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To paint or not to paint: a difficult decision

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ABSTRACT: Controversy over proposed repainting of a portion of the former US Patent Office Building in Washington, DC, stimulated technical and ethical questions about painting stone. The oldest part of the building was constructed with tan-colored Aquia Creek sandstone facing, and its surface was painted white only when the next section of the building was faced with marble. The paint had deteriorated over the years, and its last remnants were removed in 1968 when the building was renovated to become the dual seat of the Smithsonian Institution's National Collection of Fine Arts and National Portrait Gallery. As part of further rehabilitation in 2000, the consulting architects proposed painting the sandstone again, but after considerable discussion it has been decided not to repaint for the moment. Issues to be considered in making such an important decision are discussed.

1 INTRODUCTION

At least as early as antiquity humankind has applied coatings to building stone with the stated intention of minimizing deterioration. Pliny, for example, noted that pitch was being used to protect stone in Carthage as a substitute for lime render because the only available stone in Carthage was poor-quality African tuff that was adversely affected by lime (VII, 166). In some places the custom of protectively painting architectural stone surfaces has survived to the present day. The volcanic tuff of the Church in Quatro Ribeiras on Terceira Island in the Azores, Portugal, for example, was recently painted to protect it from deterioration, in keeping with local tradition. In most cases, however, the primary reason that paint has been applied to stone has probably been esthetic: to unify buildings constructed of different masonry materials, to give inexpensive masonry the appearance of more precious stone, to portray figures naturalistically or make them more readable, etc.

Variations in customs regarding the painting of stonework throughout history and in different parts of the world have depended to some extent on the quality of available stone and economic issues. In northern Europe, Romanesque and Gothic sculpture mainly made of limestone and sandstone were fully painted. "Complete polychromy applied to monumental stone sculptures in the Middle Ages (but not in all parts of Europe) had only an esthetic, ideological purpose, even though it did also provide protection" (Rossi-Manaresi 1993, 156). In central Italy, by contrast, excellent sources of stone such as Carrara marble meant that if medieval sculpture was decorated at all, it was with sparingly applied paint or gilding. In the Renaissance and Baroque periods stone window sills and surrounds as well as door frames were often painted to complement the color of adjacent rendered exterior surfaces in German-speaking countries (Pfister 1963), and a protective function of paint seems to have been recognized (De Clerq 1994, Kreisel 1963). In America paint was expensive in the 17th and 18th centuries, and few buildings were painted; but by the 19th century it was typical for side and rear walls made of poor-quality inexpensive common brick to be painted to match facades of costly pressed brick (Hawkes 1983, 190 and 205). Painting the first section of the US Patent Office Building in Washington, DC (Figs 1 and 2) was said to have been done for both esthetic and protective reasons, but the primary impetus must have been esthetic given that it was done only when the next section was constructed of a differently colored stone.

This paper explores the issue of whether paint should be reapplied to stone once it has been lost or removed, using the example of the Patent Office Building. It will take into account what is known about the protective qualities of paint as well as the ethics of reapplication.

Figure 1. The former US Patent Office Building, Washington, DC, from the southeast (March 2000). The original Aquia Creek sandstone wing is on the left, and a later Texas marble wing, on the right.

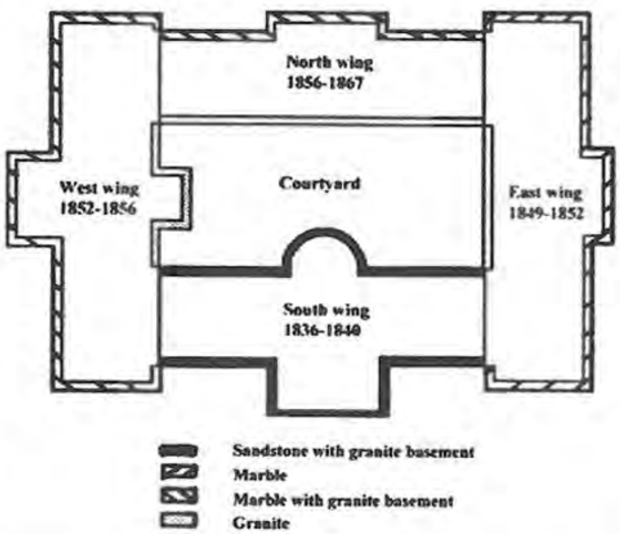

Figure 2. Plan of the US Patent Office Building showing stone facing materials and dates of construction.

2 HISTORICAL BACKGROUND

When George Washington, the first President of the United States (1789–1797), began planning the new capital, he envisioned a city of more grandeur than any other in the country. The US Congress mandated masonry construction for its most important buildings. Durable architecture was symbolically equated with a durable nation (Evelyn 1989, 13), and masonry was considered especially desirable to minimize damage from fire, since conflagrations had repeatedly destroyed buildings in the new capital (Evelyn 1997, 34). These demands for grandeur and durability, however, invariably required compromises because of the meager resources available for construction. Brick was plentiful and the least expensive masonry option, but stone facing was thought to be suitable for key buildings. Aquia Creek sandstone was mandated for facing the earliest governmental structures, including the President's House (begun 1792) and the US Capitol (begun 1793). Its use for the first section of the Patent Office Building (begun 1836) reflects the building's status as one of the most prominent of the second generation of federal buildings. Erected on a site originally intended for a pantheon of American heroes, it was known as a "Temple of Invention", displaying patent models that expressed the country's highest aspirations and values (Evelyn 1989, 113).

Figure 3. Original Aquia Creek sandstone repair (dutchman) at the center of the photograph, indicated by an arrow.

Aquia Creek sandstone was used for these buildings because it was the least expensive stone available. Government Island, located where Aquia Creek enters the Potomac River about 40 miles downstream from the capital, was purchased in 1792, and quarries on the island enabled the eponymous sandstone to be inexpensively transported by river before construction of railroads. It is a lower Cretaceous rock composed of quartz sand, pebbles, and pockets of clay, cemented by silica (USGS 1975, 9). Considerable variation – ranging from very poor to top quality – and unpredictability contributed to its rejection for later construction. Aquia Creek columns, removed from the east portico of the US Capitol in 1958 when the building was enlarged and re-erected at the National Arboretum in 1988 in the form of a Greek temple, show typical problems of poor-quality stone. Surfaces are disfigured by iron staining, pebble inclusions, scaling, and holes where pockets of clay have washed out. The Patent Office Building variety, however, was apparently top quality: fine-grained, even in color, and apparently repaired with well-crafted "dutchmen" (pieced-in portions of stones) where defects were found during construction (Fig. 3).

There are no records indicating that any of these three early Aquia Creek sandstone buildings in Washington was meant to be painted prior to construction, and in each case some time elapsed before painting occurred. In 1797, only 5 years after construction had begun, the President's House was white-washed to seal the stone and make it more uniform in color, eventually leading to its appellation the "White House" (McDaniel 1983, 39; Nelson 1992, 25). After the British set fire to it in 1814, the stone was painted with a white lead and linseed oil paint, perhaps to cover the soot marks around the windows that were still visible when all paint was removed in the 1980s prior to repainting. Exterior sandstone of the Capitol was not painted until 1818, 25 years after construction had begun. Although the building was also burned by the British, no evidence of fire damage has been found, and records suggest instead that the stone was painted to protect it from weathering (Allen 2000). In 1851, during construction of the first marble extension to the Patent Office Building and 15 years after construction of the building had begun, the sandstone section was painted both to protect it from exposure to weather and to unify the building (Mills 1844). The white marble that the paint imitated may also have been a symbolical reference to republics of antiquity. No records have been found to this effect until the mid-19th century, however, when marble was reported "more suitable for a monument" than granite (Evelyn 1997, 344 and 378). Nevertheless, Aquia Creek sandstone was not invariably painted, especially when it was indoors. One of the finest features of the US Capitol are considered to be Benjamin Latrobe's unpainted corncob-decorated columns made of the stone. One of a series of architects for the building wrote that the stone is "of very excellent quality" although not without limitations (1805).

Use of granite for important federal buildings was rejected in the 1830s because it was more expensive than Aquia Creek sandstone and by 1850 because it was considered less monumental than marble (Evelyn 1997, 344). The supervising architect for construction of the Patent Office Building, Robert Mills, had unsuccessfully argued in favor of using granite for the first section of the building (Mills 1836, 1837). For extension of the building (1849–1852), he emphasized the need for a stone of higher strength than sandstone (Mills 1849), maintaining that he could economize by making thinner walls. Results of crushing strength tests ordered in 1849 to determine the strongest material for the building's extension showed Aquia Creek sandstone samples to have relatively low and erratic compressive strength compared to samples of other materials (Johnson 1851, 7). In fact, modern engineering has shown that crushing strength is largely irrelevant because compressive strength of any stone is sufficient in most building applications (Mark 1990, 26–27). Stones of higher compressive strength, moreover, would not have permitted thinner construction (Mark 2000).

In any case, Congress chose Texas (Maryland) marble after being convinced not to use Aquia Creek sandstone by Mills' compilation of data showing high maintenance expenses for painting and repairing government buildings that had been made of it (Scott 2000). In 1839 Westchester (New York) marble was used for the US Post Office across the street from the Patent Office Building, and in 1851 Lee (Massachusetts) marble for extensions of the Capitol. Even before mid-century, however, white marble was not the only possibility. Red sandstone was used for the Smithsonian Institution Building (1846–1851), prominently placed on the Mall between the Capitol Building and the Washington Monument. Red brick and tan-colored terra cotta were used for the massive Pension Building (1882–1887).

Contemporary accounts show that application of paint was believed to enhance the Aquia Creek sandstone's durability for the White House, US Capitol, and Patent Office Building. Sodium sulfate crystallization tests, meant to predict the best stone to withstand freeze/thaw cycling, were done prior to construction of the Smithsonian Institution Building and showed poor results for Aquia Creek sandstone compared to those for granite and marble samples, including the Texas marble (Owen 1849, 117–119). Ironically, despite the superior results, the Texas marble used on the later wings of the Patent Office Building has weathered very poorly, and substantial quantities of its large white crystals are regularly swept from surfaces adjacent to the building's marble facades.

3 THE REPAINTING CONTROVERSY

The Patent Office Building is a monumental quadrangular building with a central courtyard (Fig. 2). It was constructed in four building campaigns: the original sandstone section plus three extensions, each corresponding to a side of the quadrangle. The architecture was a composite. Contemporary comparisons were made between its Doric facade and the Parthenon and between its quadrangular plan and the Louvre (Mills 1847, 68). The first section (1836–1840) was faced with the tan-colored Aquia Creek sandstone as mandated by Congress, although money was initially allocated only for construction in used brick (Fig. 4). The street elevations of all three extensions were faced with the white Texas marble and their rear elevations with Woodstock (Maryland) granite. The 1851 painting of the sandstone facade employed boiled linseed oil and white lead paint, matching the marble of the first extension (Fig. 5). A gray linseed oil paint was applied to the rear sandstone elevation, matching the granite of the new wing's rear elevation. Later owners renewed paint, but the building gradually fell into disrepair, and little paint remained when the building was renovated from 1964 to 1968. Paint remnants were removed from the

Figure 4. South Aquia Creek sandstone wing of the Patent Office Building by John Plumbe, around 1846 (courtesy, Library of Congress).

Figure 5. Patent Office Building from the southeast, around 1865. Painted Aquia Creek sandstone wing is at the left.

Figure 6. Detail of Aquia Creek sandstone cornice on original south wing.

sandstone by "hydro-silica blasting" (no records have been found of discussions about repainting at that time), and the stone has remained unpainted ever since. After the renovation, the building became the dual seat of the Smithsonian Institution's National Collection of Fine Arts (now the Smithsonian American Art Museum) and National Portrait Gallery. The entrance to the National Portrait Gallery was through the original sandstone portion of the building while that for the other museum was through the marble extension on the opposite side of the quadrangle, resulting in a clear physical distinction between the two museums for the visitor.

As part of a major rehabilitation of the museum building scheduled to begin in 2000, consulting architects proposed repainting the sandstone using silicate-based Keim paint (Hartman-Cox & Oehrlein 1997). They argued mainly that paint is responsible for the sandstone's excellent condition and that repainting would protect the stone. Moreover, they maintained that leaving the stone unpainted over the long term would prove to be the most expensive option since the stone would ultimately have to be replaced. The recommendation to paint proved far more controversial for a Smithsonian staff committee reviewing the plans than any other part of the extensive renovation. The committee, including the first author, voted unanimously not to paint the stone, and in late 1998 management decided not to do so. At the beginning of 2000, however, a new decision was made that there would be a single main entrance for both museums through the sandstone portion of the building and that space would be re-allocated so that two entities would be less distinct within the building, raising again the issue of unifying the building by painting the sandstone.

The Smithsonian staff committee objected to repainting the sandstone for a number of reasons. Employees have known no other appearance than bare sandstone, and they like it. They noted that the unchanged condition of the stone over the 30 years that has been uncovered indicates that it does not require paint for protection. Given the federal government's limited allocation of funds for building maintenance, amply demonstrated by the poor condition of the paint before the building's renovation in the 1960s, there was also well-founded concern about the likelihood of poor appearance when paint would begin to fail. Some questioned that there would be significant decrease in damage as a result of painting, especially if a subsequent decision to remove paint would subject the stone to aggressive removal techniques, such as those required for removal of Keim paint. Given these concerns, especially uncertainty about protection provided by paint, the most sensible option seemed to be not to paint the sandstone, with the possibility that it could always be done in the future.

There is consensus on all sides that the sandstone on the Patent Office Building is generally in excellent condition. This is attested by sharp arises that contrast markedly with those of marble portions of the building. Sandstone guttae, for example, appear hardly different from the day they were carved (Fig. 6), while marble guttae are often deteriorated to the point of being entirely lost (Fig. 7). Significant sandstone deterioration is found only just below the roof, especially adjacent to joints, and on the lowest sandstone course above a granite sill on the courtyard elevation, where delaminating stone has been repaired many times.

Although the renovation architects attribute the sandstone's good condition to the fact that it was painted for 70% of its life, the precise effect of white lead linseed oil paint on the sandstone has not been fully considered. In theory, the ashlar would have benefited from coating as paint prevented erosion by rainwater. In areas where water might have been trapped, however, the linseed oil paint probably contributed to deterioration because of its low vapor permeability. Water pooling on the near-horizontal, non-porous granite sill after rainstorms would have been entrapped inside the first course of

Figure 7. Detail of Texas (Maryland) marble cornice on the later west wing.

sandstone by the paint, at the very least exacerbating delamination. Poor maintenance of the roof, flashing, and mortar joints at the cornice probably permitted entry of water from above, while the paint prevented its escape, no doubt contributing to damage near the roof.

There is also general agreement that the sandstone ashlar has not visibly changed during its last 30 years of exposure. No change can be seen between areas shown in photographs taken in 1967 and the same areas today. The principal area of new damage since 1968 is just above the courtyard sill, where Portland cement mortar patching has continued to create a relatively impermeable layer and delamination of both patching and stone has continued.

Comparison to other buildings made of Aquia Creek sandstone is not very useful in measuring the precise role of paint in preventing deterioration. Variation in sandstone quality, reflected in the variability of compressive strengths, also likely results in variable weathering. Poor condition of unpainted Aquia Creek sandstone used for the Capitol gatehouses and gateposts built by Charles Bullfinch (about 1829) has been attributed to use of poor-quality stone (USGS 1975, 11). Other variables also make these structures a poor comparison. They have been moved to new locations in the city and were probably damaged by use of Portland cement mortar during re-erection. Moreover, at least one structure was flooded in the 1930s and 1940s (USGS 1975, 26). The Capitol Building and White House have been continuously painted, and the condition of the sandstone visible when paint has been removed in preparation for repainting is often cited as evidence of the protective benefits of painting. Nevertheless, during restoration of the west central front of the Capitol in the 1980s, 40% of the Aquia Creek sandstone was replaced, suggesting considerable deterioration despite the paint (Allen 1990, 33); by contrast, no stone replacement has been suggested for the Patent Office Building. At the Getty Conservation Institute recent analytical studies of samples from painted Capitol columns at the National Arboretum that were not re-erected have shown considerable surface enrichment with silica and a shift to smaller pore sizes near the surface below painted surfaces (McCarthy 2000).

4 LITERATURE REVIEW ON PAINTING STONE

The stone conservation literature provides little assistance in assessing the preservative benefits of painting. Major conservation scientists hold somewhat different opinions without citing specific examples that can be explored further. Torraca, an Italian chemist with many years' experience in the conservation of monuments throughout the world, is hardly sanguine, noting that "just as in the case of metals, coatings constitute a sacrificial protection which is progressively destroyed by the environment and must be renewed periodically; therefore the choice of coatings for the protection of stone must be associated with the establishment of a maintenance routine allowing to detect the incipient failure of the protective system and to plan a renew of the treatment. It must be recognized, however, that the protection of soft porous stones (tuffs, limestones, sandstones) poses serious problems which are not yet solved. A coating applied on such a stone hinders the direct penetration of rainwater but is easily by-passed by water which works its way into the stone pores by capillary rise from the soil, interstitial condensation of water vapor, faulty systems of rainwater disposal (roofs, gutters, etc.) or faulty hydraulic equipment, in inhabited buildings. When water is present on the back of a coating, the latter risks to become a liability rather than an advantage because it inhibits evaporation when the weather conditions are favourable" (Torraca 1988, 261).

More positive are conservation scientists Sasse and Snethlage, most likely based on experience with painted sandstone in Germany. They note that "paints render a certain protection on the stone against rain and air pollutants. However, the paint must not be damp-proof as severe damage may develop at the border between stone and paint (zone of maximum moisture). If, however, damp-proof paints such as oil paints are maintained thoroughly and regularly, and a crack-free film is provided, the protective effect can be very durable and the formation of damages can be avoided" (Sasse & Snethlage 1997, 239)

Lacking altogether scientific studies of the benefits of paint in actual use, the stone conservation literature has most often focused on laboratory testing of masonry paints, especially measurement of vapor permeability (Brandes & Stadlbauer 1992, Hern & Snethlage 1992, Jacob & Weiss 1989, Osswald & Snethlage 1996). An exception is a recent experiment in which sandstone samples coated with a thin silicate paint were placed with the painted face upwards in a wind tunnel while the lower surface was sitting in a salt solution (Franke & Reimann-Oenel 2000). After some days, salt was found to have deposited immediately below the paint layer. In contrast, salt was distributed throughout unpainted control samples, and cracks appeared. Thus, minor losses could be expected from efflorescing salts on painted samples, while significant delamination could be expected for uncoated samples.

One of the few stones described as being protected by paint in the literature is Gotland sandstone, a poor-quality building stone used in countries around the Baltic Sea. Seventeenth century polychromy on a building in Gdansk is said to have protected Gotland sandstone although how this was quantified is not specified (Angielska 1988). On the other hand, potentially adverse effects of linseed oil-based paint on the Royal Palace in Stockholm have been reported (Pühringer et al. 1992). Emphasis is placed on the contribution of the impervious paint to the formation of less porous silica-enriched surface stone, like that found on the Aquia Creek columns at the National Arboretum.

5 DISCUSSION

While entailing technical solutions, we should not forget that architectural conservation is mainly a cultural activity, and the key issue is preservation of the authenticity of the building. The Patent Office Building presents an interesting case. Local Aquia Creek sandstone was mandated for the first section of the building but 11 years later when the second part was constructed, marble had come into use for other federal buildings in the capital city – in keeping with the "Greek Revival" fashion and perhaps emblematic of ancient democracies – and the sandstone was painted white to match. Already in the midst of construction, an historical change of mind had occurred with regard to the appearance of the building, making its authentic state more difficult to establish. The issue is further complicated by the fact that the building has been unpainted for the last 20% of its life span, and many people prefer this appearance. Finally, one of the foremost historians of federal architecture in Washington, DC, has noted that the Patent Office Building's sandstone is "the only substantial architectural fragment left in the city where the color and texture of Aquia, Virginia, sandstone, mandated for law... is still visible" (Scott & Lee 1993, 190). As "an historical remnant" she would prefer it remain unpainted (Scott 2000).

The status of the Patent Office Building as an historic monument is important with respect to ethical consideration of repainting. The building is on the US' National Register of Historic Places and was designated a National Historic Landmark in 1966, indicating its national importance. If these designations can be interpreted to mean that the building is an historic monument, then principles outlined in the Venice Charter should apply, including that the "aim (of restoration) is to preserve and reveal the esthetic and historic value of the monument and is based on respect for original material and authentic documents" (1964, article 9). The "original material" is not as clear as in other instances, but contrasting tan and white surfaces were never intended by the original architects and in fact did not exist until recent times. From this point of view, it could be argued that the sandstone should be painted as it was when the building was complete.

Projects in opposition to principles of the Venice Charter have been justified on the grounds of "vox populi," although the results may no longer be considered historical monuments. Examples are the complete reconstruction of the San Marco campanile in Venice that occurred after it fell down in 1902 and the massive restoration of the Fenice Theatre following a fire in recent years (Burman 1997). The case of the Frauenkirche in Dresden is more complex because there has been a diametric change over time. Bombed at the end of the Second World War, its ruins had been left as a memorial against war. In the wake of German reunification 50 years later, however, the church has recently been reconstructed. In these three instances, there was public consensus about rebuilding, and destruction of the original structures was nearly complete. By contrast, there has been controversy rather than consensus about painting the Patent Office Building, and painting a building that has remained essentially intact is a far more limited act.

From a technical point of view, it has not been established to date how efficient paint is in protecting stone, although it is believed that paint should provide a sacrificial layer or protective skin to a stone building. In the case of the Patent Office Building, the original oil-based paint may have left the stone water-repellent even after the removal of paint residues. The proposed Keim paint is chemically compatible with stone and would leave it open to movement of water vapor. Its main drawback is that harsh methods are required for removal, should that ever be desired or necessary. Although easier to remove, other types of paints would not be as durable, such as silicone or acrylic emulsions. Regardless of the quality and potential durability of paint, however, establishment of a regular, long-term maintenance program would be more important than if the stones were left unpainted.

6 CONCLUSION

This paper has attempted to articulate theoretical and technical conservation issues raised by controversy over proposed painting of sandstone on the former Patent Office Building. From a theoretical standpoint it could be argued that if the building is considered an historic monument, then the principles of the Venice Charter should be applied, and the building should be painted to preserve its historical value and authenticity.

From a technical standpoint, further scientific work is required to establish that paint provides a sacrificial layer or protective skin for stone, but it is expected that paint would decrease the sandstone's overall rate of deterioration to some extent. Painted stone, however, requires more intense maintenance than if left unpainted. Otherwise, localized damage is likely to be greater, particularly where water ingress has been a problem in the past.

REFERENCES

Allen, W.C. 1990. *The United States capitol: a brief architectural history*. Washington, DC: US Government Printing Office.

Angielska, A.D. 1988. The effect of the presence of the original polychromy on a state of preservation of the Portal in the Tenement-House, Piwna 1, Gdansk. In J. Ciabach (ed.), *Proceedings of the 6th international congress on deterioration and conservation of stone: 175–186, Torun*, Poland: Nicholas Copernicus University.

Brandes, C. & Stadlbauer, E. 1992. Capillary water absorption of painted stone. In J. Delgado Rodrigues et al. (eds), *Proceedings of the 7th international congress on deterioration and conservation of stone: 591–600, Lisbon*, Portugal: Laboratório Nacional de Engenharia Civil.

Burman, P.A.T.I. 1997. "Hallowed antiquity": ethical considerations in the selection of conservation treatments. In N.S. Baer & R. Snethlage (eds), *Saving our architectural heritage*: 269–290. Chichester: John Wiley & Sons.

De Clerq, L. 1994. Tendenzen in de schildering van gebouwen in Vlaanderen van de middeleeuwen tot de negentiende eeuw. Paper presented at the Nederland-Vlanaderen WTA Meeting on Building Renovation and Monument Conservation (Bouwrenovatie en Monumentenzorg) *Kleur bekennen: Historische en moderne verfsystemen in de monumentenzorg*, Ghent.

Evelyn, D.E. 1997. *A public building for a new democracy: the Patent Office Building in the nineteenth century*. Ph.D. dissertation, Columbian School of Arts and Sciences, George Washington University, Washington, DC.

Evelyn, D.E. 1989. The Washington years: the U.S. Patent Office. In J.M. Bryan (ed.), *Robert Mills*: 107–140. Washington, DC: The American Institute of Architects Press.

Franke, L. & Reimann-Oenel, R. 2000. Beobachtungen zum Stofftransport und zu einhergehenden Schädigungseffekten in porösen Baustoffen, *International Journal for Restoration of Buildings and Monuments* 6(4): 451–462.

Hartman-Cox Architects & Oehrlein & Associates Architects. 1997. Patent Office Building exterior stone repair study. OPP Project No. 923420. Washington, DC: Smithsonian Institution.

Hawkes, P.W. 1983. Economical painting: the tools and techniques used in exterior painting in the 19th Century. In H.W. Jandl (ed.), *The technology of historic American buildings: studies of the materials, craft processes, and the mechanization of building construction*: 189–220. Washington, DC: Foundation for Preservation Technology.

Hern, C. & Snethlage, R. 1992. Water vapour permeability of painted stone. In J.D. Rodrigues et al. (eds), *Proceedings of the 7th international congress on deterioration and conservation of stone: 677–686, Lisbon*, Portugal: Laboratório Nacional de Engenharia Civil.

Jacob, J. & Weiss, N.R. 1989. Laboratory measurement of water vapor transmission rates of masonry mortars and paints. *APT Bulletin* 21: 62–70.

Johnson, W.R. 1851. Comparison of experiments on American and foreign building stones to determine their relative strength and durability. *The American Journal of Science and Arts* 11: 1–15.

Kier, H. 1980. Wie bunt waren die Kölner Fassaden der Gründerzeit? In *Von Farbe und Farben*: 171–173. Zurich: Manese Verlag.

Kreisel, H. 1963. Die Farbgebund des Äusseren alter Bauwerken. *Deutsche Kunst und Denkmalpflege*: 111–136. München: Deutscher Kunstverlag.

Latrobe, B.H. 1805. Letter to the President of the United States, December 22. In *Documentary history of the construction and development of the United States capitol building and grounds*, 1904, 115. Washington, DC: US Government Printing Office.

Mark, R. 1990. *Light, wind, and structure*. Cambridge, MA: MIT Press.

Mark, R. 2000. Private communication, March 15.

McCarthy, B. 2000. Private communication, March.

McDaniel, J.I. 1983. Stone walls preserved, White House history. *Journal of the White House Historical Association* 1: 39–45.

Mills, R. 1836. Letter to President Andrew Jackson, August 3.

Mills, R. 1837. Letter to President Martin Van Buren, March 27.

Mills, R. 1844. Letter to the Honorable Thomas Ewing, Secretary of the Interior, May 6.

Mills, R. 1847. *Guide to the capitol and national executive offices of the United States*. Washington, DC: W. Greer, printer.

Mills, R. 1849. Letter to Thomas Ewing, May 26.

Nelson, L.H. 1992. *White House stone carving: builders and restorers*. Washington, DC: US Department of Interior.

Osswald, J. & Snethlage, R. 1996. The hardening process in silicate paints. In J. Riederer (ed.), *Proceedings of the 8th international congress on deterioration and conservation of stone*: 1265–1275. Berlin: Möller Druck und Verlag.

Owen, R.D. 1849. *Hints on public architecture, containing, among other illustrations, views and plans of the Smithsonian institution*. New York: G.P. Putnam.

Pfister, R. 1963. Die Farbe in der Architektur. In Deutsche Kunst und Denkmalpflege: 137–142. München: Deutscher Kunstverlag.

Pliny. *Natural History*.

Pühringer, J., Makes, F. & Weber, J. 1992. Deterioration of Gotland sandstone at the Royal Palace, Stockholm. In J. Delgado Rodrigues et al. (eds), *Proceedings of the 7th international congress on deterioration and conservation of stone: 687–695, Lisbon*, Portugal: Laboratório Nacional de Engenharia Civil.

Rossi-Manaresi, R. 1993. Stone protection from antiquity to the beginning of the industrial revolution. *Science and Technology for Cultural Heritage* 2: 149–159.

Sasse, H.R. & Snethlage, R. 1997. Methods for the evaluation of stone conservation treatments. In N.S. Baer & R. Snethlage (eds), *Saving our architectural heritage*: 223–243. Chichester: John Wiley & Sons.

Scott, P.J. Private communication, March 14, 2000.

Scott, P. & Lee, A.J. 1993. *Buildings of the District of Columbia*. New York: Oxford University Press.

Torraca, G. 1988. General philosophy of stone conservation. In L. Lazzarini & R. Pieper (eds), *The deterioration and conservation of stone. Notes from the international Venetian courses on stone restoration*: 243–270. Studies and Documents on the Cultural Heritage 16, UNESCO.

United States Geological Survey (USGS). 1975. Building stones of our nation's capital. Washington, DC: United States Geological Survey.

Venice Charter. International Charter for the Conservation and Restoration of Monuments and Sites. 1964. Website: http://www.icomos.org/docs/venice_charter.html