/or matrix are powder-like fines, as sanding when the stone disintegrates into sand grains, and as sugaring when various sand grains attached to one another weather from the stone surface. Flaking is defined as the condition that results in the development of loose flakes on the surface of the stone which dislodge under finger pressure. (Based on Fitzner definitions 3a and 3d.)

9. Contour Scaling/Detachment: This condition combines the often interrelated contour scaling and detachment. Contour scaling is observed as the detachment of larger, platy stone elements parallel to the stone surface, either following the stone structure or independent of stone structure. Detachment is defined as exfoliation which occurs where the leaves of a foliate stone are weathered into layers which detach from the sound stone substrate and delamination which occurs in laminar stones when layers separate from one another and/or the sound stone substrate. (Based on the Fitzner definitions 3e and 3f.)

CATEGORY 4: Other

10. Condition Unique: Examples of unique conditions include missing screens on basement windows, evidence of a feature from a historic photo, or an unusual inclusion.

Methodology

Subsequent to the design of the glossary, steps were taken to prepare for recording the conditions in the field. AutoCAD drawings of the four elevations were obtained from the firm Friday Architects and Planners. The drawings were very general and required significant revision including verification measurements, redrawing all windows and doors, and the addition of stone coursing. To assist in this process, rectified photographic montages were created for the three masonry elevations and rubbersheeted to the CAD drawing. (See Figure 4.1) After the drawings were complete a grid overlay was applied to each elevation, dividing the façade into manageable areas which allow for sufficient detail but also fit on legal size paper to facilitate recording in the field. Grid sections were plotted in pdf format and then printed on 11" x 14" paper.

Figure 4.1: *Photographic montage of south elevation.*

In the field, the conditions were traced onto the drawing using predetermined graphics and colors. The Architectural Conservation Laboratory's color system, which uses red for previous loss, blue for deposition, and green for active loss, provided the framework for color choices. Figure 4.2 is an image of the field survey sheet for a corner of the west elevation; one of twenty-two sheets. Digitization began when the field recording was complete. Each grid section was scanned and imported to CAD where each of the 10 conditions were traced onto the drawing in individual layers. The file was then imported into GIS for analysis which will be discussed further in Chapter 5.

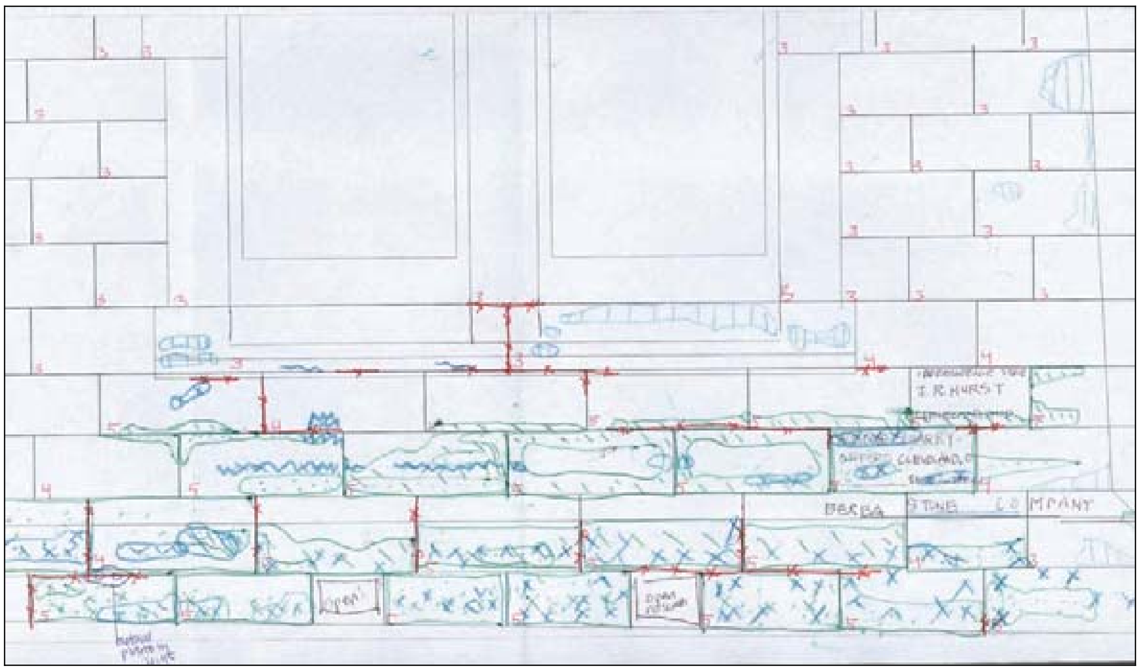

Figure 4.2: *Example of field survey sheet, corner of the west elevation.*

CRITICAL PROPERTY SURVEY

Goal

The Ohio House critical property survey was created as a means to record and organize the data collected for each stone type and each individual stone. This information was collected for the purposes of identification and documentation, as well as obtaining critical information for evaluating performance. In Chapter 5 these variables are applied to the condition survey and serve as a basis for drawing conclusions regarding performance. The data is analyzed in GIS in conjunction with the condition survey to understand the various relationships.

Review/Research

The variety of information obtained in the critical property survey is large and was collected through historic research, visual examination, or field testing. A review of the historic literature provided locations and descriptions of the geologic formations as well as mineral compositions for the majority of the 20 stone types. The most useful resources were the *10th Census of the United States from 1880*, George Merrill's *Stones for Building and Decoration*, the *US Geological Survey of Ohio*, and Bownocker's *Building Stones of Ohio*. Several geology field texts were very helpful in accurately defining visual characteristics, such as Robert Compton's *Geology in the Field.* For the field testing component of the survey a variety of standard conservation tests were reviewed. After it was decided which information should be collected, the survey form was designed and data was collected in the field.

Critical Property Glossary

The following definitions and descriptions explain the methodology for gathering information for each field in the survey form. Appendix B includes the illustrated critical property glossary and an example of the survey form used to collect the data in the field.

1. VISUAL

Identification: Identification letters are given for each of the 20 stone types, A to T. The system is based on coursing and starts at top of the building moving sequentially down. When stones are utilized in more than one course the letter is followed by an additional letter system and the window surrounds are located at the end of the list. Individual stones in each course are assigned a number which comes after the type letter, for example A1, A2, A3, or JA1, JA2, JA3 and so on.

Carving: The specific carving inscription is recorded.

Quarry Location: Indicates the location of the quarry within the state of Ohio. (See quarry map, Appendix A3)

Trade Name: This field records either the trade name, company, or individuals associated with the specific stone type.

Color: Color was determined with the use of the Munsell guide which assigns a value based on hue, chroma, and value, written as 10YR 8/4.[75] Color values were determined for the stones with the least soiling.

[75] *Munsell Soil Color Charts, Revised Washable Edition* (GetagMacbeth, 2000).

Installation: Stones in the Ohio House can be described in one of two ways depending on the orientation of their bedding planes. When the planes are perpendicular to the face of the stone they are edge-bedded when the bedding planes are parallel to the face of the stone they are face-bedded.

Surface Finish: There is huge variety in the surface finishes applied to the various stones in the Ohio House. The display of stereotomy at the Ohio House is one the defining features of the building and makes it truly irreplaceable. Descriptions of the many surface finishes seen on the stones are described below and were found in George Merrill's book *Stones for Building and Decoration*[76] or the article "Concerning Building Stones" in The Manufacture and Builder 1890.[77]

> 1) Rock Face: The face of the stone is left rough, just as it comes from the quarry, and the joints, or edges, are pitched off.
> 2) Tooled Face: A tooled finish is produced with a tooth chisel, creating continuous lines across the width of the stone.
> 3) Broached Face: The stone is dressed with a point, leaving continuous groves over the surface.
> 4) Pointed Face: Natural face, trimmed down with sharp pointed tool called a pointed chisel. It is run over the face of a stone to knock off any large projections. This work is can be defined as rough or fine pointed work, according to the number of times the work is gone over.
> 5) Ax-hammered Face: The surface is struck with repeated blows with sharp-faced implement called ax or pean hammer.
> 6) Tooth Chiseled Face: The surface is produced by dressing stone with a tooth chisel, it can resemble pointed work.
> 7) Crandalled Face: The finish produces a fine, pebbly appearance; it is often used for sandstone.

[76] Merrill, *Stones for Building and Decoration* 401- 403.
[77] "Concerning Building Stones," *The Manufacture and Builder* 22.6 June 1890: 129-130.

8) Rubbed Face: The surfaces of stones are rubbed with softer stone, sand, and water until smooth.

Figure 4.3: *Detail various surface finishes, under porch on west elevation.*

Relief: The amount of stone loss was visually determined for individual stones based on a 1 through 6 scale of severity. (See the backweathering/relief definition in the conditions glossary for illustrated examples of each number, Appendix B.)

Texture: Texture properties were examined using a 10x triplet lens to evaluate three separate categories: grain size, grain shape, and sorting.[78] Grain size was assigned a value between 1 and 4, where 1) silt is >.06mm, 2) fine is <.125mm, 3) medium is

[78] Compton 48-51.

<.5mm, and 4) coarse is >.5mm. Grain shapes were also assigned a 1 to 4 value, where 1) rounded, 2) sub-rounded, 3) sub-angular, and 4) angular. The sorting was divided into three values, 1) poorly sorted, 2) moderately sorted, and 3) well sorted. However, for the purposes of the GIS analysis, texture was simply defined by touch and ranked on a scale of 1 to 4.

Location: The design of the building and where each stone is located within the design plays a major role in determining the causes of decay factors. The following five variables are the most important at the Ohio House and are each assigned a severity of 1 to 4, 4 being the most likely to cause deterioration.

- Distance from Ground: The first three courses were designated 1, next 5 courses 2, next 5 courses 3, and everything above 4.
- Proximity to Open Joints: Assigned values 1 to 4 based on proximity to open joints.
- Exposure to Deicing Salts: An interview with a building caretaker was conducted to determine where deicing salt is laid down and stones were assigned a severity (1 to 4) based of proximity to these areas.[79]
- Degree of Protection: Stones protected from the elements of sun, wind and rain by porches and overhangs were assigned a 1 to 4 value.
- Exposure to Roof Run-off: Values were determined based on observation made of the rain water conduction system during a rain storm.

Environmental: The following environmental conditions were determined visually and from the data collected from the National Climate Center.[80] The climate in Philadelphia, including the area around the Ohio House can be unpredictable, displaying a range of

[79] Jessicia Baumert, personal interview, 23 Mar 2006.
[80] National Climate and Data Center, 16 Mar 2006 <http://www.ncdc.noaa.gov/oa/ncdc.html>.

activity according to the season. The winters experience periods of extreme cold, however, sub-freezing temperatures are not sustained for long periods of time. Mean temperatures fall between 30 to 40 degrees Fahrenheit and dewpoint temperatures range between 20 and 30 degrees Fahrenheit. Snow fall amounts vary in the winters, ranging from blizzard like conditions to little or now accumulation. The Ground Snow Load is 14 lb/ft^2 and the frost depth is 22 in (both at 50 year recurrence).

Mean summer temperatures fall between 70 and 80 degrees Fahrenheit and the mean dewpoint is between 58 and 65 degrees Fahrenheit. Spring temperatures vary greatly and the mean is between 40 and 65 degrees Fahrenheit, with a dewpoint between 30 and 40 degrees Fahrenheit. Mean temperatures for fall are between 45 and 65 degrees Fahrenheit and the dewpoint falls between 65 and 35 degrees Fahrenheit. The average number of annual freeze-thaw cycles in Philadelphia is 59.

Annual precipitation is dispersed throughout the calendar year and averages include total precipitation of forty-one inches and a Rain Rate of 3.1 in/hr (at a hundred year recurrence).

Winds are predominantly from the west/northwest and fairly consistent with the exception of a more southern wind in the summer and less wind in the winter. Air pollution in Philadelphia has reduced in recent years, but the Clean Air Council still reports Philadelphia as the thirteenth worst area in the country. Philadelphia had eighty-four days of unhealthy air quality from 2000 to 2002.

The sun generally moves from east to west in a southern arc, therefore the south façade gets the most intense exposure to the sun. However, the sun's path varies with the season and is high in the summer and low in the winter. Another variable taken into consideration is the shade provided from tree leaves.

- Summer Sun: The sun is stronger in the summer and comes from a higher angle. It is important to note sun is affected by the shade provided from leaves on surrounding trees.
- Summer Wind: Summer wind predominantly comes out of the west and south, and is stronger in summer than the winter.
- Summer Rain: Summer and winter rainfall are even.
- Winter Sun: Sun is not as strong in the winter and is at a lower angle.
- Winter Wind: Out of the west/northwest
- Winter Rain: Summer and winter rainfall are even.

2. LITERATURE REVIEW

Geologic Formation: Information regarding the geologic formation and its age were found in historic or current literature.

Composition: Mineral compositions were obtained from the historic literature: Bownocker's *Building Stones of Ohio* (1915), Merrills's *Stones for Building and Decoration* (1910), and the *10th Census* (1880). Compositions for several types were determined through Powder XRD. (See Table 3.2)

	Type	Name	Composition	Sandstone Binder
1	A	Dayton Limestone (Bossler and Huffman)	Limestone: Calcium Carbonate	--
2	B	Massillon Sandstone (Warthorst & Co)	Sandstone	Argillaceous
3	C	Massillon Sandstone	Sandstone	Argillaceous
4	D	Youngstown Sandstone (TOD Quarry)	Sandstone	Siliceous
5	E	Unidentified Buff Sandstone	Sandstone	n/a
6	F	Cincinnati Sandstone (M. Finnigan)	Sandstone	n/a
7	G	Springfield Limestone (Frey and Sintz)	Limestone: Calcium/Magnesium Carbonate	--
8	H	Columbus Limestone (Stitt Price Co.)	Limestone: Calcium Carbonate	--
9	I	Unidentified Purple Sandstone	Sandstone	n/a
10	J	Berea Sandstone (J. McDermott & Co.)	Sandstone	Siliceous
11	K	South Amherst Sandstone (Ohio Stone) Company)	Sandstone	Siliceous
12	L	Unidentified White Sandstone	Sandstone	n/a
13	M	Amherst Sandstone (Amherst Stone Company)	Sandstone	Siliceous
14	N	Independence Sandstone (John Wagner)	Sandstone	Siliceous
15	O	Independence Sandstone (J.R. Hurst)	Sandstone	Siliceous
16	P	Berea Sandstone (Berea Stone Company)	Sandstone	Siliceous
17	Q	Euclid Sandstone	Sandstone	Ferruginous or Siliceous
18	R	Columbus Sandstone (W. Fish & Co.)	Sandstone	Ferruginous
19	S	Coshocton Sandstone (Coshocton Stone Co.)	Sandstone	Argillaceous
20	T	Unidentified Liesgang Ring Sandstone	Sandstone	n/a

Table 4.1: *Composition of the 20 types of stone used in the Ohio House.*[81]

[81] Bownocker's *Building Stones of Ohio* (1915), Merrills's *Stones for Building and Decoration* (1910), *10th Census* (1880), and Powder XRD.

3. FIELD TESTING

Water Absorption: The RILEM Water Absorption Test measures the volume of water absorbed by masonry systems within a specified time period.[82] The water permeability of stone is directly related to its durability. It can be used to determine water permeability, degree of weathering, and the effectiveness of a treatment.[83] This procedure is a simple method which can be easily used in the field. It was applied to 20 stone types found in the Ohio House. It should be noted that although there are many desirable qualities of this test there are also many sources of error which can influence results such as temperature, inhomogeneous areas of stone surface, soiling, effectiveness of putty seal, etc. Given the time restraints, the test was preformed twice on each stone and averaged. Ideally many more test results would be combined and averaged. Therefore the following water absorption rates are gross, but still useful for the purposes on this study. The results of the tests are presented below in a water absorption graph, where water absorption (cm^3) is a function of time (min.).

[82] "RILEM test N° II.4 in Commission 25-PEM Protection et Érosion des Monuments Recommended Tests to Measure the Deterioration of Stone and to Asses the Effectiveness of Treatment Methods," *Materials and Structures* 13 (1980): 175-253.
[83] Frances Gale, "Measurement of Water Absorption," *APT Bulletin* 21 (1989): 8-9.

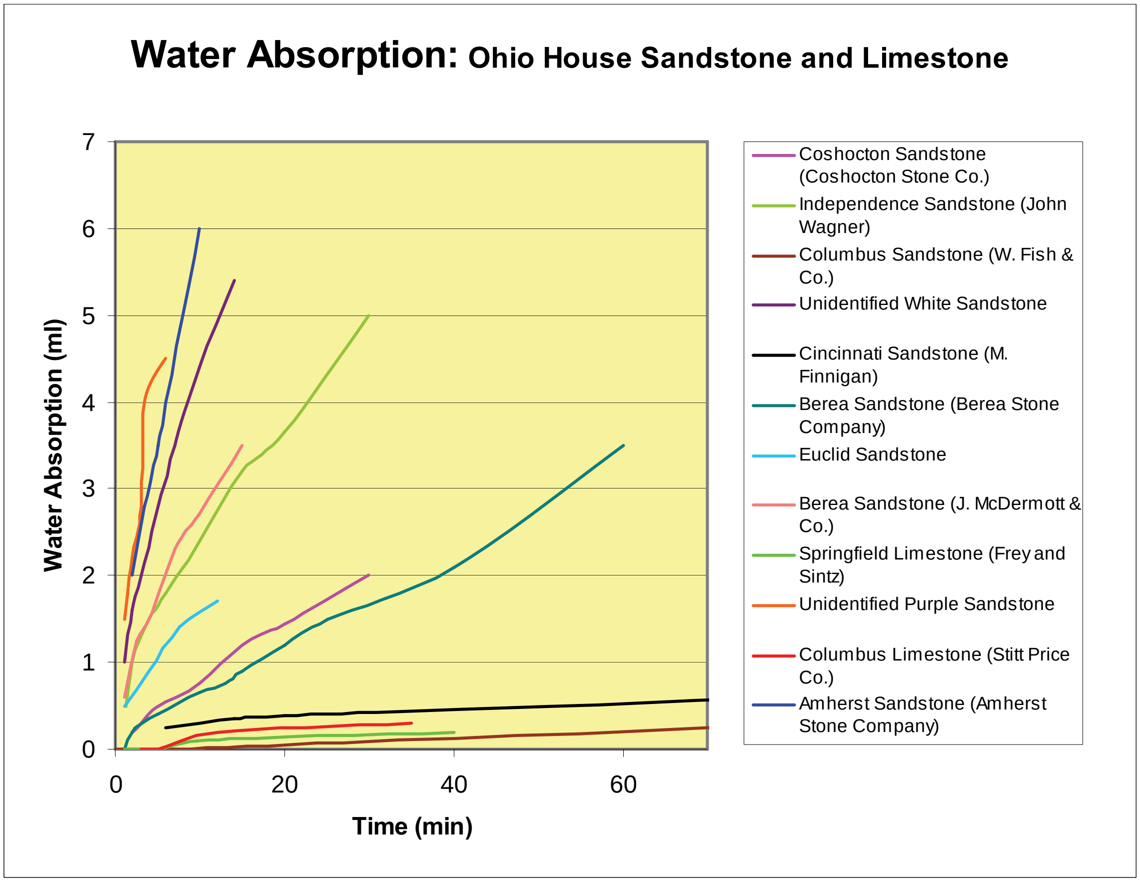

Figure 4.4: *Water absorptions of Ohio House stone types, where water absorption (cm^3) is a function of time (min.), graph includes 12 of the 20 types of stone (* indicates limestone).*

Figure 4.5: *Rilem Water Absorption Test on Berea Sandstone (J. McDermott & Co.)*

Figure 4.6: *Rilem Water Absorption Test on Columbus Sandstone (W. Fish & Co.), note zero water absorption after 16 minutes.*

Hardness: Hardness can be defined as a rock's resistance to being scratched by a range of materials with varying hardness. In 1824, these values were quantified in a scale of 10 minerals by the scientist Frederick Mohs. To determine the Mohs hardness value for the 20 different rock types, each type was scratched with relative materials (fingernail 2.5, coin 3, iron 4-5, knife blade 5.5, glass 6-7) and assigned a value 1 to 3, three being the hardest.[84]

Hardness: Ohio House Sandstone and Limestone	
Value 1 (3 or below)	Dayton*, Columbus*, Springfield*
Value 2 (Between 3 and 5.5)	Cincinnati, McDermott, Massillon1, Massillon2, Unidentified Purple Sandstone, Berea, Unidentified Liesgang Ring Sandstone, Unidentified White Sandstone, Columbus
Value 3 (5.5 or above)	Coshocton, Euclid, Youngstown, South Amherst, Amherst, Independence, Cleveland

Table 4.2: *Hardness values for Ohio House stone, based on Mohs hardness scale (* indicates limestone).*

[84] Chris Pellant, *Smithsonian Handbooks: Rocks and Minerals*, (New York: Dorling Kindersley, Inc.: 2002) 25.

Figure 4.7: *Mohs hardness test indicating Springfield limestone is softer than 5.5.*

Carbonate ID: To determine which of the stones in the Ohio House contain a significant amount of calcium carbonate, hydrochloric acid was dropped on each stone type and monitored for effervescence. When exposed to acid, insoluble carbonates (XCO_3) will dissolve and produce CO_2 gas. This test was used to identify the stones composed of calcite (calcium carbonate, $CaCO_3$) and/or dolomite (calcium and magnesium carbonate, $CaCO_3.MgCO_3$).[85] The test was performed as a means to verify the results of the literature review regarding composition.

[85] Compton 48-51.

Figure 4.8: *Detail of hydrochloric acid effervescing on Dayton limestone indicating the presence of calcium carbonate.*

Figure 4.9: *Detail of hydrochloric acid not effervescing on Berea sandstone.*

CHAPTER 5: EVALUATION

The final goal of this project is an accurate diagnostic assessment of the historic stone used in the Ohio House. A Geographic Information System (GIS) file was designed to compile information from the field condition survey and the critical property survey for analysis. In the first section of this chapter details regarding each condition are described and decay mechanisms are discussed. The second section of the chapter explores the various factors affecting the observed conditions. Using GIS as a tool, stone performance is measured against the following five critical parameters: composition, location in building, environment, water absorption and surface finish. These variables are assessed based on an index regarding their effect on performance and ranked accordingly.

OBSERVED CONDITIONS: CAUSE AND EFFECT

The most prominent conditions at the Ohio House were examined visually and recorded in the condition survey, as defined in the previous chapter. In analyzing the condition drawings, maps were made of the three categories of deterioration.

The first category, **Previous Long-term Loss** (see Appendix layouts C1, C2, and C3), includes the areas of the stone which have receded back from the original surface over time. This category technically combines several conditions into one and assigns a value of 1 to 6 based on the overall previous loss of stone material for each stone in its entirety. Although this method combines uniform previous loss and selective previous loss, in the case of the Ohio House it primarily represents the degree of uniform backweathering. These conditions may take slightly different forms but they are responses to the same deterioration mechanisms: exposure to rain wash, damaging salts, sun, and wind. Locations of high previous loss were found in areas with higher exposure, closer proximity to the ground, direct exposure to damaging salt, or with certain mineral compositions such as clay.

Relief in the form of pitting was recorded separately in this first category, because it can be specifically linked to composition. The three limestones used in the Ohio House display areas of pitting, particularly the Dayton limestone used in the projecting bay on the second floor. Softer areas of the stone weathered out which created small concave cavities. (The conditions pitting and open joints are displayed on the Active Loss drawings, see Appendix layouts C7, C8, and C9.)

The second major category, **Deposition** (see Appendix drawings C4, C5, and C6), is defined by the addition or discoloration of various materials on or intrinsic to the stone and was recorded in four conditions.

A significant amount of soiling was found at the Ohio House in several different forms. A greasy black bird repellant was discovered above many of the window lintels, on decorative work surrounding the windows, and in areas under the porches. Unfortunately there are also locations of bird guano, but the building does not appear to be currently inhabited by birds. Several areas of unidentified dark soiling was recorded, a significant amount of which is now thought to be small black biological growth because it is found in areas of shade and moisture. Pyrite mineral inclusions found in the Dayton limestone were recorded as soiling and many of them include a stain streak below from the hydrated iron oxides.

Although efflorescence is included in the deposition category it directly correlates with much of the active deterioration in category three. Efflorescence deposits were found almost exclusively on the west façade due to the use of deicing salts as well as sun and wind exposure. Based on conversations with building occupants, deicing salts are utilized at the northwest corner of the building. The topography runs slightly south, which could have facilitated the spread of salts to contaminate the entire façade, in addition to salts intrinsic to the soil.

Biological growth occurred in damp areas with minimal sun exposure. The majority was found in the courses closest to the ground and primarily on the east façade. (As previously described, the north façade is not masonry and was not included in the survey.) The east façade is shaded by three large pine trees all year.

Several composite repairs were found on the recessed areas of the masonry window surrounds. The patches appear to be a Portland cement mixture with an incompatible formulation for permeability, based on the degree of surrounding deterioration of the sandstone. Some of the surrounds exhibit an unidentified light-colored substance which could be silica residue from a previous patch. The decay associated with these recessed areas of the windows, particularly in the south façade, is extremely severe and high risk.

The final category, **Recent Active Deterioration** (see Appendix drawings C7, C8, and C9), was separated into two classes of deterioration mechanisms: flaking/disaggregation and contour scaling/detachment.

Flaking and granular disintegration were combined in the survey because they primarily occur simultaneously at the Ohio House, with granular disintegration beneath the flaking or flaking yielding to the disaggregation. This condition is a result of exposure to soluble salts and environmental conditions creating damaging wet/dry cycles. Flaking and sanding are a result of water containing salts moving through the stone, evaporating at the surface, and leaving salt crystals behind which break apart the stone grains on the surface. It is important to note, in this condition the maximum moisture content, or place of evaporation is situated near the surface. Flaking and granular disintegration occurs at the Ohio House in areas with high exposure to salts, water, and wet/dry cycles which that tend to dry out quickly and do not remain wet. The condition is most common on the west façade.

Contour scaling and detachment were combined in the Ohio House survey because they represent a greater amount of active material loss (or potential loss) than the flaking/disaggregation condition and are the result the same deterioration mechanism. Contour scaling/detachment is a result of soluble slats and environmental conditions, but in this situation the maximum moisture content or place of evaporation occurs below the surface of the stone causing damage below. This condition also is influenced by the orientation of bedding planes and natural inconsistencies of weaker planes.
Similar to the first active condition, contour scaling is more severe on lower areas of the west elevation and exposed areas of the southern elevation. Patterns from the survey revealed the condition occurring around the edges of areas of previous loss.

In addition, hydric and hygric dilatation or expansion can induce the active deterioration mechanisms discussed above. Water cycling causes stone to expand and contract which can cause material fatigue, especially for argillaceous sandstones and is influence by the presence of salts.[86]

FACTORS AFFECTING PERFORMANCE

Conditions occurring at the Ohio House vary from façade to façade, from course to course and even from stone to stone, as is represented in the condition drawings in Appendix C. The factors producing these seemingly inconsistent maps of conditions are numerous and can affect decay mechanisms at various intensities depending on the time of year. Because there are 20 different types of stone used in the building and so many variables affecting the decay, GIS proved to be an invaluable tool in organizing the information and ultimately linking the data to performance. Although conditions are presented for each of the three facades and factor data is available for each façade, the drawings included in the Appendix focus on the west façade. The GIS drawings produced illustrate each category and the corresponding relationships. (See Appendix D) The factors responsible for the decay of the sandstone and limestone at the Ohio House were examined in the following five categories.

[86] A. Elena Charloa, "Salts in Porous Materials," *Journal of the American Institute of Conservation* 39 (2000): 3.

- Location in Building/Design
- Environment
- Composition
- Surface Finish
- Water Absorption

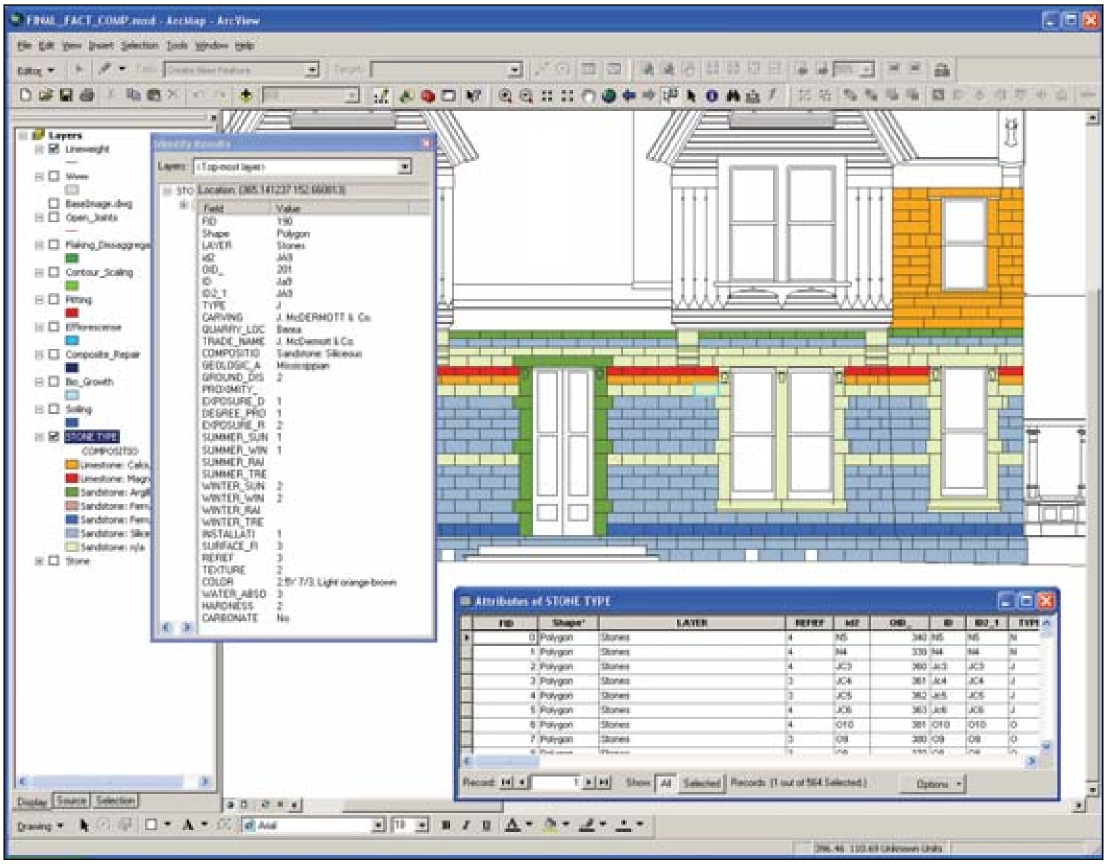

Figure 5.1: *Image representing computer screen with GIS Ohio House map displayed, note stone highlighted in blue and the corresponding information box attached. Each stone is linked to the data.*

Location in Building/Design

The most influential factor on stone performance at the Ohio House is based on the location of the stone within the design of the building. The variables recorded in this category include distance from the ground, proximity to open joints, exposure to deicing salts, exposure to roof run-off and degree of protection. The various porches and overhangs incorporated into the design of the building create areas of protection from sun, wind, and rain. Proximity to the ground indicates the potential for rising damp to transport water and salt by capillary action deep into the stone and proximity to open joints indicates a direct entry point for damaging moisture. The steep gable roof on the Ohio House generates a large amount of roof runoff and there are points where the rain water management system in the building fails, dumping water directly onto the historic stone. As discussed in the previous section, deicing salt is deposited in the northwest corner of the building which is potentially moving south.

The GIS maps directly correlate active decay with all of the variable factors in this category. Contour scaling/detachment is particularly more severe in the areas where deicing salt is found. Advanced active decay is primarily found in the four or five courses closest to the ground, areas which are exposed to rising damp and which are more exposed to the elements. Therefore, not surprisingly the previous loss map indicates stones with a high degree of protection display less overall material loss, such as under the porches. There is one particular area which experiences high quantities of roof run-off, to the left of the porch, and displays corresponding damage.

There is a very strong correlation between active decay and open joints; there are very few open joints recorded without adjacent active decay. Location and design also account for the severe deterioration on the underside of the window lintels and surrounding trim. The window lintels on the projecting front bay (Unidentified Liesgang Ring Sandstone) of the south façade and the window lintels on the right side of the south façade display areas of loss from 2 inches to as great as 5 inches deep. (See Figure 5.2)

Figure 5.2: *Detail of underside of window lintel on south façade, stone displays over 2 inches of loss.*

Environment

The environment surrounding the Ohio House includes the following variables affecting stone performance: summer sun, summer wind, winter sun, winter wind, and summer and winter rain. Differentiating between summer and winter is crucial, as the path and intensity of the sun is different, the shade provided by tree leaves is different, and the direction of wind varies.

The environmental mapping revealed a strong correlation between patterns of sun and shade and active decay. For example, on the west façade in the Coshocton stone trim surrounding the central door, the lower stone on the right is severely deteriorating but the stone on the opposite side of the door is not. The sun exposure map indicates that the stone on the right receives a longer more intense sun exposure time, while the stone on the left is protected by the shade of the porch. (See Figure 5.3 and 5.4) The map illustrating winter winds on the west façade (see Appendix D2), which come out of the northwest, suggests a corner of protection on the limestone front bay and a pattern of advanced contour scaling on the right side which is not protected. This suggests winds are accelerating the decay of the limestone.

Although not included in the sun exposure maps in the Appendix because it is on the south façade, there is an additional area which indicates a direct link between summer sun exposure and performance. On the lower right side of the south façade there is a

Figure 5.3: *Photo illustrating path of strong sun exposure on west façade and areas of shade from the porch, note the exposure of lower right stone in the Coshocton sandstone (Coshocton & Co).*

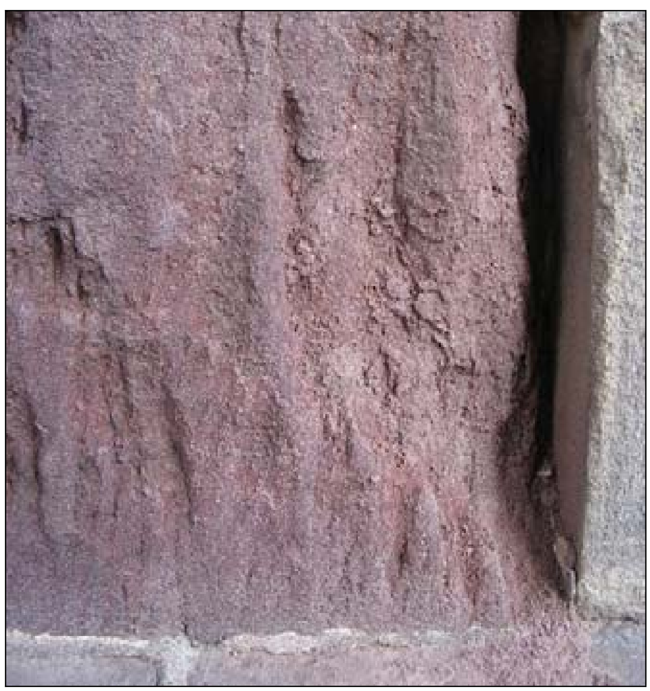

Figure 5.4: *Detail of deteriorated of lower right stone in the Coshocton sandstone (Coshocton & Co) window surround.*

central area of severe decay flanked by areas of sound stone. (See Figures 5.5 and 5.6) In mapping sun paths on this side of the building, it became clear that the sound stone is protected by the strong summer sun by leaves on surrounding shrubbery and the decay is directly exposed. In the future, more sophisticated environmental monitoring techniques on all of these factors could be preformed to produce a more specific diagnosis.

Figure 5.5: *Photo illustrating proximity of shrubbery to deteriorated area of lower right side of south façade.*

Figure 5.6: *Detail of deteriorated area of lower right side of south façade due to stronger summer sun exposure.*

Surface Finish

The physical properties and susceptibility of stone to decay can be dramatically influenced by the applied surface finish. Intricate tooling increases the surface area of the stone creating more opportunity for water entry and creating pockets where moisture can sit. Strong blows to the stone necessary to create certain tooling patterns can also weaken the structural strength in various ways. Based on the maps produced, surface finish of varying depths and styles does not appear to greatly affect performance. No correlation was discovered with the sandstone. However, the analysis indicates the tooling on some of the limestones could have accelerated decay.

Composition

There are 20 different types of sedimentary stones found in the Ohio House. Ideally, samples could be obtained and laboratory analysis run, however, samples were not available for each stone. A historic and contemporary literature review was conducted to obtain the mineral compositions and in the three cases where samples were available, Powder XRD was run.[87] The variables recorded in the composition category include the type of stone, sandstone or limestone, and the binder, silica, iron oxides, calcite, or clay. (See Table 4.1 and Appendix D4.)

Although not as strong as other factors affecting the Ohio House, the composition maps indicate a definite link between composition and performance. For example, pitting displayed by the limestones is a direct function of composition, as the softer mineral inclusions in the calcium carbonate or magnesium carbonate weather out first. The maps also revealed more advanced active deterioration in the Coshocton Co. sandstone which has an argillaceous binder. In the presence of water, soluble salts, and with intense sunlight speeding up the expansion and contraction of the clays, the deterioration in the Coshocton Stone is more advanced than other stones in similar conditions without argillaceous binders. (See Figure 5.3) Further analysis is needed to more accurately identify specific mineral composition in preparation for treatment.

[87] Powder XRD analysis was conducted by Bill Romanov at the Laboratory for Research on the Structure of Matter (LRSM), University of Pennsylvania, Nov. 1 2005.

Water Absorption

Water absorption can be a direct indicator of durability. The water absorption values for each stone type were collected in the field and mapped through GIS (see Figure 4.1). Stone types with the highest rates include the Unidentified Purple Sandstone, Amherst Sandstone (Amherst Stone Company), Unidentified White Sandstone, and the Berea Sandstone (J. McDermott & Co.). Stone types with the lowest water absorption values include Columbus sandstone (W. Fish & Co.), Cincinnati sandstone (M. Finnigan), Columbus limestone (Stit and Price) and Springfield limestone (Frey and Stinz). Stones with high water absorption rates do not display greater deterioration than other stones. Stones with low water absorption rates seem to have slightly more areas of significant decay, such as the Columbus sandstone (W. Fish & Co.) which tends to hold water for longer periods of time. Based on these results, there does not appear to be consistent patterns or very strong correlations between water absorption rates and performance.

Final Ranking

The following list indicates a ranking of the most influential factors affecting performance at the Ohio House, from most influential to least influential:

1) Location in Building/Design
2) Environment
3) Composition and Water absorption
4) Surface finish

CONCLUSIONS

The collection of 19th century building stone displayed in the Ohio House, originally for the Centennial Exhibition of 1876, is a significant and irreplaceable contribution to the West Fairmount Park landscape in Philadelphia. This study thoroughly identified and documented the 20 types of Ohio stone used in the building for the first time.

The most prominent conditions of the masonry were examined and recorded in a stone-by-stone field survey, revealing patterns of decay and the many etiological relationships at work. The diagnostic assessment identified the stones which are high risk and in need of intervention. Of the 1,590 stones surveyed, 1% were determined to be in need of emergency stabilization and 6.5% were identified as high risk. (See Table 6.1)

This thesis took advantage of the unique opportunity presented by the Ohio House collection of stone to link the conditions survey to the factors affecting performance and ultimately ranking them in terms of influence. Through the use of GIS the following factors were studied, mapped and linked to the condition survey: location in

OHIO HOUSE STONE		
In need of emergency stabilization	18	1%
Very severe loss	104	6.5%
Severe loss	192	12%
Medium loss	928	58%
Mild loss	165	10%
Very mild loss	183	11.5%
Total	1,590	

Table 6.1: *Table displaying at risk stone in percent.*

building/design, environment, composition, surface finish, and water absorption. The results indicated that location in building/design was the most influential factor affecting performance in the Ohio House, followed by environment variables as the second most influential category. Composition and water absorption were determined to have similar influence in third place and surface finish displayed the least correlation with performance.

GIS proved to be an invaluable tool in the organization and storage of many different types of data in this study. It provided a relatively quick way to relate the degree of damage to the critical factors that cause it. GIS also provided the crucial ability to graphically manipulate various forms of data in order to display results in a meaningful fashion.

It is the authors hope that the information provided in this study will serve as a useful foundation for the Fairmount Park Historic Preservation Trust in developing an effective treatment program for the stone in preparation for restoration efforts scheduled for the summer of 2006.

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APPENDICES

STONE TYPE LEGEND

- A -- Dayton Limstone (Bossler and Huffman)
- B -- Massillon Sandstone (Warthorst and Co.)
- C -- Massillon Sandstone
- D -- Youngstown Sandstone (TOD Quarry)
- E -- Unidentified Buff Sandstone
- F -- Cinncinnati Sandstone (M. Finnigan)
- G -- Springfield Limestone (Frey and Sintz)
- H -- Columbus Limestone (Stitt Price Co.)
- I -- Unidentified Purple Sandstone
- J -- Berea Sandstone (J. McDermott and Co.)
- K -- South Amherst Sandstone (Ohio Stone Co.)
- L -- Unidentified White Sandstone
- M -- Amherst Sandstone (Amherst Stone Co.)
- N -- Independence Sandstone (John Wagner)
- O -- Independence Sandstone (J.R. Hurst)
- P -- Berea Sandstone (Berea Stone Company)
- Q -- Euclid Sandstone
- R -- Columbus Sandstone (W. Fish and Co.)
- S -- Coshocton Sandstone (Coschocton Stone Co.)
- T -- Unidentifed Liesegang Ring Sandstone

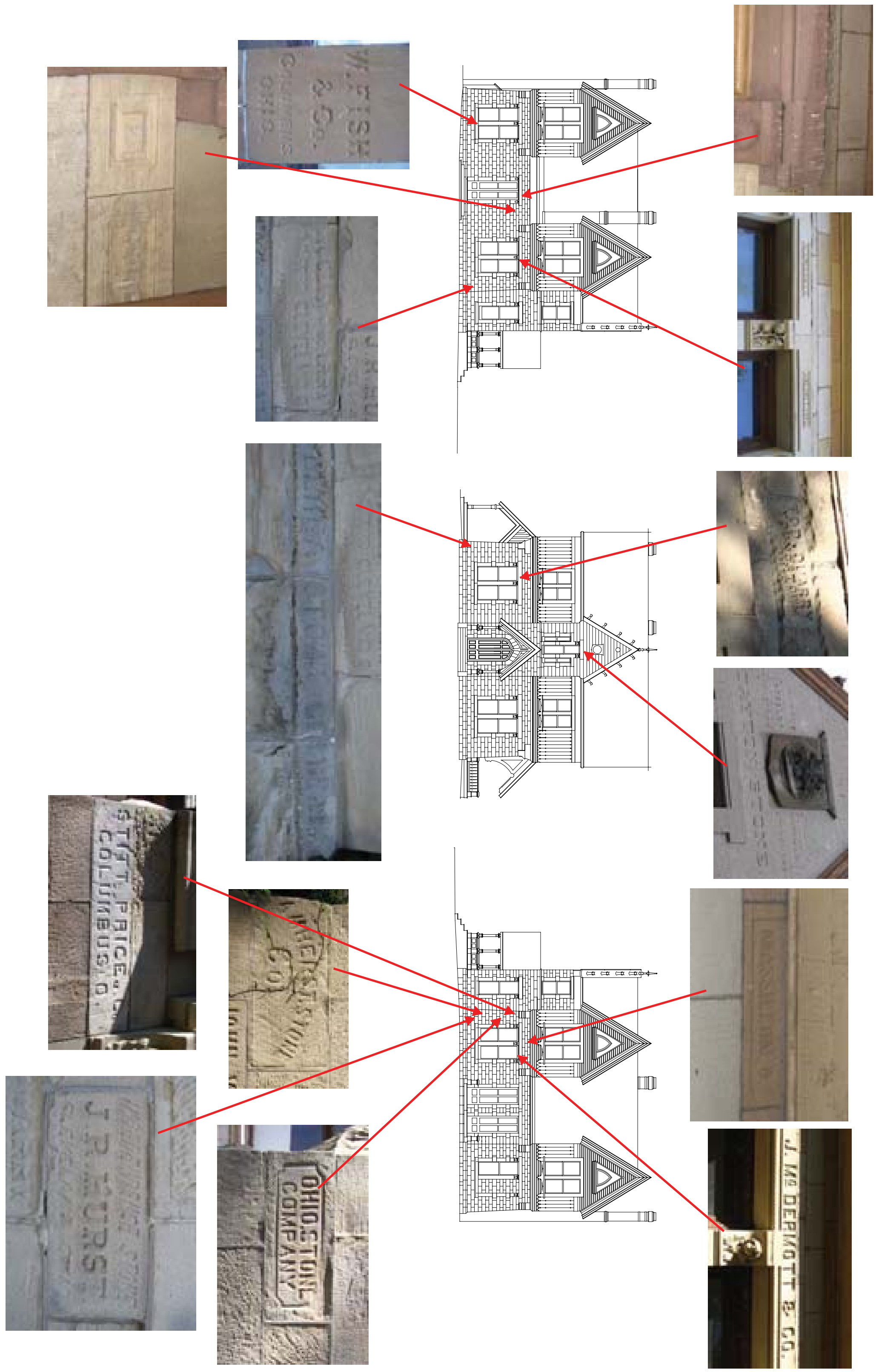
A1: STONE TYPE

OHIO HOUSE, WEST ELEVATION

FAIRMOUNT PARK, PHILADELPHIA, PA

Elizabeth H. Seyfert
2006

Masters Thesis, Historic Preservation
University of Pennsylvania, School of Design



OHIO HOUSE
FAIRMOUNT PARK, PHILADELPHIA, PA

A2: EXAMPLES OF CARVING AND CARVING LOCATIONS

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A3: QUARRY LOCATIONS IN OHIO

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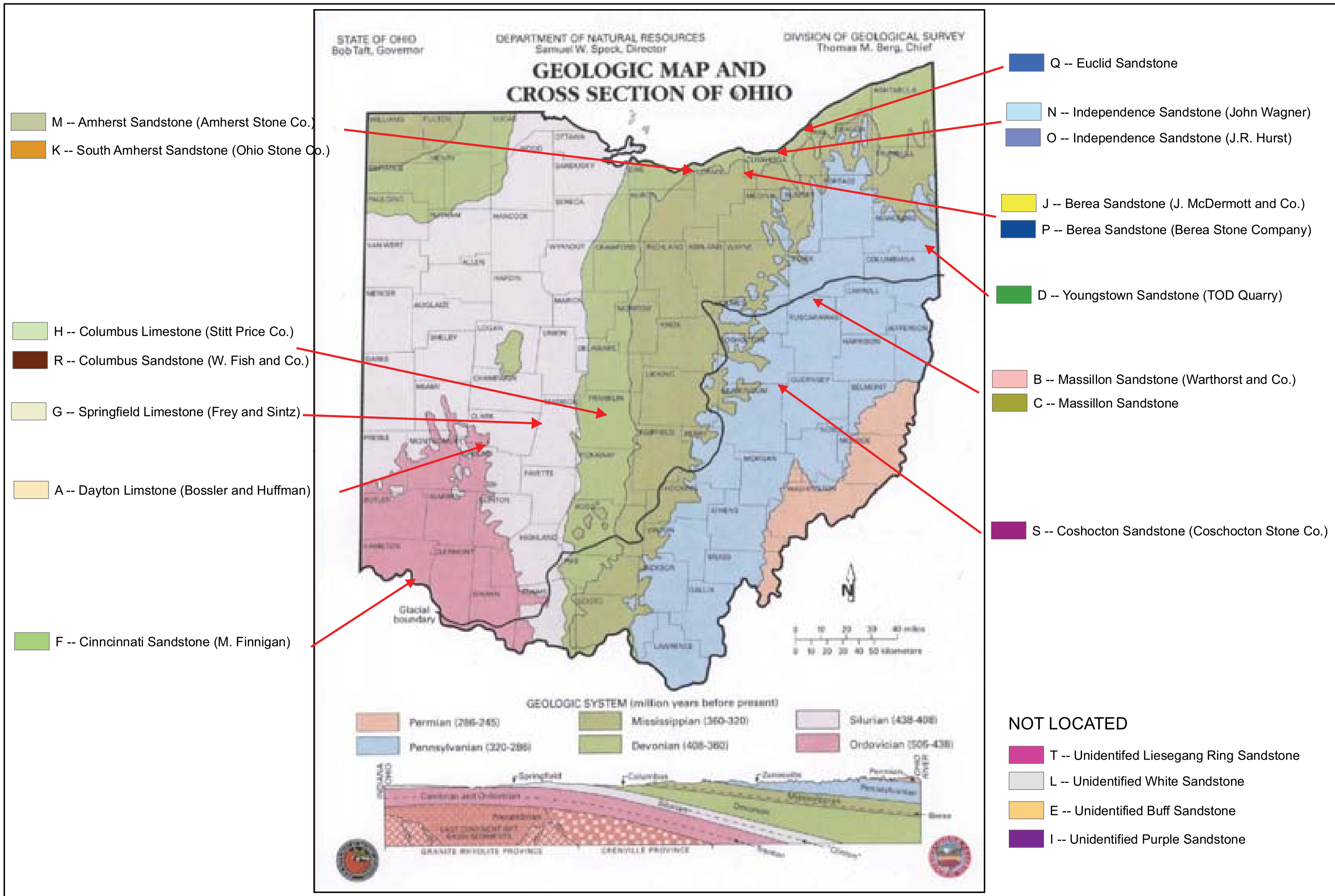

Map: Courtesy of Ohio Department of Natural Resources

SOUTH

WEST

EAST

OHIO HOUSE
FAIRMOUNT PARK, PHILADELPHIA, PA

A4: PHOTO MONTAGES

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CONDITIONS GLOSSARY

CATEGORY 1: Previous Loss of Stone Material

1. Backweathering/Relief: This condition is based on the overall previous loss of stone material for each stone. The degree of deterioration is given a numerical value for each stone, 1 to 6, with 6 indicating the highest amount of previous loss. (Based on Fitzner definitions 1a and 1b.)

Photographs:

Severity 1

Severity 2

Severity 3

Severity 4

Severity 5

Severity 6

2. Pitting: Pitting of the stone surface due to the weathering out or erosion of the matrix of aggregate creating small concave cavities. (Based on Fitzner definition 1b.g)

Photographs:

3. Open Mortar Joints: Missing, deteriorated, or detaching mortar in joints. About 20 percent of the joints in the Ohio House are faux and pointing is used to give the appearance of regular coursing. The majority of actual joints are between 3mm and 1cm and there is evidence of original mortar as well as of 2 repointing campaigns. (Based on ACL definition.)

Photographs:

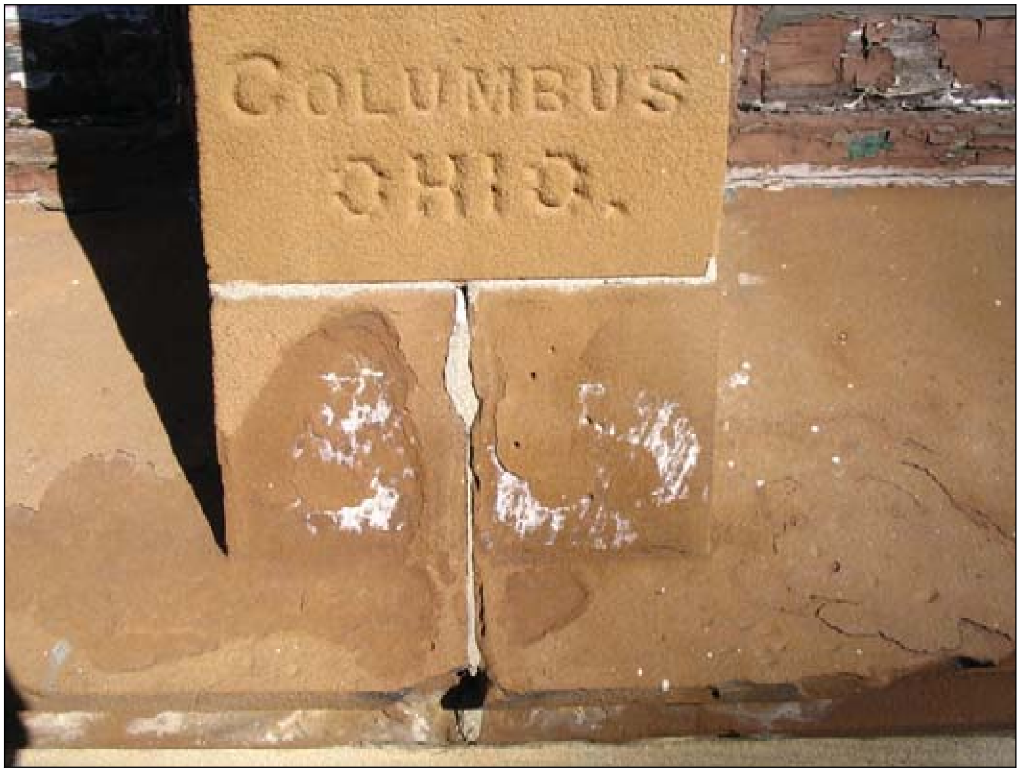
CATEGORY 2: Discoloration/Deposit

4. Soiling: Includes the deposition of materials that alter the appearance of the stone surface and build up forming layers. The deposits are a result from atmospheric pollutants, ground water and rising damp, animal droppings, from direct anthropogenic causes, and metallic staining. (Based on Fitzner definition 2b.)

Photographs:

5. Efflorescence: Loose salt deposits on or under the surface of the stone. (Based on Fitzner definition 2c.)

Photographs:



6. Biological Growth: The growth or presence of biological life on the surface of the stone by microbiological colonization of algae, fungus, or lichens. (Based on the Fitzner definition 2e.)

Photograph:

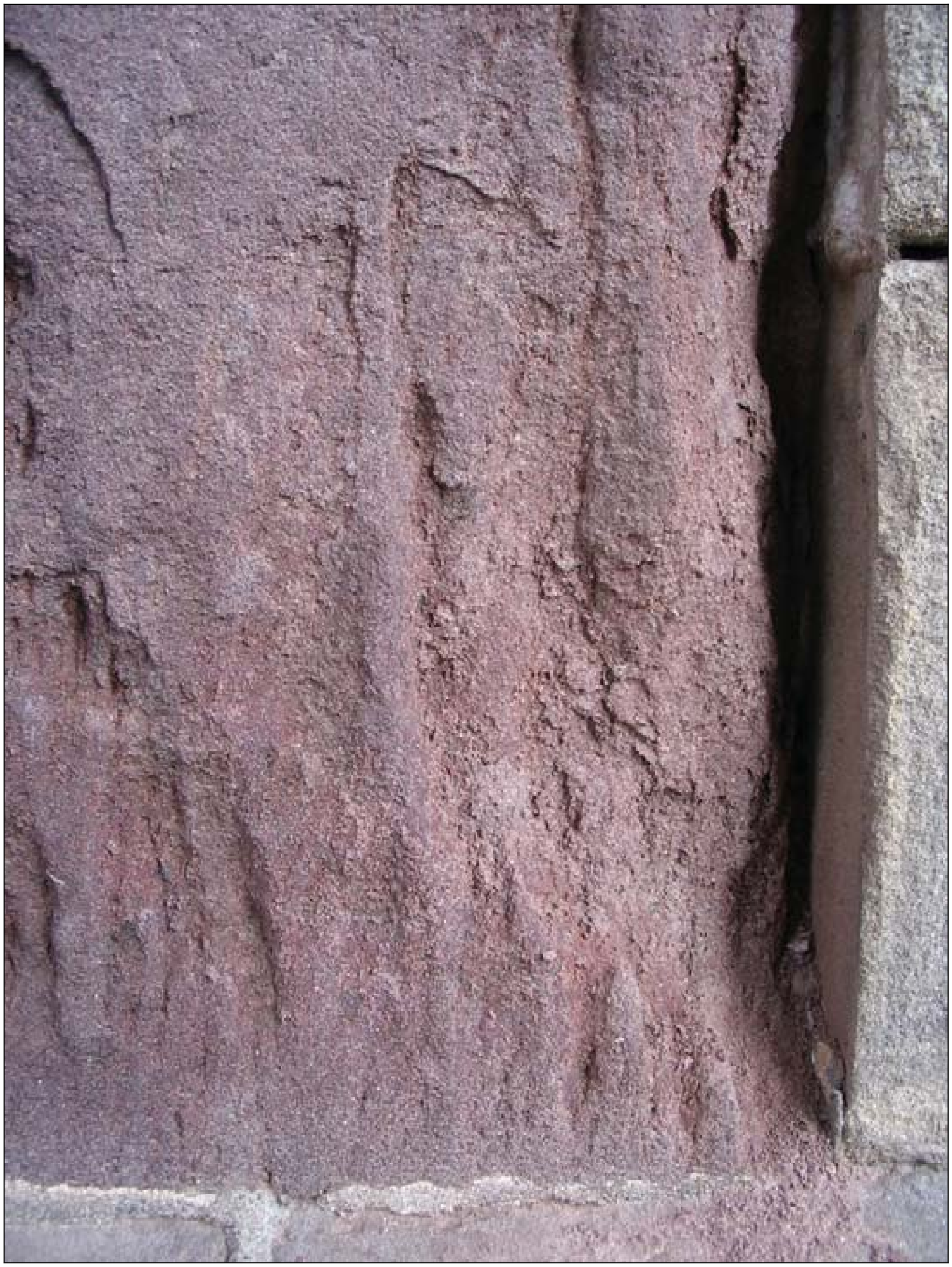
7. Composite Repair: A Portland cement mortar based system used as a surface repair for losses greater ¾ inch in width. They are primarily found on the window trim in the Ohio House. (Based on ACL definition.)

Photographs:

CATEGORY 3: Recent Active Deterioration

8. Flaking/Granular Disintegration: This condition combines the often interrelated flaking and granular disintegration. Granular disintegration is defined as the disintegration of the stone surface due to the loss of the matrix binding the aggregate into the stone. It can occur as powdering when the aggregate and/or matrix are powder-like fines, as sanding when the stone disintegrates into sand grains, and as sugaring when various sand grains attached to one another weather from the stone surface. Flaking is defined as the condition that results in the development of loose flakes on the surface of the stone which dislodge under finger pressure. (Based on Fitzner definitions 3a and 3d.)

Photographs:



9. Contour Scaling/Detachment: This condition combines the often interrelated contour scaling and detachment. Contour scaling is observed as the detachment of larger, platy stone elements parallel to the stone surface, either following the stone structure or independent of stone structure. Detachment is defined as exfoliation which occurs where the leaves of a foliate stone are weathered into layers which detach from the sound stone substrate and delamination which occurs in laminar stones when layers separate from one another and/or the sound stone substrate. (Based on the Fitzner definitions 3e and 3f.)

Photographs:

CATEGORY 4: Other

10. Condition Unique: Examples of unique conditions include missing screens on basement windows, evidence of a feature from a historic photo, or an unusual inclusion.

Photographs:

CRITICAL PROPERTY SURVEY – OHIO HOUSE

ID: ______________________________

Location Sketch:

Carving	Carving	
	Quarry Name	
	Quarry Location	
	Trade Name	

Literature	Composition	
	Geologic Formation	

Visual	Location	Distance from Ground		
		Proximity to Open Joints		
		Exposure Deicing Salt		
		Degree Protection		
		Exposure Roof Run-off		
	Environmental	Summer	Sun	
			Wind	
			Rain	
		Winter	Sun	
			Wind	
			Rain	
	Installation			
	Surface Finish			
	Relief			
	Texture			
	Color			

Field Testing	Water Absorption	
	Hardness	
	Carbonate ID	

C1: PREVIOUS LOSS
WEST EVELATION

OHIO HOUSE, CONDITION DRAWINGS
FAIRMOUNT PARK, PHILADELPHIA, PA

Elizabeth H. Seyfert
April, 2006

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PREVIOUS LOSS LEGEND
1 - Very Mild Loss
2 - Mild Loss
3 - Medium Loss
4 - Severe Loss
5 - Very Severe Loss
6 - Emergency Loss
OHIO HOUSE, CONDITION DRAWINGS
FAIRMOUNT PARK, PHILADELPHIA, PA
C2: PREVIOUS LOSS
SOUTH EVELATION
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PREVIOUS LOSS LEGEND

- 1 - Very Mild Loss
- 2 - Mild Loss
- 3 - Medium Loss
- 4 - Severe Loss
- 5 - Very Severe Loss
- 6 - Emergency Loss

OHIO HOUSE, CONDITION DRAWINGS
FAIRMOUNT PARK, PHILADELPHIA, PA

C3: PREVIOUS LOSS
EAST EVELATION

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OHIO HOUSE, CONDITION DRAWINGS

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C4: DEPOSIT
WEST EVELATION

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OHIO HOUSE, CONDITION DRAWINGS
FAIRMOUNT PARK, PHILADELPHIA, PA

C5: DEPOSIT
SOUTH EVELATION

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OHIO HOUSE, CONDITION DRAWINGS

FAIRMOUNT PARK, PHILADELPHIA, PA

C6: DEPOSIT
EAST EVELATION

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OHIO HOUSE, CONDITION DRAWINGS

FAIRMOUNT PARK, PHILADELPHIA, PA

C7: ACTIVE LOSS
WEST EVELATION

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C8: ACTIVE LOSS
SOUTH EVELATION

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OHIO HOUSE, CONDITION DRAWINGS

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OHIO HOUSE, CONDITION DRAWINGS
FAIRMOUNT PARK, PHILADELPHIA, PA

C9: ACTIVE LOSS
EAST EVELATION

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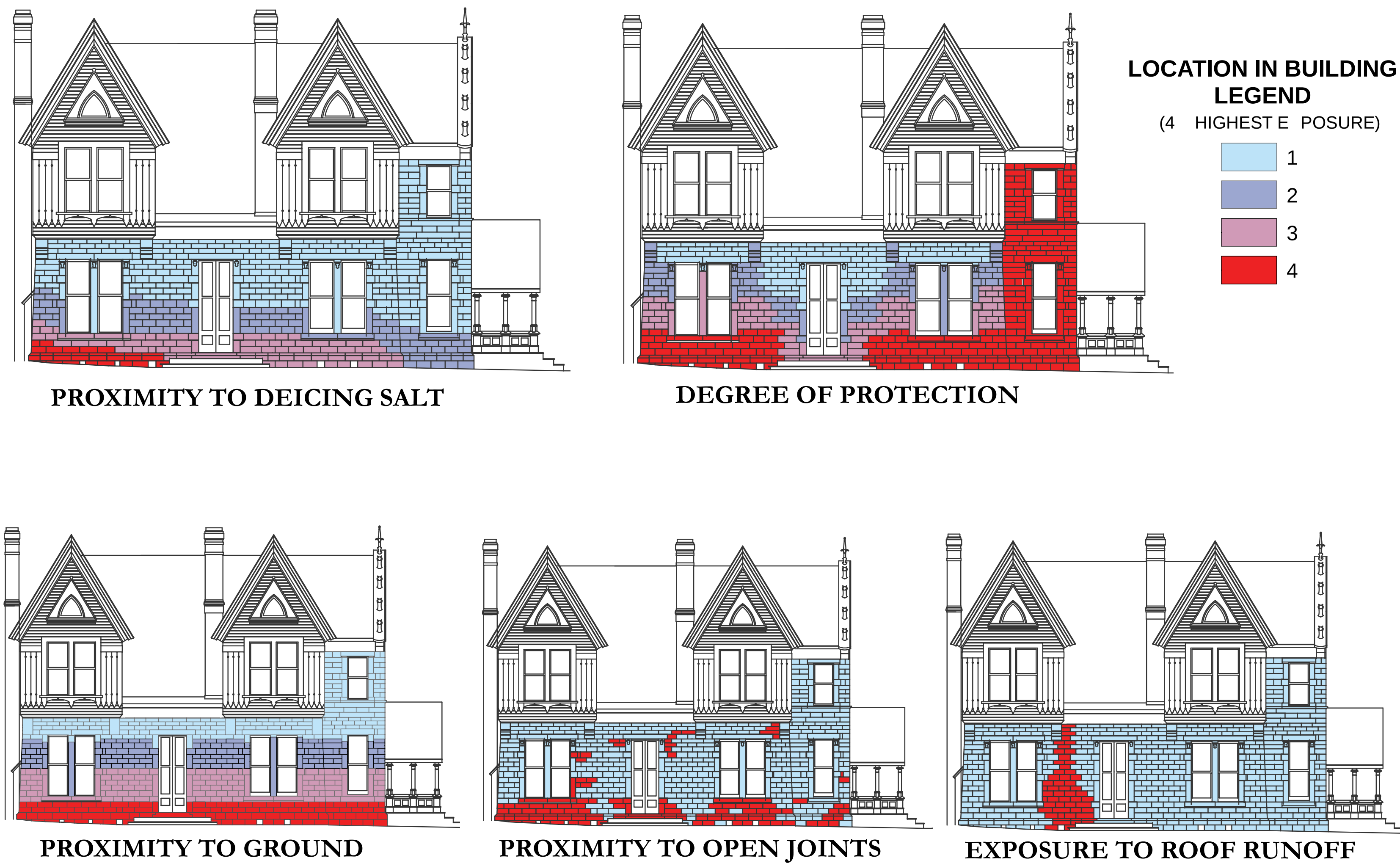

OHIO HOUSE, FACTOR DRAWINGS

FAIRMOUNT PARK, PHILADELPHIA, PA

D1: LOCATION IN BUILDING WEST EVELATION

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April, 2006

WINTER WIND

WINTER SUN

ENVIRONMENT LEGEND
(4   HIGHEST E   POSURE)

1
2
3
4

SUMMER WIND

SUMMER SUN

RAIN (SUMMER AND WINTER)

D2: ENVIRONMENT
WEST EVELATION

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OHIO HOUSE, FACTOR DRAWINGS
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D3: SURFACE FINISH
WEST ELEVATION

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D4: COMPOSITION
WEST ELEVATION

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OHIO HOUSE, FACTOR DRAWINGS
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D5: WATER ABSORPTION WEST ELEVATION

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