The Geological Society of America
Field Guide 40
2015

Building stones of the National Mall

Richard A. Livingston
Materials Science and Engineering Department, University of Maryland, College Park, Maryland 20742, USA

Carol A. Grissom
Smithsonian Museum Conservation Institute, 4210 Silver Hill Road, Suitland, Maryland 20746, USA

Emily M. Aloiz
John Milner Associates Preservation, 3200 Lee Highway, Arlington, Virginia 22207, USA

ABSTRACT

This guide accompanies a walking tour of sites where masonry was employed on or near the National Mall in Washington, D.C. It begins with an overview of the geological setting of the city and development of the Mall. Each federal monument or building on the tour is briefly described, followed by information about its exterior stonework. The focus is on masonry buildings of the Smithsonian Institution, which date from 1847 with the inception of construction for the Smithsonian Castle and continue up to completion of the National Museum of the American Indian in 2004. The building stones on the tour are representative of the development of the American dimension stone industry with respect to geology, quarrying techniques, and style over more than two centuries. Details are provided for locally quarried stones used for the earliest buildings in the capital, including *Aquia Creek sandstone* (U.S. Capitol and Patent Office Building), *Seneca Red sandstone* (Smithsonian Castle), Cockeysville Marble (Washington Monument), and Piedmont bedrock (lockkeeper's house). Following improvement in the transportation system, buildings and monuments were constructed with stones from other regions, including Shelburne Marble from Vermont, Salem Limestone from Indiana, Holston Limestone from Tennessee, *Kasota stone* from Minnesota, and a variety of granites from several states. Topics covered include geological origins, architectural design considerations, weathering problems, and conservation issues.

INTRODUCTION

Geological Setting

The District of Columbia is located at the Fall Line between the Piedmont Plateau and the Atlantic Coast Plain to the east. This siting is intentional. As president, George Washington was assigned the task of selecting a place for the district at an appropriate point somewhere on the Potomac River between the Anacostia River to the southeast and Conococheague Creek, 176 km to the northwest (Reps, 1967, p. 2). He chose a location at the head of navigation of the Potomac at Little Falls. In order to

Livingston, R.A., Grissom, C.A., and Aloiz, E.M., 2015, Building stones of the National Mall, *in* Brezinski, D.K., Halka, J.P., and Ortt, R.A., Jr., eds., Tripping from the Fall Line: Field Excursions for the GSA Annual Meeting, Baltimore, 2015: Geological Society of America Field Guide 40, p. 543–571, doi:10.1130/2015.0040(15). For permission to copy, contact editing@geosociety.org. © 2015 The Geological Society of America. All rights reserved.

incorporate as much of the shoreline of the Anacostia River as possible and the existing port of Alexandria in Virginia, however, it was necessary to rotate the mandated 16-km- (10-mile-) square district boundaries 45° from true north-south. Consequently, the Little Falls actually lie midway along the northwestern boundary. Thus, the northwestern region of the district is on Piedmont bedrock, including the preexisting town of Georgetown, while to the southeast, the Piedmont bedrock is covered with the Tertiary marine and fluvial sediment deposits of the Atlantic Coastal Plain (Fleming et al., 1994). Within the area chosen for the district, Quaternary alluvial deposits have been cut into a series of terraces. The designer of the city, Pierre L'Enfant, selected Jenkin's Hill on the Wicomico terrace as the site for the U.S. Capitol (Fig. 1). At the request of President Washington, L'Enfant sited the president's house (the White House) on the Burnes Farm knoll of the Talbot terrace (O'Connor, 1989a). The low land lying west of the Capitol and south of the White House eventually became the National Mall.

When the district was founded, this lowland area extended only from Jenkin's Hill west to the Potomac shoreline south of Burnes Farm knoll (see Fig. 1 for the shoreline). On the north side, it was bounded by the Tiber Creek, a tidal creek that flowed west from the foot of Jenkin's Hill. Another tidal creek, James Creek, flowed from Jenkins Hill south into the Anacostia River. The Tiber Creek vicinity was prone to flooding by both high water of the Potomac River basin and storm water surges from the Chesapeake estuary. Eventually, as a flood control and public health measure, the tidal area was filled in the 1880s with sediments dredged from the Potomac to give the present shoreline (Williams, 1977). The Tiber and James Creeks are now piped

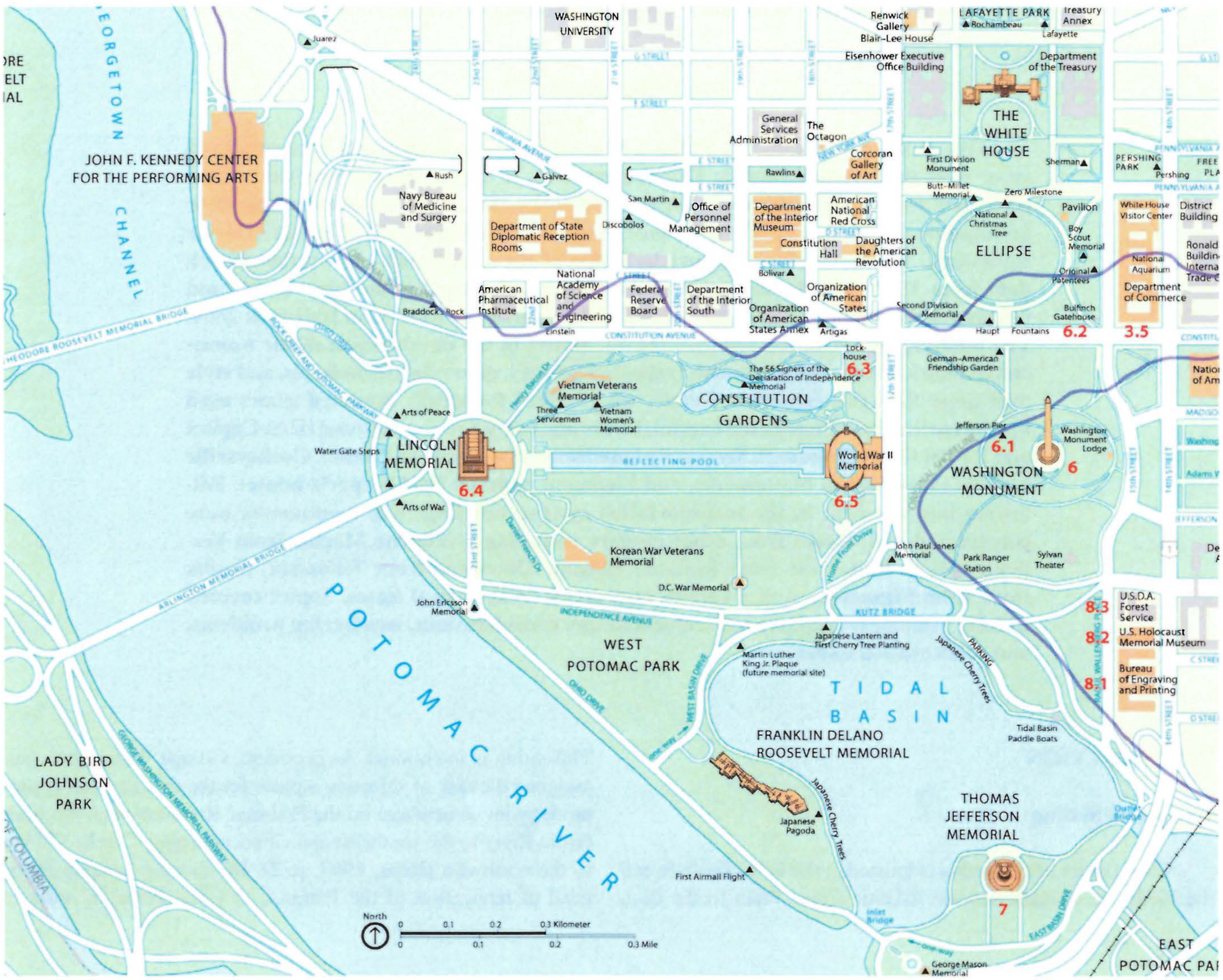


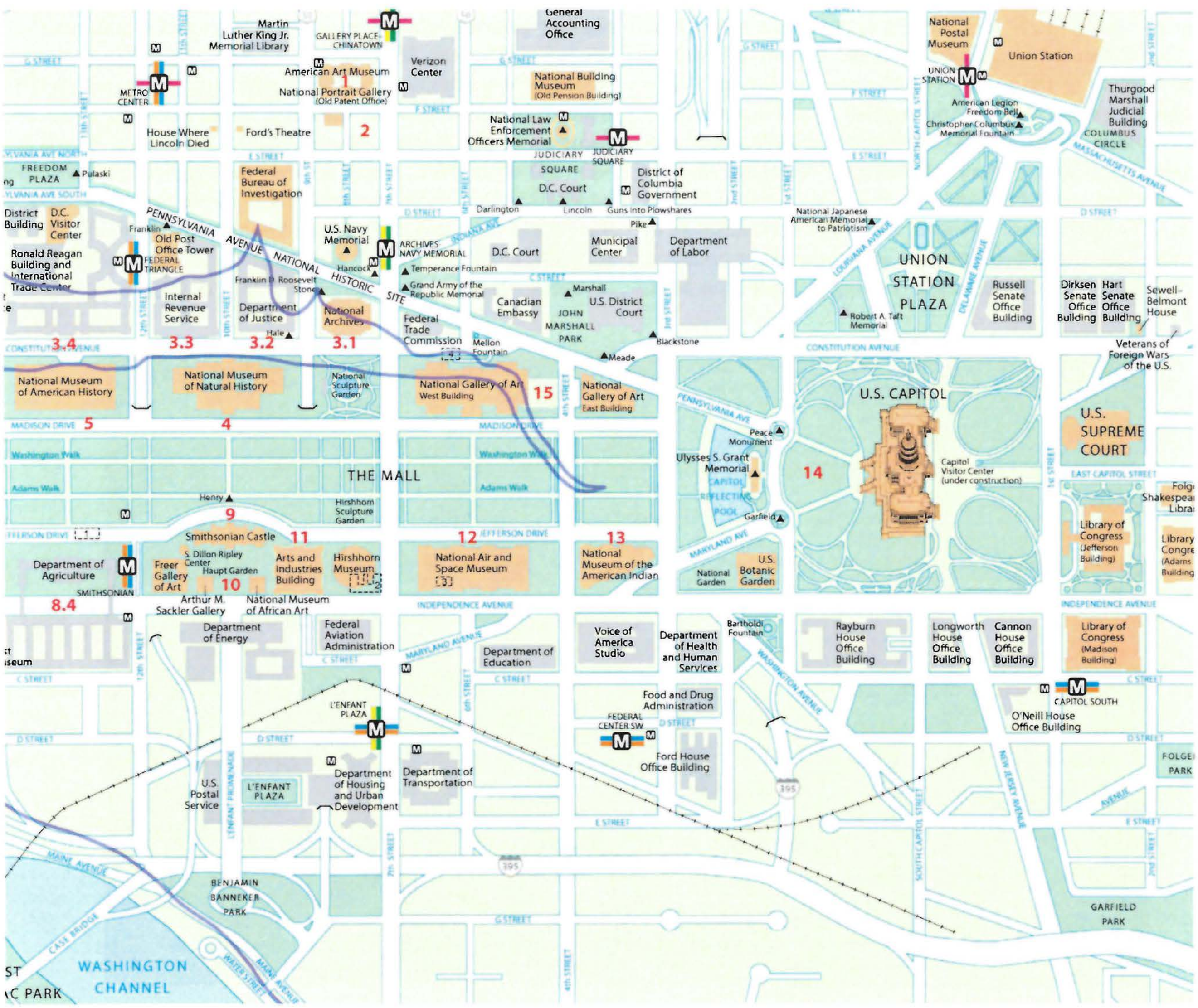
Figure 1 (*Continued on facing page*). Map of the Mall with tour stops indicated in red. The 1792 shoreline is indicated in purple. Courtesy National Park Service, base map; Don Alexander Hawkins, original shoreline; Peter R. Penczer, razed buildings (dotted outlines).

underground, but the high water table of the National Mall remains a problem for buildings located there, especially given the shortage of museum space that has led to increasing underground construction.

Development of the National Mall

The concept of the Mall has varied significantly over time, not only as a function of changing tastes in landscaping and architectural styles, but also in response to changing opinions about the role of such public spaces (Savage, 2009, p. 1–22). The first indication of the Mall appears on Pierre L'Enfant's plan of the federal city. In keeping with the formal French baroque style of urban planning that he favored, L'Enfant drew the Mall as an open vista reaching to the Potomac with an east-west axis passing through the Capitol and a north-south axis passing through the White House. At the intersection of these axes would be an equestrian statue of George Washington (Savage, 2009, p. 33–34). The Tiber Creek would be converted into a canal that would also serve the practical purpose of transporting goods between the Potomac River and a commercial port to be developed on the Anacostia River. The Mall would be lined with elegant mansions with gardens.

After L'Enfant's dismissal in 1792, little attention was paid to overall landscape planning of the Mall until this responsibility was assigned to the U.S. Army Corps of Engineers in 1870. Consequently, the Mall was left essentially vacant land except for a few developments commissioned piecemeal by Congress. A lottery was organized to develop the canal along the Tiber Creek, which was completed as the Washington City Canal in 1815.



The most notorious feature of the Mall was a slave market on its north side at 7th Street, which operated until 1850. Work was undertaken on a monument to Washington in 1848, but instead of L'Enfant's proposed equestrian statue, this eventually took the form of an obelisk, although not a monolith as are ancient Egyptian obelisks (see Stop 6 section). It was determined that the ground at the intersection of the two axes selected by L'Enfant was too weak to support the structure, and the site of the monument was moved east by 133 m and south by 37 m (Reps, 1967, p. 44). Its original intended location was marked by an Aquia Creek masonry pillar placed by Thomas Jefferson to establish a true local meridian; see Figure 2 (Bedini, 1999, p. 28–34; Waffe, 2001). However, this was subsequently lost, and the present stone marking L'Enfant's intersection was placed in 1889 (stop 6.1).

Perhaps the most important development on the Mall prior to the Civil War was the construction of the Smithsonian Institution Building (Smithsonian Castle) on its southern side (stop 9 and Fig. 2). The choice of this location rather than a more urban site next to the Patent Office (stop 1) was the outcome of a debate over the mission of the institution (Hafertepe, 1984, p. 1–21). Some people thought that the Smithsonian should function as a museum or library, while others envisioned it as a laboratory pursuing agricultural and horticultural research, requiring grounds for experimental work that would be available on the Mall. The research faction prevailed. However, in 1862, the Department of Agriculture was established and took over most of the botanical and agricultural research functions, creating experimental fields and greenhouses on the Mall (Penczer, 2007, p. 16, 88). Over time, the Smithsonian grew from a single building to a series of specialized museums located next to each other around the Mall. Along with the National Gallery of Art, which is not part of the Smithsonian Institution system, this growth made the Mall a unique museum district.

Following the Civil War, the District of Columbia had a territorial form of government for three years, which undertook a major program to improve the city's streets and sewage system. This included filling or covering over the Washington City Canal, which had become an open sewer, to form present-day Constitution Avenue on the north side of the Mall. The only remaining visible structure of the canal is the lockkeeper's house at 17th Street (Williams, 1977) (stop 6.3).

At the same time, Congress appropriated major funds for improvement of the Mall and assigned responsibility for this program to the Army Corps of Engineers. Improvements included planting trees and grass, laying out carriage paths, and installing gas lights (Penczer, 2007, p. 19, 21). One major Corps accomplishment was completion of the Washington Monument in 1884 (stop 6). Another was the dredging of the Potomac River and dumping of the dredged sediments to fill in the tidal flats at the west end of the Mall, which doubled the length of the Mall and added 628 acres of land by 1892. Also encroaching on the Mall in this period was the Baltimore and Potomac (B&P) Railroad passenger terminal (1873) at 6th Street and Constitution Avenue, with its tracks traversing the Mall (Reps, 1967, p. 66). At the east end

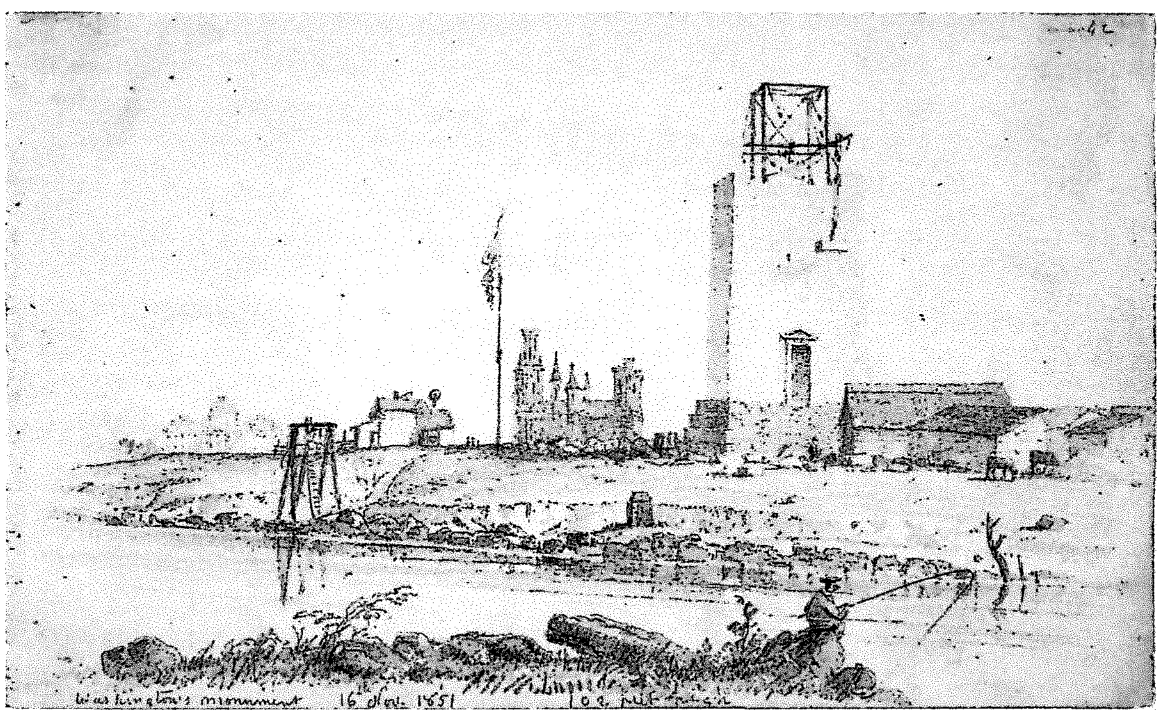


Figure 2. Seth Eastman, *Washington's Monument under Construction* (1851). In the center foreground is the Jefferson pier on the bank of the Tiber Creek; in the background, the U.S. Capitol at left and Smithsonian Castle, center. Photograph © 2015 Museum of Fine Arts, Boston. All rights reserved.

of the Mall, on the other hand, the Architect of the Capitol had responsibility for the Botanic Gardens, and at the west end, the Department of Agriculture maintained its experimental gardens and greenhouses until the 1930s.

At the turn of the twentieth century, a movement developed to redesign the Mall according to the principles of Beaux-Arts architecture, which had come to public attention through the hugely successful Columbian Exposition in Chicago in 1893 (Penczer, 2007, p. 20). The effort was led by prominent architects Daniel H. Burnham and Charles F. McKim, who made up the Senate Park Commission along with the landscape architect Frederick Law Olmsted Jr. (1870–1957) and eminent sculptor Augustus Saint-Gaudens. The commission was created by a resolution of the U.S. Senate sponsored by Senator James McMillan, and its recommendations, which were presented in January 1902, became known as the McMillan Plan.

The McMillan Plan revived L'Enfant's original concept of the Mall, but with a stricter interpretation of a long vista: a green lawn over 90 m wide between rows of identical trees (American elms). The east-west axis would be extended 1.6 km to the west beyond the Washington Monument, taking advantage of the newly made land. The western end would be anchored by the planned Lincoln Memorial (stop 6.4) and the eastern end by the Ulysses S. Grant Memorial (stop 14.3), thus giving the Mall a Civil War theme. Due to the southward offset of the Washington Monument, this axis deviates from a true east-west alignment by ~1.3°. Buildings added to the Mall since the McMillan Plan have followed this deviation. The plan also proposed a reflecting pool between the Lincoln Memorial and the Washington Monument.

The north-south axis would be anchored by the White House to the north and a monument, not yet defined in 1902, which would be located on the bank of the Tidal Basin to the south. Around this monument would be a complex of recreational facilities. Several alternatives for the monument were considered over time, but ultimately under the leadership of President Franklin Roosevelt, it was decided in 1934 to make it a memorial to Thomas Jefferson (Penczer, 2007, p. 118). The proposed recreational complex never materialized.

Although the McMillan Plan never achieved the force of law, it has been largely followed, first by the Army Corps of Engineers up until 1933 and after that by the National Park Service, which took over responsibility for the Mall. The Victorian trees, gardens, and buildings were removed, and the 6th Street railroad station was relocated to the Union Station site at Massachusetts Avenue and F Street, NE. The Smithsonian Institution had already added the National Museum (now the Arts and Industries Building) in 1879 (stop 11) and has continued to build museums around the Mall up to the present time. The National Museum of African American History and Culture, scheduled to open in 2016, is under construction at one of the last available building sites.

In order to prevent a haphazard proliferation of monuments and buildings in the district, including the Mall, Congress created the Commission of Fine Arts in 1910 as an expert panel to advise on the design and location of statues, fountains, and monuments. This advisory body was complemented by creation of the predecessor of the National Capital Planning Commission (NCPC) in 1924, with responsibility for developing a comprehensive master plan for federal property within the district. The NCPC has generally adhered to the McMillan Plan (Penczer, 2007, p. 32–37). In 2001, it proposed the Memorials and Museums Master Plan, which specified the "Reserve," a zone in which new memorial sites would be banned. As shown in Figure 3, this encompasses the Mall along with West Potomac Park (National Capital Planning Commission, 2014). In a second area (II), the memorials would be limited. The Master Plan became law in November 2003, when Congress passed amendments to the Commemorative Works Act (Penczer, 2007, p. 44–46).

The original Commemorative Works Act, passed in 1986, was in response to a changing public perception of the National Mall. Prior to the construction of the Vietnam Veterans Memorial, monuments had been dedicated mainly to individual heroic figures such as George Washington or Abraham Lincoln. The Vietnam Veterans Memorial, in contrast, emphasized the role of all Americans who gave their lives in that conflict by listing their names as the principal design element. This in turn led to public pressure to install monuments to the veterans of other wars. As a result, memorials to the veterans of the Korean War and World War II (stop 6.5) have been added to the Mall. These will be the last. A memorial to all World War I veterans is in the planning stage, but it will be located at Pershing Place on Pennsylvania Avenue.

Another change in the role of the Mall has been its emergence as a place for public gatherings in protest, or in support, of political or societal policies. This began with the concert by Marian Anderson on the steps of the Lincoln Memorial in 1939 in an implied protest against racial discrimination. It was followed there in 1963 by the even more famous "I Have a Dream" speech by Martin Luther King Jr. Marches and rallies for many other causes ranging from anti-Vietnam protests to demands for AIDS research have used the Mall as a stage. As Savage has pointed out, this represents a transformation from the former concept of a Victorian recreational park as public ground to a public space in the nation's consciousness (Savage, 2009, p. 147–175).

In addition to political demonstrations, many other events have taken place on the Mall, ranging from folk life festivals to musical concerts to presidential inaugurations. This has led to serious deterioration of the grounds. The National Park Service has recently developed a comprehensive plan to improve the appearance and health of soils, vegetation, and the overall landscape, as well as to improve water quality and storm water management (National Park Service, 2010). The current phase of this restoration, which began in October 2014 and is expected to last up to 18 months, covers the center of the Mall between 8th and 12th Streets. Already, the National Park Service has restricted use of restored areas of the Mall for events and is expected to continue to do so in future.

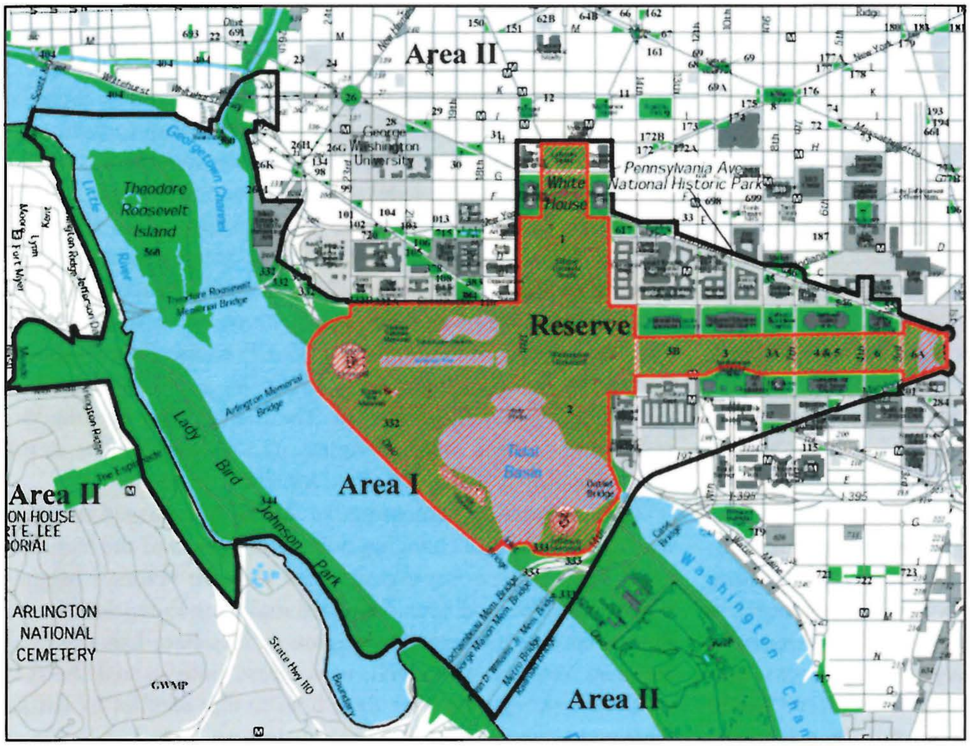


Figure 3. National Capital Planning Commission (NCPC) Memorials & Museums Master Plan showing the "Reserve" no-build zone (hatched area). Courtesy NCPC.

Local Stone Industry

The most important government buildings in the new nation's capital were mandated to be built of stone by the U.S. Congress, since durable architecture was equated with a durable nation (Evelyn, 1997, p. 13–14). Masonry was also considered desirable to minimize damage from fire, which had repeatedly destroyed buildings in the new capital. Given the impecunious republic and poor road transportation network, at first stone had to be obtained from local quarries near water transportation. *Aquia Creek sandstone* was readily moved to Washington by boat along the Potomac River, and the opening of the Chesapeake and Ohio (C&O) Canal as far as Seneca in 1831 made shipping *Seneca sandstone* to Washington commercially viable. As railroads developed in the 1830s, stone could be transported to Washington from further afield, first of all from Baltimore County where Cockeysville Marble was quarried. Eventually stone could be obtained from anywhere in the country, and occasionally it was imported, particularly statuary marble such as Carrara from Italy (stop 14.4).

Aquia Creek Sandstone (Virginia)

As early as 1757, sandstone was quarried near Aquia Creek, Virginia (McKee, 1973, p. 13). A quarry was acquired there by the U.S. Government to use in the construction of federal buildings, first of all for the U.S. Capitol (stop 14) and White House. The early nineteenth-century Architect of the Capitol Benjamin Latrobe described the cutting of horizontal and vertical channels at the quarry, which are seen in Figure 4 (Latrobe, 1809). The quarry's location on an island (now a Stafford County park), near where Aquia Creek enters the Potomac 64 km downstream, made transportation by water to the federal city relatively easy. For the Capitol, stone was transported to the Navy Yard on the Anacostia River and from there moved by sledge to the Capitol building (Arnebeck, 1991, p. 233). Two other prominent federal buildings for which this stone was used are the U.S. Treasury Building and Patent Office Building (stop 1). Bullfinch gatehouses and gateposts made of *Aquia Creek sandstone*, which originally stood on the Capitol grounds, are scattered along Constitution Avenue

Figure 4. *Aquia Creek sandstone* quarry, Stafford, Virginia. Note channels and pecking to define the vertical surface.

(stop 6.2) and elsewhere in the city. The sandstone was also used for more workaday purposes, e.g., to build bridges (Fig. 5) and line walls of the C&O Canal in Georgetown (Southworth et al., 2008, p. 23–25).

Aquia Creek sandstone is the informal name for sandstone of the Lower Cretaceous Potomac Formation. It is composed primarily of quartz and feldspar sands cemented by silica; quartz pebbles and pockets of clay are common. As a freestone, it was easily carved, and sufficient quantities of stone were available to cut 24 monolithic shafts nearly 8 m high for the east front of the U.S. Capitol. As Latrobe noted (1809), however, the stone is also variable and unpredictable in terms of durability. The *Aquia Creek sandstone* used for most federal buildings was painted white within five years of completion, in part as a preservation measure. It was abandoned for use around 1840 in favor of various types of white marble, which by then were more readily available because of the development of the railroads. For the U.S. General Post Office (stop 2), in 1839 Congress mandated granite or marble instead of the *Aquia Creek sandstone* (Evelyn, 1997, p. 166, n. 11).

Figure 6. Waste stone fills Bull Run Creek, where *Seneca sandstone* for the Smithsonian Castle was quarried. The C&O Canal runs over the culvert in the background. Courtesy James C. Douglas.

Seneca Sandstone (Maryland)

Seneca sandstone is an arkosic, micaceous sandstone found near where Seneca and Bull Run Creeks enter the Potomac River ~40 km northwest of Washington (Fig. 6). It has been quarried since 1774, but the opening of the C&O Canal to Seneca in 1831 made possible the operation of the quarries on a large-scale commercial basis. The stone was also used to line the canal's walls and locks along several reaches in Maryland (Southworth et al., 2008, p. 23–27). The first major use in the district was for the Smithsonian Castle (stop 9). The stone was popular in the Victorian period for churches as well as homes, but fell from fashion with the end of that era. Quarrying had mostly ceased by 1900 as good-quality stone became scarce, and the quarries were completely abandoned after severe flooding in 1924 (Peck, 2013, p. 114). Remains of the quarry, including the ruins of a stonecutting mill, can be visited in Seneca Creek State Park in Potomac, Maryland (Fig. 7).

The formal name for *Seneca sandstone* is the Poolesville Member of the Manassas Formation (Lee and Froelich, 1989). The Manassas Formation is in turn a member of the Newark Supergroup, a series of Triassic sandstone basins that reach from North Carolina to Massachusetts (Olsen, 1980). The Newark Basin in New Jersey, as well as quarries along the Connecticut River in Massachusetts, supplied much of the brownstone used in

Figure 5. Wisconsin Avenue Bridge over the C&O Canal, Georgetown, *Aquia Creek sandstone*.

Figure 7. Cutting building, *Seneca sandstone*, Seneca Creek State Park.

New York City buildings during the nineteenth century (Matero and Teutonico, 1982).

Micro X-ray diffraction (XRD) analyses of samples of *Seneca Sandstone* from the Smithsonian Castle showed that quartz, alkali feldspar, and muscovite predominate (Aloiz, 2013, p. 14–15). Instrumental neutron activation analysis (INAA) measured ~5% Fe_2O_3, which likely accounts for the characteristic red color. Trace amounts of manganese (0.05% MnO_2) may also affect the color. High levels of Mn (11%–22% MnO_2) have been found by laser ablation mass spectrometry in black surface deposits on the Castle stone (stop 9) (D. Macholdt, Max Planck Institute for Chemistry, 2015, personal commun.). The apparent porosity of the stone, derived from weight change after 24 h of immersion in water, was found to be moderately large, ~10%, which may encourage deterioration (Aloiz et al., 2012, p. 16).

Texas Marble (Maryland)

Texas marble is the informal name for coarse-grained calcitic Cockeysville Marble, which was quarried starting around 1814 in Baltimore County north of Baltimore by immigrant Irish masons near the small town of Texas, Maryland. Cockeysville Marble is in the Precambrian to Early Paleozoic Glenarm Group, which lies above the pelitic schist Wissahickon Formation and below the muscovite-microcline Setters Formation (Sanford, 1980). *Texas marble* was used by Robert Mills in the construction of the first Washington Monument in the nation, located in Baltimore (1815–1829). Completion of the Baltimore and Susquehanna (B&S) railway to Texas in 1834 made possible transport of the marble from the quarries to Baltimore and then to Washington (Wrabel, 2008), where the stone was used for the lowest third of the Washington Monument (stop 6) and on the three later wings of the Patent Office Building (stop 1). Bluegrass Materials operates an enormous gravel quarry at Texas today, which can be glimpsed from Interstate-83 northbound. Pits and ponds left by former quarries dot the area, but many have been filled in and paved over for big box stores in the heavily developed commercial area near the highway.

Texas marble is characterized by coarse grain sizes (Fig. 8). Thin sections made from cores taken from the Patent Office Building showed grains as large as 8 mm in their largest dimension, but grains more than twice that size were observed in situ on the building (Weiss et al., 1987, p. 19). In addition to calcite, smaller amounts of quartz and the trace accessory minerals pyrite and tremolite were found.

Cockeysville Marble (Maryland)

Cockeysville marble is an informal name used here to distinguish a fine-grained dolomitic Cockeysville Marble from coarse-grained pure calcitic *Texas marble. Cockeysville marble is* quarried only a few km from *Texas marble* in Baltimore County. Grains of the dolomitic *marble* are "seldom exceeding 1/16 of an inch in diameter, the component particles forming a loosely interlocking aggregate" (Merrill and Matthews, 1898, p. 177).

Cockeysville marble is often associated with a quarry that became known as Beaver Dam. The B&S railroad route reached Cockeysville by 1835 (Wrabel, 2008), and an 1839 report noted that a "quarry on the lands of Mr. Wm. Bosley has been worked for many years past by Messrs. Baker and Connolly" (Merrill and Matthews, 1898, p. 174). It was purchased by the Beaver Dam Marble Company in 1879 and provided stone for many important structures, such as the upper two-thirds of the Washington Monument (stop 6). On the monument, the stone appears slightly warmer and more even in color than the *Texas marble.* It was also on the U.S. Capitol (stop 14), for which huge blocks (nearly 8 m in length) were quarried for 108 columns on the west front (1859–1861) and for the Peabody Institute in Baltimore (1859–1860, 1875–1878). For a view of the quarry in operation, see Hannibal and Bolton (this volume, their figure 1). The last major contract for the quarry was awarded in 1929, but by 1940 the quarry had filled with water and was operated as a swim club (Purdum, 1940), still popular on hot summer days. A stone derrick has been modified for use as a swing for jumping into the water, and the nineteenth-century cutting plant stands across Beaver Dam Road, now an office building.

Potomac Bluestone and Kensington Gneiss

The Piedmont bedrock has been exploited for building stone at numerous quarries within the District of Columbia, including a stone outcropping known as Braddock's Rock, which was completely expended by early builders in the region (Penczer, 2007, p. 103). This bedrock has experienced a complex geological history involving both metamorphic and igneous processes, which is still not completely understood (Reed and Obermeister, 1989). One prominent building stone is known informally as *Potomac bluestone*, a metasedimentary unit of the Sykesville Formation, also found in nearby Virginia and Maryland; see Figures 9 and 10. A quarry at Little Falls on the Maryland shore supplied stone for foundations of the Washington Monument (stop 6). An associated stone known informally as *Kensington gneiss* is also nicknamed "*Salt and pepper stone*" because of the grains of dark biotite in a matrix of light-colored quartz and feldspar (Robertson, 1989). The formal name for this early Ordovician intrusive rock is Kensington Tonalite (Fleming et al., 1994). At one time there were as many as 22 quarries of this stone operating in the district (O'Connor, 1989b).

These stones were used for many homes and private buildings, notably the oldest house in Washington—the Old Stone House (1765) on M Street in Georgetown. For public buildings, they were mainly used for foundations, such as those of the White House, Capitol (stop 14), and Washington Monument (stop 6), or as backing stone, such as in the Washington Monument (stop 6) or Smithsonian Castle (stop 9). In the early twentieth century, they were used for buildings at the National Zoo, which were meant to evoke the American wilderness in keeping with Frederick Law Olmsted's plan for the landscape (Ewing and Ballard, 2009, p. 48). Their characteristic visual appearances can be seen on a gatepost at the National Zoo in Figures 9 and 10 and on the lockkeeper's house (stop 6.3).

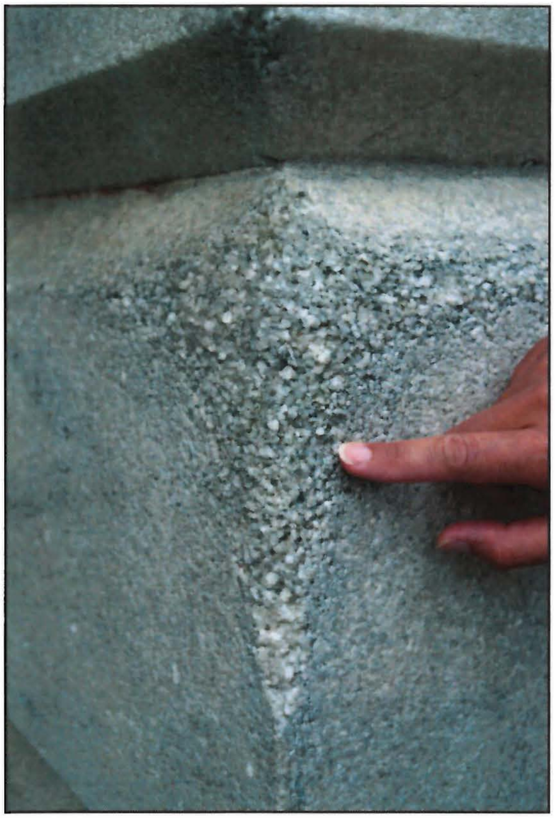


Figure 8. *Texas marble* corner, Patent Office Building. Erosion at grain boundaries shows the coarse texture of the stone.

Figure 9. Gatepost (91 cm wide), entrance to the National Zoo, made of local stones.

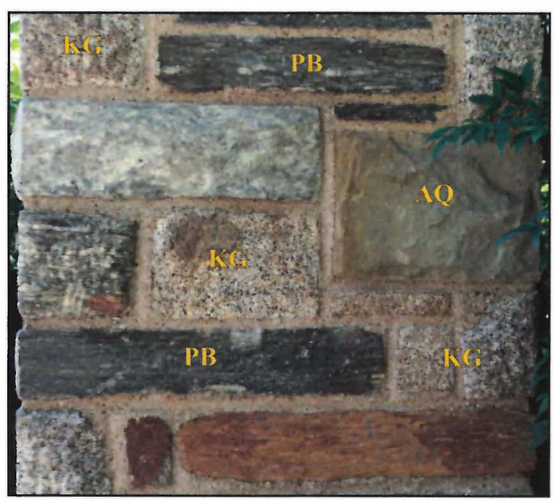


Figure 10. Examples of Piedmont bedrock on the east face of the zoo gatepost shown in Figure 9. *Key:* KG—*Kensington gneiss*; PB—*Potomac bluestone*; AQ—*Aquia Creek sandstone.*

STOPS

Table 1 lists tour stops and the principal stones at each stop, with both their informal and formal names. Informal names are italicized and generally used for the building stones in the text. Formal names are capitalized in Roman typeface and ages identified when the building stone is first introduced. Overall images are not included for every building or monument, since there are many excellent publications in which they can be found, such as Penczer (2007) and Ewing and Ballard (2009). Many images are also available online at the websites for the Smithsonian Institution (www.si.edu/) and National Park Service (www.nps.gov/nama/planyourvisit/directions.htm).

For simplicity, the names of the District of Columbia quadrants in which buildings and monuments are located on the National Mall have been omitted. Those on the north side of the Mall are in northwest Washington, and those on the south side are in southwest Washington.

Stop 1: U.S. Patent Office Building

The U.S. Patent Office Building (renamed the Donald W. Reynolds Center for American Art and Portraiture in 2006) is a

TABLE 1. BUILDING OR MONUMENT AT EACH TOUR STOP AND ITS STONE(S)

Stop	Building or monument	Building stone's formal geological name, state, and age	Informal name(s)	Description
1	U.S. Patent Office Building, 1836–1867	Original south wing: Sandstone of the Potomac Formation (VA), Lower Cretaceous	*Aquia Creek sandstone, Virginia freestone*	Tan sandstone with iron streaks
		Later wings: Cockeysville Marble (MD), near the base of the Glenarm Series, Late Proterozoic to Early Paleozoic	*Texas marble*	Coarse-grained marble
		Foundations: Woodstock Granite (MD), Ordovician	—	Medium-grained gray granite
2	U.S. General Post Office/Hotel Monaco, 1837–1866	Original south portion: Inwood Marble (NY), Late Cambrian to Early Ordovician	*Westchester marble, Tuckahoe marble, Kingsbridge marble*	Coarse-grained white dolomitic marble
		North addition: Cockeysville Marble (see stop 1)	*Cockeysville marble, Beaver Dam marble*	Fine-grained white dolomitic marble
3	Federal Triangle			
3.1	National Archives, 1935	Salem Limestone (IN), Late Mississippian	*Indiana limestone, Cathedral limestone, Bedford stone, Bedford oolitic limestone*	Buff, gray, or variegated buff-and-gray freestone; uniform, abundant, and durable
3.2	Department of Justice, 1931–1934			
3.3	Internal Revenue Service, 1928–1935			
3.4	EPA and Mellon Auditorium, 1935			
3.5	Department of Commerce, 1926–1932			
4	National Museum of Natural History, 1910	Ground floor: Milford Granite (MA), Late Proterozoic Precambrian	—	Pink granite
		2nd & 3rd floors: Bethel Granite (VT), Devonian	—	Bluish-white granite
		Top floor: Mount Airy Granite (NC), Devonian	—	White granite
5	National Museum of American History, 1964	Holston Limestone (TN), Holston Formation, Middle Ordovician	*Tennessee marble, Tennessee Pink marble*	Pink to white limestone, with prominent gray stylolites
6	Washington Monument, 1848–1884	Lowest third: Cockeysville Marble (see stop 1)	*Texas marble*	Coarse-grained marble
		Next four courses: Stockbridge Formation (MA), Early Ordovician	*Sheffield marble*	White dolomitic marble, with red areas
		Upper two thirds: Cockeysville Marble (see stop 2)	*Cockeysville marble*	Fine-grained white dolomitic marble
6.1	Jefferson stone, 1889	Petersburg Granite (VA), Precambrian	*Richmond granite*	Gray granite
6.2	Bullfinch Gatehouse and Gatepost, 1829	Sandstone of the Potomac Formation (see stop 1)		
6.3	Lockkeeper's House, 1835	Piedmont Bedrock (DC, MD, and VA), Late Proterozoic and/or Early Cambrian	*Potomac bluestone*	Blue schistose stone
			Potomac gneiss, Kensington gneiss, Salt-and-pepper stone	Stone of white quartz and feldspar matrix and black specks of biotite
6.4	Lincoln Memorial, 1913–1922	Leadville Limestone (CO), Mississippian	*Yule marble* or *Colorado Yule marble*	Pure-white marble
6.5	World War II Memorial, 2004	Kershaw Granite (SC), Carboniferous to Permian	—	Gray granite
7	Jefferson Memorial, 1939–1943	Shelburne Marble (VT), Ordovician	*Imperial Vermont marble* variety, *Danby*	Mostly white with tan traces
8	Wallenberg Place to Department of Agriculture			
8.1	Bureau of Printing & Engraving, 1914	Salem Limestone (see stop 3)		
8.2	U.S. Holocaust Memorial Museum, 1993	Salem Limestone (see stop 3)		
8.3	Sidney Yates Federal Building, 1880	Trim	*Sandstone (unidentified)*	Dark-red sandstone

(*Continued*)

TABLE 1. BUILDING OR MONUMENT AT EACH TOUR STOP AND ITS STONE(S) (*Continued*)

Stop	Building or monument	Building stone's formal geological name, state, and age	Informal name(s)	Description
8.4	Department of Agriculture, 1908–late 1920s	Wings: Shelburne Marble (see stop 7)		
		Center section: Murphy Marble (GA), Cambrian	*Georgia White Cherokee marble*	Coarse-grained white marble
9	Smithsonian Castle, 1847–1855	Poolesville Member of the Manassas Sandstone (MD), Upper Triassic; Member of the Newark Supergroup	*Seneca Red sandstone, Seneca sandstone*	Reddish-brown sandstone (lilac gray when quarried)
10	Quadrangle, 1987			
10.1	Freer Gallery of Art, 1917–1923	Stony Creek Granite (CT), Late Proterozoic	—	Gray granite
	Arthur M. Sackler Gallery, 1987	Rockville Granite of Stearns Granitic Complex (MN), Early Proterozoic	*Rockville White granite*	Gray granite
10.2	Enid A. Haupt Garden and Gateposts, 1987	Poolesville Member of the Manassas Formation (see stop 9)		
10.3	National Museum of African Art, 1987	Town Mountain Granite (TX), Precambrian	*Sunset Red granite*	Pink granite
11	Arts & Industries building, 1879–1881	Trim: Euclid Member, Bedford Shale (OH), Upper Devonian	*Euclid bluestone*	Blue-gray fine-grained sandstone, often with iron stains from pyrite
		Repair stone: Buena Vista Sandstone, Cuyahoga Formation (OH), Mississippian	*Waller stone, Scioto sandstone*	Gray sandstone, with fossil trails
12	National Air and Space Museum, 1976	Holston Limestone (see stop 5)		
13	National Museum of the American Indian, 2001–2004	Kasota Beds of Oneota Dolomite of Prairie du Chien Group (MN), Early Ordovician	*Kasota stone, Mankato stone*	Buff-colored dolomite
14	U.S. Capitol, 1793–1865	Center: Sandstone of the Potomac Formation (see stop 1)		
		Wings: Stockbridge Formation (MA), Early Ordovician	*Lee marble*	Dolomitic white marble
		Columns on wings: Cockeysville Marble (see stop 2)	*Cockeysville marble*	Fine-grained dolomitic white marble
14.1	U.S. Botanic Garden, 1933	Salem Limestone (see stop 3)		
14.2	Garfield Memorial, 1887	Pedestal for bronze statues: Quincy Granite, Devonian or Carboniferous (?)	—	Gray granite
14.3	Grant Memorial, 1909–1922	Bases of bronze statues: Shelburne Marble (see stop 7)		
14.4	Peace Monument, 1877	Carrara Marble (Italy), Jurassic	*Statuary marble (Marmo statuario), Luni marble*	Fine-grained white statuary marble
15	National Gallery of Art West Building, 1937–1941; East Building, 1978	Holston Limestone (see stop 5)		

State abbreviations: CO—Colorado; CT—Connecticut; DC—Washington, D.C.; GA—Georgia; IN—Indiana; MA—Massachusetts; MD—Maryland; MN—Minnesota; NC—North Carolina; NY—New York; OH—Ohio; SC—South Carolina; TN—Tennessee; TX—Texas; VA—Virginia; VT—Vermont.

rectangular structure with a central courtyard, located between 7th, 9th, F, and G Streets, NW (Fig. 11). Its prominent site had been designated in Pierre L'Enfant's 1793 plan for a nondenominational church or pantheon to honor the nation's heroes, and it was selected by President Andrew Jackson for the "Temple of Invention" to house patent models and important documents, such as the "Declaration of Independence" (Robertson, 2006, p. 24–25). The building was begun in 1836. In 1958, the Smithsonian acquired it for the National Collection of Fine Arts (now the Smithsonian American Art Museum) and the National Portrait Gallery, which have shared the building since 1968. The courtyard was covered with a glass-and-steel structure designed by Norman Foster in 2007 following major renovation of the building.

The construction period of the building was lengthy because of interruptions associated with congressional funding and the Civil War. The initial south wing was built in 1836–1840; the east wing, 1849–1852; the west wing, 1852–1856; and finally the north wing, 1856–1867. William Parker Elliot (1807–1854) was the designer of the building; Robert Mills (1781–1855),

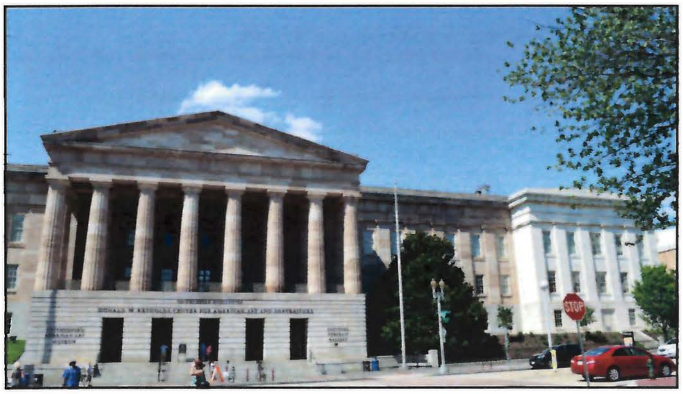


Figure 11. Patent Office Building, from the south. Tan *Aquia Creek sandstone* is at left and white *Texas marble* from Maryland at right.

Figure 12. U.S. General Post Office/Hotel Monaco, *Westchester marble*. Corroding iron cramps between blocks below corners of the pilaster resulted in the crack at left and dutchmen (stone infill). Pockmarks in the center block (81 cm wide) are from weathering out of tremolite.

the supervising architect for the south and east wings; Thomas Ustick Walter (1804–1887), the supervising architect for the west and north wings; and Adolf Cluss (1825–1905), the restoration architect following a serious fire in 1877, notable for his designs of the Great Hall and Model Hall on the top floor of the south and west wings.

Congress dictated that the building be built of stone, although it calculated the initial appropriation based on the cost of brick (Evelyn, 1997, p. 124). The original south wing was clad with *Aquia Creek sandstone* from the government-owned quarry in Virginia. However, Mills convinced Congress not to use the sandstone for the second phase of construction because of expenses associated with painting and repairing other buildings constructed of this stone (P.J. Scott, 2000, personal commun.), and subsequent wings were built with *Texas marble* from Maryland. In order to match the appearance of the marble when the second wing was built, the tan *Aquia Creek sandstone* portion was painted white in 1851.

The *Aquia Creek sandstone* (see "Local Stone Industry" section for details about the stone) used for the south wing of the Patent Office Building is of better quality than on many other buildings, and it is generally in good condition. The stone can be closely examined on massive doric columns in the ground floor west gallery near the E Street entrance. The white paint finish applied in 1851 and periodically renewed afterward may have also served as protection. Remnants of it were removed by hydrosilica blasting in 1958, creating a somewhat discordant appearance today between the tan sandstone and white marble. Consideration was given to repainting the *Aquia Creek sandstone* to match the *Texas marble* during major renovation completed in 2006, but repainting was ultimately rejected, in part because of maintenance requirements (Grissom et al., 2002).

Despite antipathy toward *Aquia Creek sandstone* on the part of Robert Mills, the *Texas marble* used for later wings of the building has fared far worse over the years, suffering considerable granular disintegration (see Fig. 8 for a close-up of the marble). Large grains are regularly swept up from the ground, and corners and edges have lost sharpness. Deterioration of sills and string courses is particularly severe at the northwest corner. Black gypsum crusts are visible below the cornice. Bright orange and red stains are found near the north entrance; they consist of oxides of lead, apparently stemming from lead inserts in the joints (Grissom et al., 2010).

Woodstock Granite was used for foundations of the building. It outcrops near the junction of the North and South branches of the Patapsco River a few km southwest of the town of Granite, Maryland, but was transported from Woodstock, a small station of the Baltimore and Ohio Railroad. It is a medium- to coarse-grained light-gray granite, and its chief constituents are feldspars, clear grayish or white quartz, evenly disseminated biotite, and small crystals of epidote. Accessory minerals are pyrite, titanite, apatite, and zircon (Knopf and Jones, 1929). Widespread delamination of the sandstone above the building's granite sills probably occurred because rainwater pooled on the low-porosity granite.

Stop 2: U.S. General Post Office/Hotel Monaco

Located between 7th, 8th, E, and F Streets NW, this building was occupied by the Post Office Department from around 1842 until 1897. It is sometimes referred to as the Tariff Building, since the Tariff Commission occupied it from 1932 to 1988. In 2000, the building was leased for 60 years from the General Services Administration by Kimpton Hotels, and after a two-year renovation, it opened as the high-end Hotel Monaco.

In 1839, Congress decreed use of marble or granite for the Post Office (Evelyn, 1997, p. 127, 166 [n. 11]), and marble was chosen. It was considered more attractive than granite but was also less expensive. The original part of the building (the present south portion of the building facing E Street) was faced with *Westchester marble* from New York. Robert Mills was the architect and oversaw construction from 1839 to 1844. Between

1855 and 1866, an addition was constructed to the north in dolomitic *Cockeysville marble* from Maryland (Merrill, 1910, p. 525) (see "Local Stone Industry" section for details about the stone). Thomas Ustick Walter was the designer of this addition.

Westchester marble is the informal name for a dolomitic marble also known as *Tuckahoe marble*. Quarries opened at Sing-Sing (Mt. Pleasant) by 1809 (McKee, 1969, p. 17) and at Tuckahoe in 1822 (Torres, 1976, p. 14). The stone was widely used for buildings in the New York area, including Federal Hall (1842) and the Washington Memorial Arch in Washington Square (1891) (Kaese and Lynch, 2008). In fact, it was the most widely used white marble dimension stone up to the advent of the Vermont marble industry (Torres, 1976, p. 14).

Formally this stone is Inwood Marble, which is part of the Manhattan prong of the Appalachian Highland Province stretching from western Connecticut southwestward across Westchester County to parts of New York City, including all of the Bronx, extreme western Queens, all of Manhattan Island, and the part of Staten Island around Todt Hill (Merguerian and Merguerian, 2014, p. 2–5). It is the result of the Late Cambrian to Early Ordovician Sauk Sequence, which deposited a shallow, tropical carbonate shelf along the eastern North American continental margin. Metamorphosed Sauk Sequence carbonates also include Shelburne (stop 7) and Stockbridge (stop 14) Marbles.

Inwood Marble is composed predominantly of white to bluish-gray medium to coarse-grained calcite and dolomite with siliceous interlayers containing diopside, tremolite, phlogopite, muscovite, and quartz (Merguerian and Merguerian, 2014, p. 16–17). On the Post Office Building, this stone displays characteristic pockmarks where tremolite inclusions have weathered out (Fig. 12).

Restoration of the Hotel Monaco included cleaning of the stone and installation of stone infill known as dutchmen, mainly in the *Westchester marble* (Fig. 12). The dutchmen were inserted below pilasters where the stone was damaged by corrosion expansion of iron cramps between blocks (M.K. Oehrlein, Office of the Architect of the Capitol, 16 July 2015, personal commun.).

Stop 3: Federal Triangle

The Federal Triangle lies north of Constitution Avenue in a triangle formed with Pennsylvania Avenue and 15th Street. Poor drainage and a tendency to flood led this low-lying site to serve marginal enterprises and light industry until reclamation of the Potomac Flats and filling in of the Washington City Canal after the Civil War (Scott and Lee, 1993, p. 166). The Public Buildings Act of 1926 set in motion plans for the Federal Triangle, overseen by Treasury Secretary Andrew W. Mellon and his architect Edward H. Bennett. Seven prominent buildings to house government agencies were constructed as part of one of the last City Beautiful plans in the nation. Each neoclassical building was designed by a different architect or architects, but all of these architects were trained in the Beaux-Arts style that originated in Paris. Moreover, it was mandated that the buildings be the same height and clad with the same stone, so that the buildings form a cohesive group. Salem Limestone was selected, because it was the only stone available in sufficient quantities (Gurney, 1985, p. 57). Decorative stonework and sculptures were also executed in Salem Limestone, including all the pedimental sculptures found on the buildings and works at ground level. From east to west along Constitution Avenue, buildings in the Federal Triangle on the tour are:

- 7th to 9th Streets: **National Archives,** 1935, John Russell Pope architect (stop 3.1);
- 9th to 10th Streets: **Department of Justice (Robert F. Kennedy Building),** 1931–1934, Zantzinger, Borie and Medary architects (stop 3.2);
- 10th to 12th Streets: **Internal Revenue Service,** 1928–1935, Louis A. Simon architect (stop 3.3);
- 12th to 14th Streets: **Environmental Protection Agency and Andrew W. Mellon Auditorium,** 1935, Arthur Brown Jr. architect (stop 3.4);
- 14th to 15th Streets: **Department of Commerce (Herbert Clark Hoover Federal Building),** 1926–1932, Louis Ayres architect (stop 3.5).

The Salem Limestone used for Federal Triangle first appeared on a public building in Washington, D.C., on the former U.S. Geological Survey Building (1915–1917), now the General Services Administration Building, on F Street between 18th and 19th Streets (Withington, 1981, p. 40). The limestone was substituted for brick when the bid came in lower than the appropriation (Scott and Lee, 1993, p. 216). It was subsequently favored for federal buildings because of advantages that include absence of bedding planes (freestone), uniform appearance, abundance, and very good durability.

Salem Limestone is Mississippian in age and characterized by fossil fragments of crinoids, bryozoans, and brachiopods (Patton and Carr, 1982, p. 7–8). It is referred to informally as *Indiana limestone, Cathedral limestone, Bedford stone, and Bedford oolitic limestone*. The most common type is gray in color, but a blue variety and a variegated gray-and-blue variety are also available. Testing showed an apparent porosity for Salem Limestone of nearly 18% (Aloiz, 2013, p. 28). This relatively high porosity is consistent with the stone's tendency to develop dark patches of biological growth in regularly wetted areas (see stop 8.2).

Salem Limestone was one of two carbonate stones used for test specimens in the National Acid Precipitation Assessment Program (NAPAP) during the 1980s (McGee, 1989). The other was Shelburne Marble (stop 7). The conclusion of the NAPAP study was that manmade acidity in rain has had a negligible effect on the erosion rates of these prominent building stones (Mossotti et al., 2001, p. 23).

Stop 4: National Museum of Natural History

The National Museum of Natural History (Fig. 13) opened in 1910 on the north side of the Mall between 9th and 12th Streets to accommodate collections that had outgrown the two earlier

Smithsonian buildings. Designed by the Washington firm of Hornblower and Marshall, it was the second building erected on the Mall after the Department of Agriculture building (stop 8.4) to reflect the Beaux-Arts classical ideals of the McMillan Plan. It is a steel-frame building entirely clad in granite slabs, which increased mechanization of quarry operations had made more affordable from the 1880s onward.

Different types of granite were selected to accentuate the various levels of the façade. The ground floor level is clad with Precambrian pink Milford Granite from Milford, Massachusetts (Dale, 1908, p. 80–73). Milford Granite is characterized by a distinctive salmon-pink color, lenticular mosaics of quartz and oriented patches of biotite (Wones and Goldsmith, 1988). The two main floors and columns are covered with quartz monzonite Bethel Granite from Bethel, Vermont, which is Devonian in age (Dale, 1909, p. 109–114). Mount Airy Granite, also Devonian and quarried in open-face pits in Surry County, North Carolina, is used for the top floor and the six-story wings completed in 1965 (Councill, 1954). Micro XRD analysis of the Mount Airy Granite identified feldspars, biotite, and hematite within a quartz matrix (Aloiz et al., 2012, p. 48–49). Woodstock Granite was used for two interior courtyards, now closed in (see Stop 1 section for more information on Woodstock Granite).

Stop 5: National Museum of American History

Originally known as the Museum of History and Technology (completed in 1964), the National Museum of American History (NMAH) is located on the north side of the National Mall between 12th and 14th Streets, Constitution Avenue, and Madison Drive. Its architect was Walker O. Cain (1915–1993) of the storied New York–based firm McKim, Mead and White. The building follows the post–World War II modernist design style, presenting a strong contrast to the neighboring National Museum of Natural History built according to Beaux-Arts architectural principles. NMAH also reflects a contemporary trend in building technology away from conventional load-bearing masonry. The exterior consists of stone cladding: 8-cm-thick slabs attached by anchorages to a steel-frame structure.

The stone cladding is *Tennessee marble* or *Tennessee Pink marble*, known for its pink coloration and distinctive stylolites, or crowsfeet. This was the second building on the Mall to use this stone on the exterior after the National Gallery of Art (stop 15). The apparent porosity of the stone has been measured at 0.31%, which is low (Aloiz, 2013). Although this low porosity and the crystal structure are similar to many marbles, in thin section grains appear to be re-crystallized near the boundaries and fossil crinoid and bryozoan remnants are visible within (Dale, 1924). Thus, the formal name for the stone is Holston Limestone from the Holston Formation in Tennessee (Knox and Blount Counties) of Ordovician age (Nelson, 1924). The prominent dark-gray or black stylolites appear as jagged lines, where insoluble inclusions congregated along compaction seams between calcite bedding planes (Park and Schot, 1968). Micro XRD analysis of a sample from the building showed that the stone is predominantly calcium carbonate, with hydroxylapatite and fluorapatite as trace minerals (Aloiz, 2013, p. 34–35, 39). Small amounts of silicon, iron, sodium, titanium, and manganese were also detected by INAA. The pink color of the stone is likely from trace manganese ion.

The stone on the building is generally in good condition, with little soiling and biocolonization, which may be attributed to its low porosity. It also shows a characteristic weathering pattern of Holston Limestone, which is a tendency to change color from pink to white, presumably due to a combination of loss of manganese and surface roughening.

Stop 6: Washington Monument

The Washington Monument (Fig. 14), located on the National Mall between 15th and 17th Streets NW, was the tallest masonry structure in the world at 169 m when it was completed in 1884, and it remains the tallest masonry structure in the world (National Geodetic Survey, 2015). In 1845, the private Washington National Monument Society adopted the design of Robert Mills for the monument: a nearly 183-m-high obelisk surrounded by a colonnaded base that would serve as a pantheon of civic and military heroes of the American Revolution. Mills also supervised the first phase of construction, but because of limited funding, he began construction only of the obelisk in 1848. This first phase of construction was halted in 1854 for lack of funds, at which point approximately one third of the obelisk had been built. When congressional funding supported resumption of construction in 1876 under the supervision of Lieutenant Colonel Thomas Lincoln Casey (1831–1896) of the U.S. Army Corps of Engineers, it was decided that the colonnaded pantheon would not be built. Casey completed construction of the upper two thirds at the end of 1884, when the apex of the roof was capped with an aluminum pyramid.

During the first phase of construction, Mills selected the coarse-grained *Texas marble* (see stop 1 and "Local Stone Industry" section for details about the stone), which he had used earlier for the first Washington Monument in Baltimore (1815–1829). The cornerstone, an 11,000 kg block, was donated by the quarry owner Thomas Symington and laid amid fanfare on 4 July 1848. Rough blocks of *Texas marble* were delivered to Washington by railroad and dressed manually on site to measure from 36 to 46 cm in thickness. *Potomac bluestone* was used to face the interior of nearly 5-m-thick walls, as well as for rubble fill between the dressed exterior and interior stonework (Torres, 1985, p. 75). *Bluestone* from Little Falls Quarry near the fall line of the Potomac River was also used for the foundations (see "Local Stone Industry" section for details about the stone).

After resumption of construction in 1876, the original foundations were deemed inadequate for the planned height of the monument: settlement and tilting of the shaft had also occurred. Casey added massive concrete buttresses and undercut the old foundation, pouring concrete there as well. He installed railroad track and turntables to haul heavy materials from the main

Figure 13. National Museum of Natural History. Ground floor is Milford Granite; next two floors, Bethel Granite; and top floor, Mount Airy Granite.

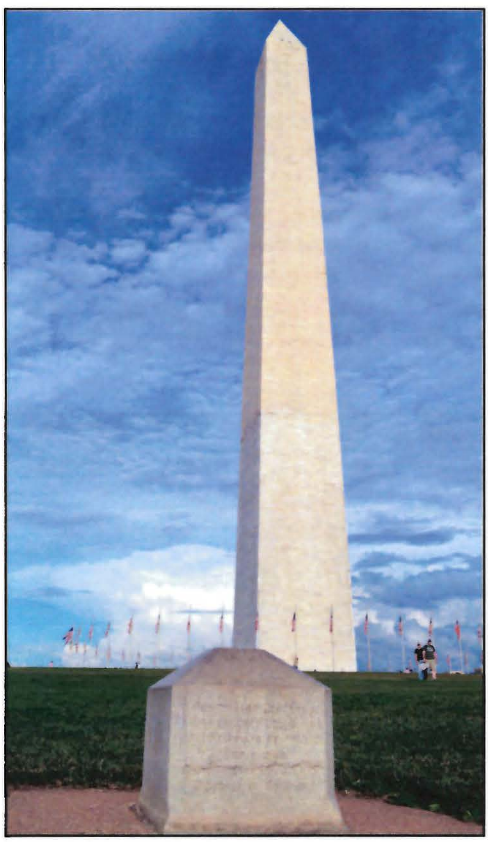


Figure 14. Washington Monument, showing *Texas marble* on the bottom third and *Cockeysville marble* on the upper two thirds. The Jefferson stone is in the foreground. Compare with the 1851 view in Figure 2.

line, altered the original construction plan to lighten the structure, and chose different stones. He began cladding the exterior in 1879 with dolomitic Stockbridge Marble (Dooley and Herz, 1995) from John A. Briggs' quarry in Sheffield, Massachusetts, laying four courses of the stone on the old shaft (Torres, 1985, p. 63). Dissatisfaction with the quality of the stone and delays in delivery led to annulment of the contract in 1880. Casey then contracted with Hugh Sisson for the fine-grained dolomitic *Cockeysville marble* from Beaver Dam quarry; the stone was used for the remainder of the monument (see stop 2 and "Local Stone Industry" section for details about the stone). The slightly yellower and more even coloration of the dolomitic *Cockeysville marble* makes it easy to distinguish from the *Texas marble* on the lower third of the monument.

Casey clad the interior with granite from Maine. The granite diminishes in thickness as the shaft rises to the 182 m level. Above that, to form the pyramidion, a single layer of Cockeysville marble measuring no more than 18 cm in thickness was carved into complex geometries; protruding marble keys rest on projections of 12 ribs on the interior (Fig. 15). The pyramidion stones were dry laid, and their relatively fragile construction made this part of the monument particularly vulnerable to damage during the 2011 Mineral, Virginia, earthquake. The pyramidion was famously topped with a pyramid of aluminum, which was then

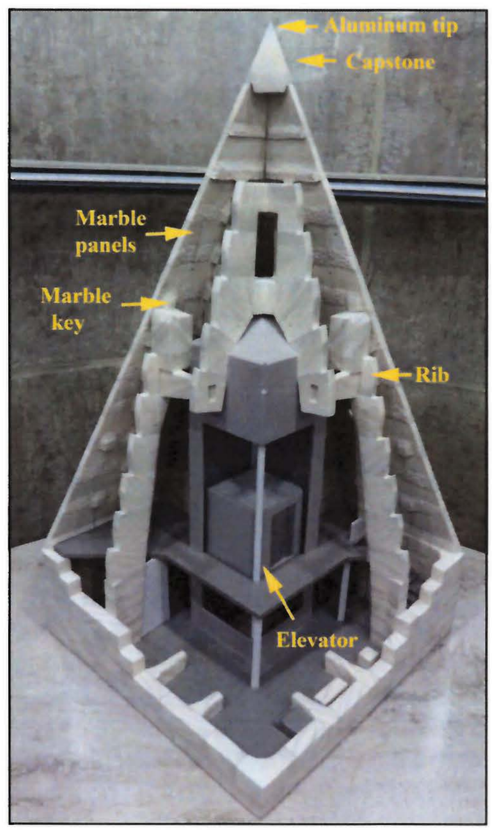


Figure 15. Cutaway model showing the interior structure of the pyramidion, Washington Monument.

a precious metal; this was the largest casting made with aluminum at that time. In addition, its high electrical conductivity was intended to serve as protection against lightning. Casey added a cast- and wrought-iron stairway of 898 steps to the interior, which provided additional structural support for the monument. For a less strenuous means of ascent, a steam-powered elevator was installed at the center of the stairway. Viewing the city from the top of the monument became an essential tourist activity during the late nineteenth century (Savage, 2009, p. 131–133).

Differential weathering also distinguishes the stone types on the Washington Monument. The *Texas marble* has suffered from disaggregation of its large grains, edges of blocks are no longer sharp, and the monument bears many patches. Yellow, red, and orange stains from lead shims used as spacers can be seen at the base (Grissom et al., 2010; Jacob, 2005, p. 12). The open joints of the dry-laid stones at the top contribute to wetness on the interior from the ingress of rainwater. The entire monument suffered damage throughout during the 2011 earthquake but the upper regions were particularly affected (Shadidi et al., 2014; Wells et al., 2015). It was completely scaffolded for repair of cracks and broken keys that secure stones in the pyramidion. While the scaffolding was still in place, the elevation of the monument was remeasured using state-of-the-art GPS methods. The architectural height was found to be 169.046 m ± 1.0 mm (National Geodetic Survey, 2015). This is ~0.19 m shorter than the 169.24 m based on Casey's original estimate. The difference is mainly due to a revised definition of the datum point.

Memorial stones made of a range of geological materials were contributed by states and organizations and installed in interior walls (Jacob, 2005). The Roman pontiff donated what became known as the Pope's Stone, said to be from the Temple of Concord in Rome. It was delivered to the monument, but stolen in 1854 by members of the anti–Roman Catholic Know-Nothing Party, who had taken over the Washington National Monument Society at that point.

Stop 6.1: Jefferson Stone

A small block of *Richmond granite* erected northwest of the Washington Monument in 1889 (see Fig. 14) marks the original location of the *Aquia Creek sandstone* masonry Jefferson Pier. The pier had been placed in 1804 at the behest of Thomas Jefferson to mark the intersection between a north-south line passing through the White House and an east-west line through the Capitol (Fig. 2). This was actually one of three markers set up in a north-south line to define a true meridian established by astronomical observations, rather than a magnetic meridian measured by compass (Bedini, 1999, p. 23–36). Jefferson was well aware of the distinction between magnetic and true north because of his experience in setting up the survey of the Northwest Territory of the River Ohio in 1785 (Pattison, 1957, p. 77–79). It has been said that Jefferson meant this to be the prime meridian, i.e., 0° longitude. However, this appears to be a misunderstanding (Waffe, 2001). The function of the true meridian was mainly to orient the city's street grid and property boundaries correctly. Jefferson's surveyor, Isaac Briggs, estimated the longitude as 76° 56′ 5″ west of Greenwich, UK (Bedini, 1999, p. 33). The most recent values for the coordinates based on 2014 GPS measurements are 77° 02′ 11.56187″ W and 38° 53′ 23.29439″ N (National Geodetic Survey, 2015).

Later, the original masonry pier was lost during construction of the Washington Monument, but it was necessary to replace it as a benchmark for surveying property boundaries. The inscription on the replacement block reads "POSITION OF JEFFERSON PIER ERECTED DEC. 18, 1804. RECOVERED AND RE-ERECTED DEC. 2, 1889 ~~BEING THE CENTRE POINT OF THE~~ DISTRICT OF COLUMBIA." The stricken words were apparently obliterated because the real center point of the original 16-km-square district lay on the grounds of the Organization of American States building at 17th and C Streets NW (Penczer, 2007, p. 94).

The *Richmond granite* comes from the Precambrian Petersburg Granite around Richmond, Virginia (Frye, 1986, p. 85–86). The numerous quarries in this vicinity supplied dimension stones for many buildings and monuments in the region including the State, War and Navy Building next to the White House, now known as the Eisenhower Executive Office Building.

Stop 6.2: Bullfinch Gatehouse and Gatepost

Gatehouses and gateposts were erected by Charles Bullfinch (1763–1844) in *Aquia Creek sandstone* around the grounds of the U.S. Capitol in 1829 (Fig. 16). They were removed in 1874 when the grounds were redesigned by Frederick Law Olmsted (1822–1903). One is now located on the northwest corner of 15th and Constitution (Fig. 17). High-water marks are inscribed to the left of the entrance for 1877 and 1881, a reminder that this area was originally at the edge of the Potomac River (Figs. 1, 2). A second

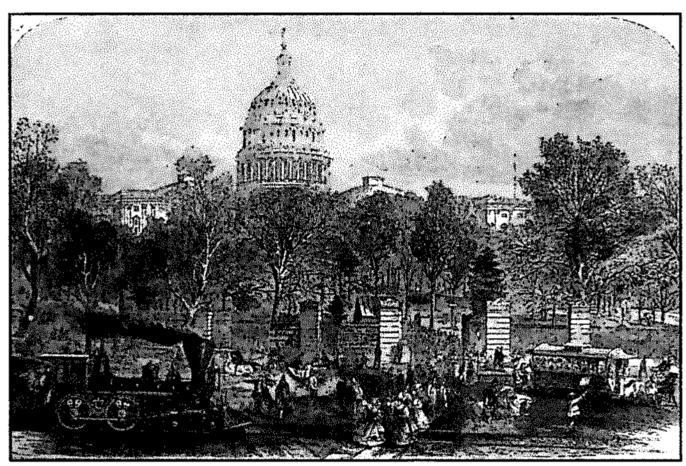


Figure 16. Bullfinch gateposts and fencing in their original location below the U.S. Capitol; Baltimore and Ohio railroad tracks are in the foreground. *Harper's Weekly*, April 18, 1866. Courtesy Library of Congress, Prints and Photographs.

gatehouse is located on the northeast corner of 17th and Constitution, diagonally opposite the lockkeeper's house (next stop).

Of the original 24 gateposts, which were linked by iron fencing, eight are extant, and the majority are along Constitution Avenue. One is located on the southwest corner across from the gatehouse on 15th Street. Partially obliterated inscriptions on this gatepost also document two high-water marks.

The *Aquia Creek sandstone* used for the gatehouses and gateposts is generally in poor condition, with significant losses and evidence of many repair campaigns (see stop 1 and "Local Stone Industry" section for details about the stone). It may be especially poor quality (Withington, 1981, p. 11), but disassembly and reconstruction is probably a contributing factor. In addition to the initial disassembly and reassembly on Constitution Avenue, the gatehouses were deconstructed and re-oriented again in 1938 (Goode, 2008, p. 117).

Stop 6.3: Lockkeeper's House

Located on the southwest corner of 17th Street and Constitution Avenue, the lockkeeper's house was built in 1835 after the eastward extension of the C&O Canal joined the Washington City Canal, where the Tiber Creek had emptied into the Potomac River (Fig. 18). The house is mainly constructed of *Potomac bluestone* (see "Local Stone Industry" section for details about the stone). It is in essentially the same location as it was originally, but it has been moved once; a second move is anticipated in the near future, so that it is further from this major intersection.

The potential for flooding not only of the Mall but a large section of downtown Washington has led to erection of berms and a floodgate across 17th Street just south of the lockkeeper's house (Climate Central, 2014). The floodgate is in line with a levee in Constitution Gardens (see next entry).

Stop 6.4: Lincoln Memorial

The Lincoln Memorial (1913–1922) is built on landfill at the west end of the Mall at the foot of 23rd Street. Thus, it was an addition to the design of the Mall not envisioned by Pierre L'Enfant. The design for the building by Henry Bacon (1866–1924) is based on a Greek temple.

The memorial was executed in *Yule marble* from a quarry near the small town of Yule in Gunnison County, Colorado. It is a nearly pure calcite marble (formally White Leadville Limestone) with minor inclusions of mica, quartz, and feldspar. Merrill noted that *Yule marble* is said to be the equal of *Carrara marble* (Merrill, 1910, p. 208) (see stop 14.4). However, repeated avalanches and washouts of the single railway into the quarry made commercial operation uneconomical for many years (Vandenbusche and Myers, 1970). Recently, the quarries have been re-opened under the ownership of a Carrara-based Italian firm using modern mechanized quarrying techniques (Voynick, 2015).

The marble on the Lincoln Memorial exhibits some sugaring typical of outdoor weathering and black gypsum crusts on the guttae on the underside of the cornice (McGee, 1999). Random blocks show severe deterioration, exhibiting cracks, discoloration, and crumbling. McGee posits that this heterogeneous weathering may be from variations in recrystallization within the quarry.

The steps of the Lincoln Memorial are made of a Milford Granite from Massachusetts. In the basement underneath them are huge stalactites, apparently because of calcium leached from the concrete substructure of the steps (Robbins and Welter, 2001, p. 26).

Daniel Chester French's nearly 6-m-high statue of a seated *Lincoln* (1922) is placed atop a 3-m-high pedestal inside the memorial. It was carved from 28 blocks of white *Georgia marble*

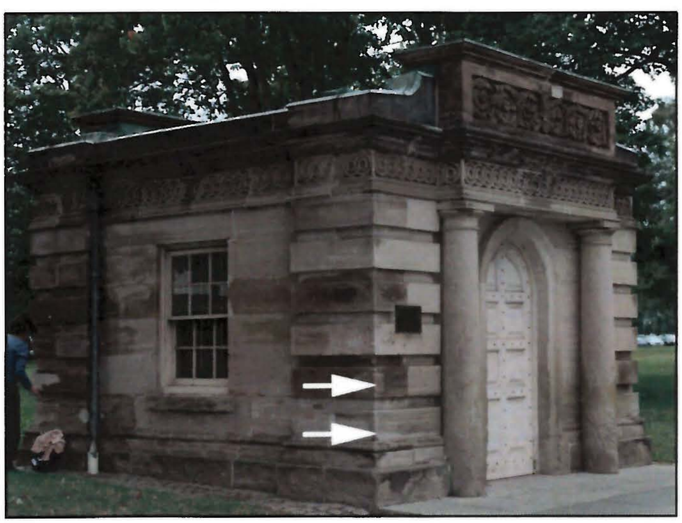


Figure 17. Bullfinch gatehouse from the grounds of the U.S. Capitol, *Aquia Creek sandstone*. Upper arrow indicates the 1881 high water mark, and the lower arrow, 1877.

Figure 18. Lockkeeper's house, *Potomac bluestone*.

by the Piccirilli Brothers in New York. *Georgia marble* is a coarse-grained marble quarried in Pickens County since around 1840 (McKee, 1973, p. 15). It is located in the Cambrian Murphy Marble Formation (Fairley, 1965).

The reflecting pool between the Lincoln and Washington Memorials was added at the same time in Mount Airy Granite from North Carolina (see Stop 4 section for details about Mount Airy Granite). The material excavated to make the pool was used to form an east-west–oriented levee in Constitution Gardens to its north for the city's flood protection (Robbins and Welter, 2001). In 2012, the National Park Service carried out a major restoration of the pool. This included replacing the original cracked 20-cm-thick concrete liner with one 28 cm thick. Additional pilings for the granite coping stones were driven. Finally, the water supply was changed from the municipal system to the Tidal Basin, and a water filtration system was installed to eliminate the buildup of algae (Ruane and Rivero, 2012).

Stop 6.5: World War II Memorial

The entrance to the 7.4-acre World War II Memorial (2004) is located at the east end of the reflecting pool opposite the Lincoln Memorial on 17th Street. Its placement there has been controversial, because Congress bypassed the procedures for siting new monuments on the Mall created under the Commemorative Works Act of 1986 (see "Development of the National Mall"). The design competition for the memorial was won by Friedrich St. Florian (b. 1932). The memorial was constructed using several types of granite. The two principal stones are Kershaw Granite from South Carolina for vertical elements and *Green County Granite* from Georgia for the main plaza paving stone.

Stop 7: Thomas Jefferson Memorial

The Jefferson Memorial (1939–1943) anchors the southern end of the north-south axis of the Mall near the Potomac River. As noted in the "Development of the National Mall," the choice of this memorial was personally championed by President Franklin Roosevelt, in part because Jefferson was a Democrat and the other major monuments on the Mall celebrated Republicans (Savage, 2009, p. 244). Its architects were John Russell Pope (1874–1937) and, after his death, his associates Otto R. Eggers and Daniel P. Higgins. The exterior of the building was built from Shelburne Marble from Vermont, which was quarried in Rutland County as early as 1785 (McKee, 1969, p. 15). Transport issues limited the stone's use for nearly a century, and it was not widely used for federal buildings in Washington until the early twentieth century: first for the Russell Building of the U.S. Senate (1906–1908) and then the Memorial Amphitheater (1915–1920) in Arlington National Cemetery. It has also been used for many headstones at the cemetery, the bases of bronze statues on the Ulysses S. Grant Memorial (stop 14.3), and the Rayburn House Office Building (1965). Interior walls of the Jefferson Memorial are made from white *Georgia marble* (see stop 6.4 for details about the marble), while the coffered ceiling is of *Indiana limestone* (see stop 3) and the floor, *Tennessee marble* (see stop 5).

Shelburne Marble is regionally metamorphosed limestone of Ordovician age, informally referred to as *Vermont marble*. Trace elements in different strata of marble create a variety of aesthetic effects through a range of colors, textures, and veins, and each layer was generally marketed under a different name. The White imperial marble variety from quarries on Dorset Mountain near Danby was used for the Jefferson Memorial, described as "mostly white with some linear traces of phlogopite and muscovite that are light tan" (McGee, 1996, p. 1; Dale, 1912, p. 108). Another popular variety is *Vermont royal marble*, which was used for the Memorial Amphitheater in Arlington National Cemetery. This variety was used for test specimens for NAPAP during the 1980s (McGee, 1989). A very low apparent porosity for the *royal marble* has been measured at 0.27% (Aloiz, 2013, p. 46).

The Jefferson Memorial has had chronic problems with biological staining from spiders and midges, which are attracted to lights on the monument at night (Fig. 19). In addition, in May 1990, the lower part of a volute, the scroll-shaped part of an ionic capital, fell to the ground (McGee, 1996). A survey of other capitals found that the combination of volute geometry and bedding planes in the stone produced horizontal cracks that could lead to failure. Consequently, loose fragments were removed from eight capitals; an additional 25 volutes on 13 columns were found to pose a significant risk of failing. These broken and cracked volutes were subsequently repaired. Pink and yellow stains seen on the column in Figure 19 have the appearance of lead oxides, probably caused by lead shims (Grissom et al., 2010).

Stop 8: From Wallenberg Place to the Department of Agriculture

The stretch of 15th Street between the Tidal Basin and Independence Avenue to its north has been renamed for Raoul Wallenberg (1912–1945), a Swedish diplomat credited with saving tens of thousands of Jews in Nazi-occupied Hungary. This renaming coincided with the siting of the U.S. Holocaust Memorial Museum there (stop 8.2).

Stop 8.1: Main Building of the Bureau of Printing and Engraving

The enormous neoclassical Main Building of the Bureau of Printing and Engraving (1914) is the southernmost building on Wallenberg Place. Salem Limestone (see stop 3) spans the 154 m façade, including its 24 columns.

Stop 8.2: U.S. Holocaust Memorial Museum

The U.S. Holocaust Memorial Museum (1993) by James Ingo Fried (1930–2005) of Pei Cobb Freed and Partners is just to the north of the previous building. It is also faced with Salem Limestone (see stop 3) as well as red brick. Chronic problems with biocolonization on the limestone led to installation of zinc strips atop the stone in 2010, which inhibit biological growth (Wessel, 2011). This has been largely effective as can be seen by the staining in a few areas where the strips were not installed (Fig. 20).

Stop 8.3: Sidney R. Yates Federal Building, Originally the Bureau of Engraving and Printing

The first section of this building, located just north of the previous building but facing Independence Avenue, was completed in 1880 by James G. Hill for the Bureau of Engraving and Printing. The bureau moved into the Main Building at the south end of the block in 1914, having outgrown the space of this building. The building now houses offices of the Department of Agriculture. As a red brick building with dark-red sandstone trim, it is one of few remnants of red federal architecture along with the Smithsonian Castle (stop 9) and the Arts and Industries Building (stop 11).

Stop 8.4: Department of Agriculture

The Jamie L. Whitten Federal Building housing the Department of Agriculture is located on the south side of the National Mall between 12th and 14th Streets. This was the first project designed for the south side of the Mall in accordance with the Beaux-Arts dicta of the McMillan Plan of 1901–1902. In 1908, Rankin, Kellogg and Crane completed the wings in Shelburne Marble (see stop 7) with granite from Massachusetts used for the base. In the late 1920s, the central section was completed in *Georgia White Cherokee marble*, a variety of *Georgia marble* (see Stop 6.4 section for details about the marble). This marble is coarsely crystalline, with micaceous streaks of gray.

Stop 9: The Smithsonian Castle

The Smithsonian Castle (1847–1855) is located on the south side of the Mall between 9th and 11th Streets; since it predates the McMillan Plan (see Fig. 2), it protrudes slightly into the elm tree region of the Mall. The Castle was the first building constructed in the Smithsonian Institution system. It was specified in legislation passed by Congress in 1846 to resolve the issue of disposition of the $500,000 bequest from the English nobleman, James Smithson (Hafertepe 1984, p. 1–21). Its location on the Mall was selected by a Board of Regents appointed by Congress. James Renwick Jr. (1818–1895) was chosen as the architect after a public competition. Other important buildings by Renwick include Grace Church and St. Patrick's Cathedral in New York City and the Corcoran Gallery of Art (now the Renwick Gallery of the Smithsonian American Art Museum) in the District of Columbia. The Romanesque or Medieval style of the Castle was meant to be a deliberate departure from the classical style selected for earlier public buildings in Washington, such as the Capitol, and it was promoted as a prototype for a "National Style of Architecture for America" (Owen, 1849, p. 109).

When it opened, the Castle housed all activities of the Smithsonian Institution, accommodating the storage and display of an extensive natural history collection, laboratories for scientific study, halls for lectures, and living quarters for Joseph Henry, the first secretary. Over time, collections were moved to other Smithsonian buildings, leaving the Castle to serve primarily as

Figure 19. Detail of a Shelburne Marble ionic capital, Jefferson Memorial. Horizontal cracks visible in the volute have resulted in falling stone from some columns. Biological staining can be seen on the wall behind.

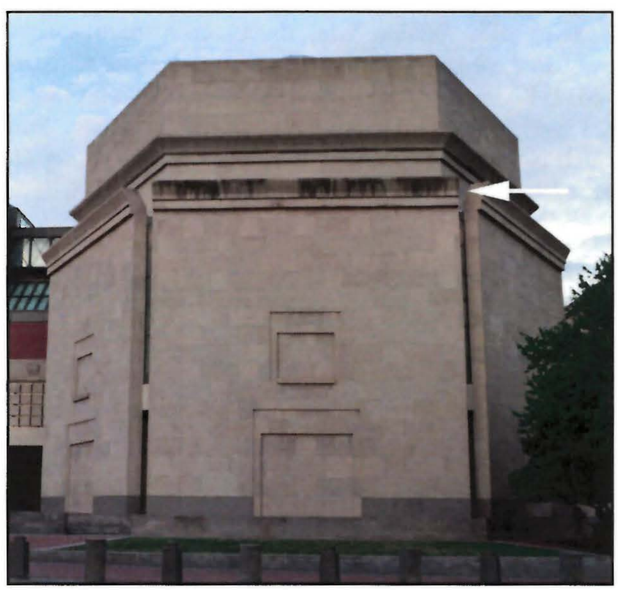


Figure 20. U.S. Holocaust Memorial Museum, Salem Limestone. Zinc strips installed in 2010 have reduced black biocolonization except in the area indicated by the arrow, where they were not installed.

an administration building and visitor information center today (Ewing and Ballard, 2009, p. 30–39).

Seneca sandstone from Bull Run Quarry was chosen for the Castle (Figs. 6, 7); see "Local Stone Industry" section for details of the stone. The sandstone was described as lilac-gray in color when first quarried, but then turned reddish-brown with exposure. Its selection occurred after frost testing 25 stones by Charles G. Page (Owen, 1849, p. 117–119), including *Aquia Creek sandstone* (see stop 1) and both the coarse calcitic and fine dolomitic Cockeysville Marble (stops 1 and 2). A major reason for choosing *Seneca sandstone* over *Aquia Creek sandstone* was the poor durability of the latter, but the bid for *Seneca sandstone* was also the lowest (Peck, 2013, p. 47–48). The opening of the C&O Canal as far as the Seneca quarries in 1831 had significantly reduced transport costs for the stone (Peck, 2013, p. 36–37). The choice of the stone also anticipated the darker colors of the Victorian brown decades (Mumford, 1955), which supplanted the white stones previously used for important federal buildings (Inwood Marble, Cockeysville Marble, and *Aquia Creek sandstone* painted white).

Seneca sandstone weathers primarily by granular disintegration and delamination along bedding planes. This process is accelerated at the Castle, because much of the stone was face-bedded, i.e., with the bedding planes oriented vertically parallel to the surface for aesthetic reasons rather than being placed with horizontal orientation. Delamination occurs especially near the ground, where rising damp and salts are a factor. Delaminated areas have been reworked to imitate original pecking as part of a regular maintenance program. Figure 21 shows a stone that has undergone several delaminations and displays new pecking.

Recently, another type of weathering has been identified on the Castle sandstone. This consists of blue-black iridescent patches growing on the stone surface (Fig. 22). Nondestructive testing with portable X-ray fluorescence spectroscopy has shown that these patches are enriched in manganese (Grissom et al., 2014; Livingston et al., 2014). They appear to be similar to desert varnish, which is produced by microbial activity. Further research is under way to develop a better understanding of the basic mechanisms of this process and its rate of growth.

Figure 21. Detail of *Seneca sandstone*, west façade of the Smithsonian Castle. Central block (206 cm wide) shows retooled surfaces after multiple delamination.

The South Mall Master Plan developed by BIG (Bjarke Ingels Group) calls for construction of two additional levels for visitor services below the building. This would require seismic retrofitting of the building (see next entry).

In front of the Castle, work on phase II of the Mall restoration project can be seen. This includes excavation and removal of damaged soil to a depth of ~1.5 m and installation of advanced irrigation and drainage technology, including compaction-resistant engineered soil. A 950 kiloliter cistern will collect and allow the sustainable reuse of storm water (The Trust for the National Mall, 2015).

Stop 10: Quadrangle

The Quadrangle (1987) is the name given to a largely underground Smithsonian complex on the south side of the Mall and the Enid A. Haupt Garden on top of it. The area is bounded by the Castle, Arts and Industries Building, and Freer Gallery of Art. The underground configuration was motivated by limited space on the Mall for additional buildings. At ground level, pavilions for the National Museum of African Art and Arthur M. Sackler Gallery are in the Haupt Garden for entry to underground galleries. A kiosk entrance on Jefferson Drive provides access to underground auditoriums, classrooms, and offices in the Ripley Center. The venerable Boston firm of Shepley, Bulfinch, Richardson and Abbott built the Quadrangle after designs by Junzo Yoshimura (1908–1997).

The roof over underground spaces below the Haupt Garden has had chronic leaks, and there have been concerns regarding insufficient egress capacity in the event of emergency evacuation. To address these and other problems, the South Mall Master Plan was developed by a Danish architectural firm (BIG), presented in 2014 (BIG-Bjarke Ingels Group, 2014). The plan calls for new Mall-facing entrances for the two museums and an entry kiosk, which would be newly linked underground to the Arts and Industries Building and the visitor center in the two new levels below

Figure 22. Dark blue–black patches on the *Seneca sandstone*, southwest corner of the Smithsonian Castle, on which X-ray fluorescence spectrometry found elevated manganese. The block with the darkest patch measures 71 cm in width.

the Smithsonian Castle. The $2 billion price tag, which includes the demolition of the popular Haupt Garden and the retrofitting of the Castle for seismic isolation, makes it uncertain if the plan will be implemented.

Stop 10.1: Freer Gallery of Art and Arthur M. Sackler Gallery

The Freer/Sackler Gallery complex is located on the south side of the National Mall on Jefferson Drive between the Department of Agriculture and Smithsonian Castle, Jefferson Drive, and Independence Avenue. The Freer Gallery of Art was designed in the style of a Renaissance Italian palazzo by the architect Charles Platt (1861–1933) and constructed from 1917 to 1923. Its exterior is faced with Stony Creek Granite from Branford, Connecticut, a durable Late Proterozoic stone first quarried in 1858. This stone was also used for many buildings in New York City, including the base of the statue of *Liberty Enlightening the World* (1889) and much of the campus of Columbia University. The interior is faced with Salem Limestone (see stop 3) and the courtyard with white *Tennessee marble* (see stop 5).

The entrance pavilion for the underground Arthur M. Sackler Gallery (1987) is located near Independence Avenue on the west side of the Enid A. Haupt Garden. The museum is physically linked underground to the Freer Gallery and other areas below the garden in the Quadrangle complex. The exterior of the Sackler's entrance pavilion was clad to match the Freer in gray *Rockville White granite* from Rockville, Minnesota (Carlhian, 1991; D. Krueger, Coldspring USA, 2015, personal commun.). The formal name for the cladding is Rockville Granite of Stearns Granitic Complex, which is Early Proterozoic. Geometric designs are accentuated by rough and polished blocks. Like the Freer, the interior is clad with Salem Limestone.

Stop 10.2: Enid A. Haupt Garden and Gateposts

The Enid A. Haupt Garden is at the center of the Quadrangle complex; in addition to Victorian-style planting and fountains, it contains the entrance pavilions for the underground National Museum of African Art and Arthur M. Sackler Gallery. On Independence Avenue, it is bordered by four *Seneca sandstone* gateposts after a design by James Renwick, the architect of the Castle (Owen, 1849, p. 119). The gateposts were carved by Constantine Seferlis (1930–2005) and erected in 1987. Similar *Seneca sandstone* gateposts, also designed by Renwick, were erected around 1850 at the entrance to Oak Hill Cemetery in Georgetown (see "Local Stone Industry" section and stop 9 for details about the stone).

The gateposts are damaged by hygroscopic soluble salts, which go in and out of solution in response to humidity cycles, resulting in the delamination of the sandstone. Chlorides formed during the cleaning up of the cementitious mortar with hydrochloric acid are likely the culprit. In winter, the salts become visible as unsightly white spots where they crystallize on the surface as the relative humidity drops. In addition, blue-black urban rock varnish patches colored by manganese have been identified, similar to those on the Castle (stop 9). These gateposts are absent from the drawings for the proposed Quadrangle makeover in the South Mall Master Plan, which seeks to open the Smithsonian to the south.

Stop 10.3: National Museum of African Art

The largely underground National Museum of African Art (1987) mirrors the Sackler Gallery opposite it with an entrance pavilion of a slightly different style on the east side of the Haupt Garden near Independence Avenue. It is also linked underground to other areas of the Quadrangle. The entrance pavilion is clad in pink *Sunset Red granite* from Marble Falls, Texas, for compatibility with the adjacent red brick Arts and Industries Building (Carlhian, 1991; D. Krueger, Coldspring USA, 2015, personal commun.). *Sunset Red granite* is formally the Precambrian Town Mountain Granite (Clabaugh and McGehee, 1972). As on the Sackler pavilion, rough and polished blocks emphasize geometric patterns on the façade. The interior is clad with Salem Limestone (see stop 3).

Stop 11: Arts and Industries Building

The Arts and Industries Building is located on the south side of the National Mall just east of the Smithsonian Castle and Quadrangle between Independence Avenue and Jefferson Drive. Built in the Norman Romanesque style, it was the second building of the Smithsonian. It was also the first purpose-built structure to house collections of the National Museum previously displayed in the Smithsonian Castle, as well as 60 boxcars full of items from exhibits at the Centennial Exhibition of 1876 in Philadelphia. The building was renamed the Arts and Industries Building in 1910 when natural history collections were moved into the National Museum of Natural History (stop 4).

The building was constructed from 1879 to 1881 and was said to be the least expensive building per square foot ever erected by the federal government. The architects were Adolf Cluss (1825–1905) and Paul Schulze (1827–1897). The building is primarily of red brick, decorated with buff-, black-, and blue-glazed brick, but it is trimmed with *Euclid bluestone* from Ohio (Fig. 23). This sandstone is a Euclid Member of the Upper Devonian Bedford Shale (EwingCole, 2009). It "is a dense, well-indurated, very fine grained sandstone that crops out in northeastern Ohio in and near Cleveland," quarried early in the nineteenth century because of its accessibility to Cleveland and the quarry railroad, which opened in 1834 (Hannibal et al., 2007). *Euclid bluestone* is quartz-rich, with minor albite, muscovite, chlorite, and accessory minerals enclosed in a ferroan-dolomite matrix. Its use was largely limited to sidewalks, as the common occurrence of pyrite in the stone prevented its widespread use for building exteriors because of orange discoloration induced by iron, which is visible on the Arts and Industries Building.

Weathering has caused spalling and disaggregation of the *Euclid bluestone*, especially of the lowest stones of the

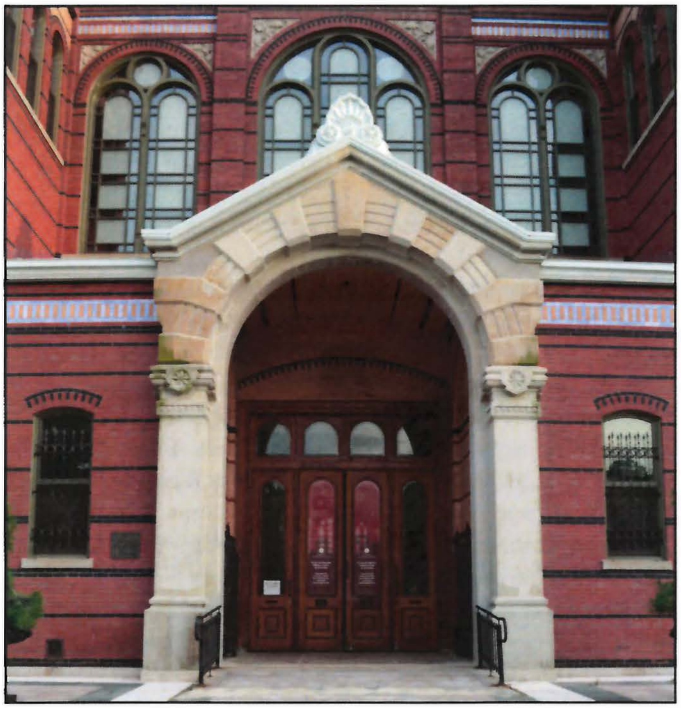


Figure 23. North entrance to the Arts and Industries Building, *Euclid bluestone*. Iron staining on the archway is typical of the stone. Bases for the shafts were replaced with Buena Vista Sandstone around 2009.

entranceways. During recent restoration of the building (2009–2013), some blocks were replaced with *Scioto sandstone* from Waller Brothers Stone Company of McDermott, Ohio. This stone is almost certainly Buena Vista from the Mississippian Cuyahoga Formation found in the Waller Brothers' Crabtree Quarry (Hannibal, 1995). Fossil trails, which distinguish this stone from Berea sandstone, can be seen on a base block at the west entrance to the building. Other blocks were honed during the restoration to achieve smooth surfaces and sharp corners. Iron stains were removed from some blocks with a chemical cleaner.

Stop 12: National Air and Space Museum

The National Air and Space Museum (1976) is located on the south side of the Mall between Independence Avenue, Jefferson Drive, and 4th and 7th Streets. Guy Obata (b. 1923) of Hellmuth, Obata and Kassabaum was the principal designer for the building. At the request of the Commission of Fine Arts, *Tennessee marble* (Holston Limestone) was selected for cladding the building both on the exterior and portions of the interior to complement the National Gallery of Art across the Mall (Obata, 1991). See Stop 5 section for details about the stone.

The structure of the building reflects another step in the evolution of the use of stone in architecture from load-bearing masonry to stone cladding (Lewis and MacDonald, 1997). It is basically a steel cage (Obata, 1991) with a stone skin. Each panel of the stone measures 1.5 m by 0.75 m by 3 cm in thickness and is affixed to a steel lattice, in turn attached to a steel structural member. An air gap, serving either as a return-air plenum or for mechanical ductwork, ranges from 0.7 m to 1.2 m between the cladding/lattice and steel-supported wall of the museum (Quinn Evans Architects, 2013).

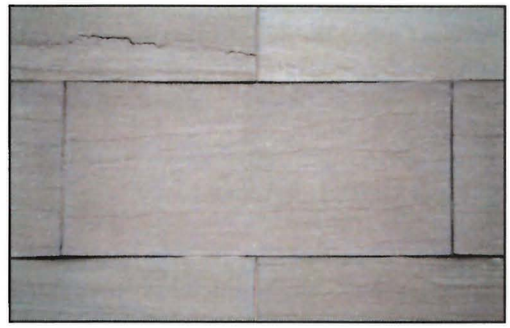


Figure 24. Detail of a *Tennessee marble* panel (1.5 m wide) on the west façade of the National Air and Space Museum. Convex warping away from anchors creates shadows below vertical joints.

This building also illustrates some of the durability problems associated with thin stone cladding frequently used in recent years: note that the cladding's 3 cm thickness is less than half the 8 cm of cladding on the National Museum of American History (stop 5). A comprehensive study (Quinn Evans Architects, 2013, p. 3–4) has found that 8% of the *Tennessee marble* panels have greater than 0.8-cm warp (mostly convex but in some instances concave) at their vertical edges on all except the north façade (Fig. 24). This is apparently because of the thinness of the panels, which reduces their resistance to deformation from loads such as thermal expansion. Solar heating is likely a factor in this instance, since warping is not present on the north façade, and bowing of marble occurs readily under thermal cycles; the effect is enhanced by high humidity levels (Siegesmund and Durrast, 2011, p. 157–158). Failure of mortar at the joints because of the warping has resulted in entry of water. In addition, 1% of the panels were observed to have significant cracks. Finally, stone stacking, which is the transfer of gravity load from one panel to the next one below, was found throughout, contrary to the design intent of independent support for each panel. Complete replacement of the stone with thicker cladding is under consideration in 2015. It is unclear if sufficient stone is available in new *Tennessee marble* quarries for replacement in kind, although it is preferred by the Commission of Fine Arts, whose approval is required.

Stop 13: National Museum of the American Indian

The principal building of the National Museum of the American Indian (2001–2004) is located on the south side of the National Mall between Independence Avenue, Jefferson Drive, Maryland Avenue, and 3rd and 4th Streets. It is the museum site located closest to the U.S. Capitol. The Native American architect Douglas Cardinal (b. 1934) designed the building to imitate a natural rock formation; hence he created an undulating building with few flat surfaces. Native groups were also consulted throughout the design process. Tribal elders requested that the principal entrance to the museum face east toward the Capitol. Thus, it greets the rising sun in keeping with indigenous architecture.

Kasota stone was selected for cladding the building after it was found that insufficient *Tennessee marble* was available. The warm buff color of this Ordovician dolomitic limestone marks a significant departure for buildings on the Mall. The stone for the building was quarried at Kasota in southeastern Minnesota, where it was first quarried in the 1880s. Its formal name is Oneota Dolomite (Lathram and Thiel, 1946). At the beginning of the twentieth century, many quarries were in operation, supplying building stones for construction throughout the Midwest. Museum buildings clad with the stone include the Philadelphia Museum of Art (1919–1933) and Eiteljorg Museum of American Indians and Western Art (1989) in Indianapolis. Most stone used for other buildings has come from the surrounding Mankato area and is sometimes referred to by that name.

Several different techniques were employed to achieve the effect of a rock formation. Most of the façade is covered with blocks of "splitface" stone. These stones were split with hydraulic chisels perpendicular to the bedding planes into 10-cm-thick blocks to achieve a range of curved and irregular surfaces on the façade. In addition, the blocks, which were sawn into four different course heights and various widths, were placed irregularly on the façade to contribute to a natural appearance. They are supported on stainless-steel shelf brackets every 3 m, with each block mortared in place and secured to the interior masonry structure with V-ties. A 5-cm air gap between the stones and interior masonry serves as a thermal barrier to modulate the interior climate of the building.

"Roughback" stones, also known as fleuri or quarry creek, are the highly colored blocks located at ground level on some areas of the building (Fig. 25). These face-bedded blocks were split parallel to the bedding planes to show the bedding surfaces, which are colored by iron and manganese deposits in rusty hues ranging from yellow to red to dark-brown and purple. Many trace fossils are also exposed, as seen in Figure 25. They can be interpreted as filled tunnels of burrowing creatures, although the exact identification can be problematic (Bengtson and Rasmussen, 2009). Because beds are generally level, these blocks create a faceted surface at the base of the curvilinear building.

Blocks sawn for sills, copings, window surrounds, and interior walls were sandblasted to remove saw marks for a smooth natural-looking finish.

Analyses of stone leftover from construction of the museum show that it contains calcite, dolomite, alkali feldspars (orthoclase and microcline), quartz, and very small amounts of clay (Aloiz, 2013, p. 21–23). The stone was found to have 12% apparent porosity, which is moderately high.

Only a few years after the building opened in 2004, black deposits began to appear on the facade, which were determined to consist of cyanobacteria that readily colonized the porous stone. Contributing factors are the nontraditional architecture and especially the absence of an overhanging cornice that would shield the façade from rainwater. Cleaning with a biocide occurred in 2011 on the most disfigured areas (Fig. 26), but significant biocolonization returned by 2015. Zinc test strips adhered to top ledges of roughback blocks seem to have reduced biocolonization (Fig. 27), but the irregularity of the building's masonry makes it unlikely that they can reduce biological growth significantly in many locations.

A number of other stone types were used around the building. The cascade portion of the watercourse was constructed of *Golden sand limestone* from Mexico, selected to match the *Kasota stone* but more resistant to abrasion by water (Stinnard, 2005). Exterior paving was made of *American mist granite* quarried by Rock of Ages in Morgantown, Pennsylvania. Thermal torch-finished Mount Airy Granite (see stop 4 for details of the stone) decorates the curbs of planters along the site's perimeter and exterior stair treads. In addition, large boulders donated by Native communities mark the cardinal directions around the building and reflect different

Figure 25. Trace fossils on a "roughback" block of *Kasota stone* (157 cm wide), National Museum of the American Indian.

Figure 26. Cleaning biocolonization with a biocide from the *Kasota stone* on the National Museum of the American Indian in April 2011.

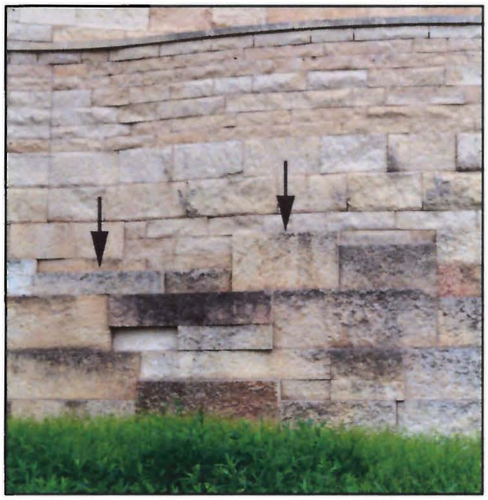


Figure 27. Locations of zinc strips installed on ledges atop cleaned roughback blocks in 2012 are indicated by arrows, National Museum of the American Indian; the block indicated at right measures 101 cm in width. Less biocolonization appeared to have recurred compared to surrounding stones when this image was taken in 2015.

geological epochs of the Earth (Ottesen, 2011, p. 92). On the north is a boulder made of Hadean *Acasta gneiss* from the Tlicho (Dligo) culture living north of Yellowknife in Canada's Northwest Territories. On the east, a Cambrian quartzite boulder from the Monocacy valley in Maryland was placed to maintain a positive relationship between Native peoples and the federal government. On the south, a Cretaceous boulder is from the Yagán people on Isla Navarino in Chile. On the west, the youngest boulder is from a Keomoku lava flow (ca. 1602) in Hawaii.

Stop 14: U.S. Capitol Building

The site of the Capitol Building was designated by Pierre L'Enfant on Jenkins Hill, and in 1793 President Washington laid the southeast cornerstone in *Aquia Creek sandstone* from the government quarry (see "Local Stone Industry" section for details about the stone and Fig. 2 for an image of the building in 1855). Dr. William Thornton had drawn the original design, and Stephen H. Hallet, James Hoban, George Hadfield, and Benjamin Latrobe took subsequent turns at directing the work in the early years. The north wing was completed in 1800 and the south wing in 1807; both were burned by the British in 1814. After repair and reconstruction, sandstone on the exterior was painted white in 1818, but Benjamin Latrobe's sandstone corncob capitals can still be seen unpainted in the crypt. Installation of 24 *Aquia Creek sandstone* columns on the east façade was completed in 1826 by Charles Bulfinch, with each monolithic shaft measuring nearly 8 m in height. The columns were removed to storage in 1958 and erected in 1986 at the U.S. National Arboretum, while identical columns in *Georgia marble* replaced them in a portico built nearly 10 m out from the previous façade (see stop 8.4 for details of *Georgia marble*). Many studies have been done on the *Aquia Creek sandstone* of the Capitol building related to repair (Hockman and Kessler, 1957; Clifton, 1987; Sykes, 1986; McCarthy and Ginell, 2001; Aloiz, 2013). The sandstone was consolidated with an ethyl silicate solution after removal of all paint in 1984 and repainted (Clifton, 1987, p. 19, A2; O'Neil, 1995).

From 1851 to 1865, extensions for new Senate and House chambers designed by Thomas U. Walter were built in dolomitic *Lee marble* from Massachusetts on the north and south sides of the building (Dooley and Herz, 1995); it is formally a member of the Stockbridge Formation. The 108 columns of dolomitic *Cockeysville marble* from the Beaver Dam Quarry north of Baltimore were installed on the extensions in 1859–1861 (see "Local Stone Industry" section for details about the stone).

The Architect of the Capitol is responsible not only for the Capitol building but also for monuments and related federal buildings in the precincts of the Capitol. These include the Senate and House office buildings and the Library of Congress, as well as the Botanic Garden and several monuments on the Mall itself.

Stop 14.1: U.S. Botanic Garden

The U.S. Botanic Garden, established in 1820, formerly occupied the spot at the foot of Capitol Hill now occupied by the Grant Memorial. That building was demolished to provide a clear vista along the Mall's central swath in accordance with the McMillan Plan. The present building (1933), designed by Bennett, Parsons and Frost, was constructed to the south with Salem Limestone. In the northwest room of the building, an original *Aquia Creek sandstone* capital from the west façade of the Capitol is on display (Fig. 28).

Stop 14.2: James A. Garfield Memorial

The James A. Garfield Memorial by J.Q.A. Ward was erected in 1887 at the foot of Capitol Hill in a traffic circle northeast of the U.S. Botanic Garden (Fig. 29). President Garfield is depicted standing with a speech in his hand, while bronze figures of a *Student, Warrior*, and *Statesman* are seated below (Sharp, 1985, p. 61–71, 223–227). The Quincy Granite pedestal was designed by the architect William Morris Hunt, who, among many other projects, designed the base for the statue of *Liberty* in New York harbor. Quincy Granite is Devonian or possibly Carboniferous in age. As a congressman from Ohio, Garfield was essential to the formation of the U.S. Geological Service in July 1879 (Hannibal, 2015).

Stop 14.3: General Ulysses S. Grant Memorial

The General Ulysses S. Grant Memorial is located on Union Square at the foot of the U.S. Capitol at the east end of the National Mall, at 1st Street. Memorializing the most important military leader for the Union during the Civil War, it was first proposed for the ellipse in front of the White House, but President

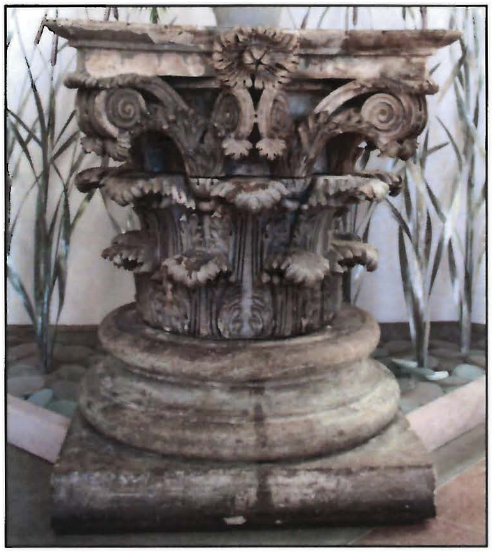


Figure 28. Original *Aquia Creek sandstone* column capital from the U.S. Capitol, on view at the U.S. Botanic Garden.

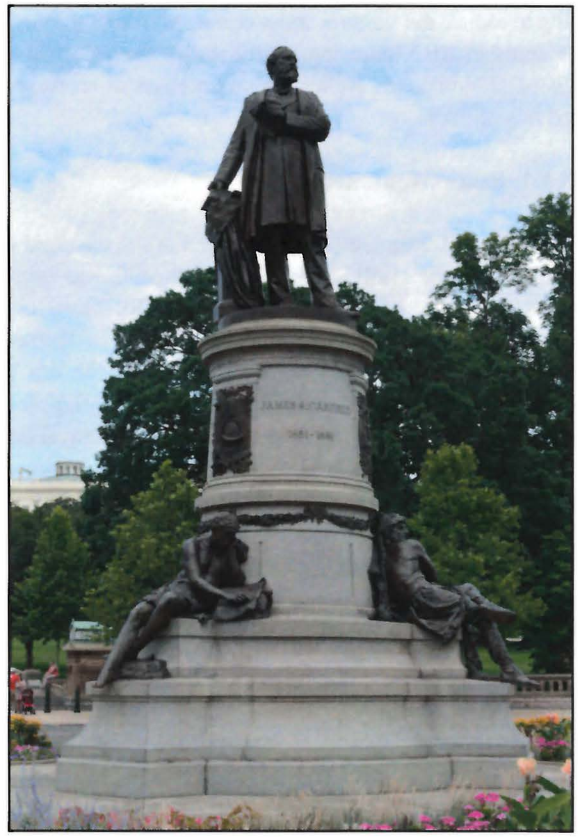


Figure 29. James A. Garfield Memorial by J.Q.A. Ward, bronze statues on a Quincy Granite pedestal.

Theodore Roosevelt and others objected, and it was placed at the Capitol. The monument was transferred from the National Park Service to the Architect of the Capitol in 2011.

Sculptor Henry Merwin Shrady (1871–1922) won the contest for the memorial, which was constructed from 1909 to 1922. The enormous monument consists of seven bronze statues cast by Roman Bronze Works: the equestrian statue of *Grant*, four *Lions*, and large groups representing *Artillery* and *Cavalry*. The *Imperial Vermont marble* variety of Shelburne Marble was used for pedestals of the bronze statues (see Stop 8 section for details about the stone). The marble bases were severely stained green and purple by copper runoff from the bronze statues (Fig. 30). A calcite grain from the base shows black (probably tenorite) and green (brochantite) coatings from the copper on its surface at high magnification (Fig. 31).

Figure 30. Copper runoff from the Grant Memorial's bronze *Lion* has left disfiguring green and purple stains on the *Vermont marble* base.

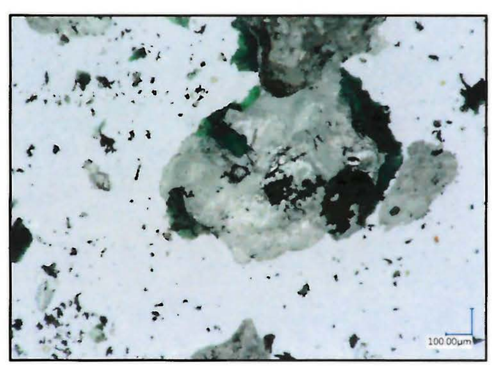


Figure 31. Detail of calcite grain from the colored area along the crack in Figure 30, showing green (brochantite) and black (probably tenorite) coating.

Cleaning to reduce the stains is under contract through the Architect of the Capitol in 2015 following a 2012 study (Hord Coplan Macht et al., 2012). Granite was often selected for bases of bronze statues to avoid this problem.

Stop 14.4: Peace Monument

The Peace Monument (1877), located at the east end of the National Mall to the north of the Grant Memorial, was originally known as the Navy Monument (Goode, 2008). Franklin Simmons (1839–1913) carved it in Carrara Marble in Rome after a rough sketch by Admiral David D. Porter. At the top of the 12-m-high memorial are allegorical figures representing *America* weeping on the shoulder of *History* over the loss of naval defenders during the Civil War. Small boys representing *Neptune* and *Mars* are seated below a figure of *Victory* (Fig. 32).

Marble has been quarried in the Carrara district (ancient Luna) since Etruscan times in Italy (Pliny, 1968, p. 36.14) and is especially noted for its use during the Renaissance by Michelangelo. It is of medium hardness with extremely fine grain (maximum crystals 1.5–2 mm), ranging in color from creamy to snow-white (Meccheri et al., 2007). The monument has been repaired many times on account of losses sustained by climbers and severe weathering of the marble (Figs. 32 and 33). In the past 25 years, many extremities have been replaced, and the stone has been strengthened using an ethyl silicate solution with water repellent (Wolanin, 2003).

Figure 32. Peace Monument, Carrara Marble, after restoration in 2015.

Stop 15: National Gallery of Art

The original building of the National Gallery of Art (1937–1941), a gift of Andrew W. Mellon to the nation, is located on the north side of the Mall between Constitution Avenue, Madison Drive, and 4th and 7th Streets. Its architect was John Russell Pope, also the architect of the National Archives (stop 3.1) and Jefferson Memorial (stop 7). After completion of a second building between 3rd and 4th Streets by I.M. Pei (b. 1917) in 1978, the original building became known as the West Building and the new building, the East Building.

Pope suggested using pale-pink *Tennessee marble* to Andrew Mellon, who selected it despite its significant cost (Daniels and Wertheim, 2014; Finley, 1973, p. 55–56); see Stop 5 section for details about the stone. Blocks were chosen from warm rose to pale pink and placed so that the lower courses of the walls would be darkest, with the color gradually lightening to brilliant white at the dome. Columns of the porticos were also carefully matched:

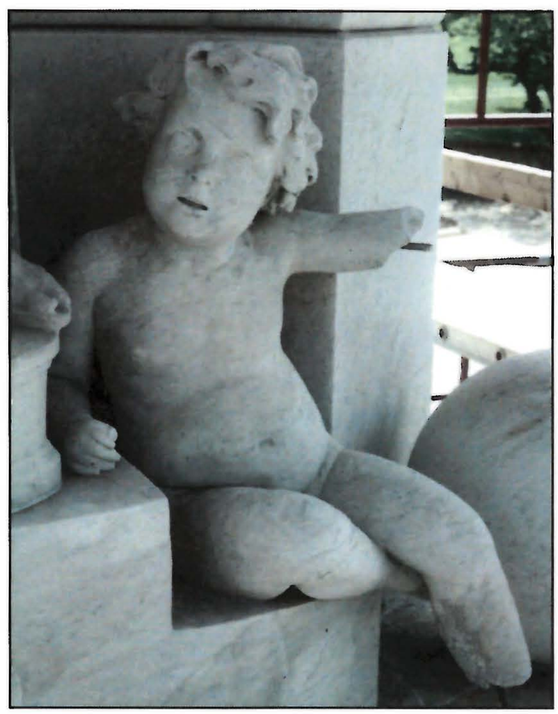


Figure 33. Detail of the figure of *Mars* (at lower right in the previous figure), showing the poor condition of the Carrara Marble before replacement of feet, fingers, and the left arm in 1991. Note the loss of detail in facial features.

Figure 34. National Gallery of Art West Building, *Tennessee marble*. Note stronger banding on outermost columns.

Figure 35. National Gallery of Art East Building during removal of 10-cm-thick blocks of *Tennessee marble* in 2012, subsequently replaced using new anchors.

those with the most prominent banded coloration frame the others (Fig. 34).

On the West Building, *Tennessee marble* is load bearing and mortared to masonry. On the East Building, by contrast, 8-cm-thick blocks are anchored to masonry with 10-cm-wide air gaps in between. The blocks are not intended to be load bearing, but failure of the brackets led to stone stacking and an $85 million bracket replacement project from 2012 to 2014 (Leigh, 2009). More than 17,000 stone panels were removed (Fig. 35), the brackets were replaced, and panels were reinstalled in their original locations.

ACKNOWLEDGMENTS

The authors would like to acknowledge staff of the Museum Conservation Institute who read and commented on this manuscript, Janet Douglas and A. Elena Charola; provided assistance in analyses of Smithsonian stone materials, including Nicole Little, Edward P. Vicenzi, and Gwenaelle Kavich; or supported this work, including Robert Koestler, Paula DePriest, Jessica Johnson, and E. Keats Webb. Thanks also to Smithsonian staff who contributed directly or indirectly to this guide, including Sharon Park, Richard Stamm, and especially Amy Ballard, who read and commented on the manuscript. We would like to thank Constance Lai, Grunley Construction, for her insights into the restoration of buildings on the Mall. Finally, thanks to our reviewers, Joseph T. Hannibal and Eric Doehne. Unless otherwise indicated, all images are courtesy of Carol Grissom.

REFERENCES CITED

Aloiz, E., 2013, Final Report for Investigation of the Feasibility of Nondestructive Measurement of Moisture in Porous Materials Using Prompt Gamma Neutron Activation (PGNA): Washington, D.C., Smithsonian Museum Conservation Institute, MCI# 6453, 114 p.

Aloiz, E., Grissom, C., Davis, J.M., and Livingston, R.A., 2012, Characterization of the Smithsonian Institution's building stones using conventional and advanced analytical methods, *in* Proceedings, 12th International Congress on the Deterioration and Conservation of Stone, Columbia University, http://iscs.icomos.org/pdf-files/NewYorkConf/aloietal.pdf (accessed 15 August 2015).

Arnebeck, B., 1991, Through a Fiery Trial: Building Washington 1790–1800: Lanham, Maryland, Madison Books, 701 p.

Bedini, S.A., 1999, The Jefferson Stone: Demarcation of the First Meridian of the United States: Frederick, Maryland, Professional Surveyors Publishing Co., 184 p.

Bengtson, S., and Rasmussen, B., 2009, New and ancient trace makers: Science, v. 323, p. 346–347, doi:10.1126/science.1168794.

BIG-Bjarke Ingels Group, 2014, Smithsonian Institution south mall campus master plan, http://southmallcampus.si.edu/project-overview.html (accessed 15 August 2015).

Carlhian, J.P., 1991, Smithsonian Institution: South Quadrangle project, *in* Longstreth, R., ed., The Mall in Washington, 1791–1991: Washington, D.C., National Gallery of Art, p. 316–325.

Clabaugh, S.E., and McGehee, R.V., 1972, Precambrian rocks of Llano region, *in* Barnes, V.E., Bell, W.C., Clabaugh, S.E., Cloud, P.E., Jr., McGehee, R.V., Rodda, P.U., and Young, K., eds., Geology of the Llano Region and Austin Area: Field Excursion Guidebook Number 13: Austin, Texas State Bureau of Economic Geology, p. 9–23.

Clifton, J.R., 1987, Preliminary Performance Criteria for Stone Treatments for the United States Capitol: National Bureau of Standards Internal Report 98-3542, 21 p.

Climate Central, 2014, Washington, D.C., and the surging sea: A vulnerability assessment with projections for sea level rise and coastal flood risk, http://sealevel.climatecentral.org/research/reports/washington-dc-and-the-surging-sea (accessed 14 August 2015).

Councill, R.J., 1954, The Commercial Granites of North Carolina: North Carolina Department of Conservation and Development Bulletin 67, 59 p.

Dale, T.N., 1908, The Chief Commercial Granites of Massachusetts, New Hampshire, and Rhode Island: U.S. Geological Survey Bulletin 354, 240 p.

Dale, T.N., 1909, The Granites of Vermont: U.S. Geological Survey Bulletin 404, 143 p.

Dale, T.N., 1912, The Commercial Marbles of Western Vermont: U.S. Geological Survey Bulletin 521, 170 p.

Dale, T.N., 1924, Part II: Constitution and adaptation of the Holston marble of east Tennessee, *in* Nelson, W.A., ed., Marble Deposits of East Tennessee: Nashville, Tennessee State Department of Education Bulletin 28, p. 87–161.

Daniels, M.F., and Wertheim, S., 2014, National Gallery of Art: Architecture and Design: Washington, D.C., National Gallery of Art, 62 p.

Dooley, K., and Herz, N., 1995, Provenance determination of early American marbles, *in* Maniatis, Y., Herz, N., and Basiakos, Y., eds., The Study of

Marble and Other Stones Used in Antiquity: London, Archetype Publishers, p. 243–252.

Evelyn, D.E., 1997, A public building for a new democracy: The Patent Office Building in the nineteenth century [Ph.D. dissertation]: Washington, D.C., George Washington University, 682 p.

Ewing, H., and Ballard, A., 2009, A Guide to Smithsonian Architecture: Washington, D.C., Smithsonian Books, 159 p.

EwingCole, 2009, Arts & Industries Building Historic Structure Report, 204 p., www.si.edu/ahhp/aihrsr2009home.

Fairley, W.M., 1965, The Murphy Syncline in the Tate Quadrangle, Georgia: Georgia Geological Survey Bulletin 75, 79 p.

Finley, D.E., 1973, A Standard of Excellence: Andrew W. Mellon Founds the National Gallery of Art at Washington: Washington, D.C., Smithsonian Institution Press, 193 p.

Fleming, A.H., Drake, A.A., and McCartan, L., 1994, Geologic Map of the Washington West Quadrangle, District of Columbia, Montgomery and Prince George's Counties, Maryland, and Arlington and Fairfax Counties, Virginia: Reston, Virginia, U.S. Geological Survey Geologic Quadrangle Map GQ-1748, scale 1:24,000.

Frye, A., 1986, Roadside Geology of Virginia: Missoula, Montana, Mountain Press, 278 p.

Goode, J.M., 2008, Washington Sculpture: A Cultural History of Outdoor Sculpture in the Nation's Capital: Baltimore, Maryland, Johns Hopkins, 830 p.

Grissom, C.A., Charola, A.E., and Henriques, M.A., 2002, To paint or not to paint: A difficult decision, *in* Protection and Conservation of the Cultural Heritage of the Mediterranean Cities: Proceedings of the 5th International Symposium on the Conservation of Monuments in the Mediterranean Basin, Seville, Spain, 2000: Lisse, the Netherlands, A.A. Balkema, p. 585–592.

Grissom, C.A., Gervais, C., Little, N., Bieniosek, G., and Speakman, J., 2010, Red "staining" on marble: Biological or inorganic origin?: Bulletin of the Association for Preservation Technology, v. 41, p. 11–20.

Grissom, C.A., Vicenzi, E.P., Livingston, R.A., Aloiz, E., Little, N., Giaccai, J., and Freedman, W., 2014, Manganese in black crusts on Seneca sandstone: Microscopy and Microanalysis, v. 20, Supplement S3, p. 2044–2045.

Gurney, G., 1985, Sculpture and the Federal Triangle: Washington, D.C., Smithsonian Institution Press, 464 p.

Hafertepe, K., 1984, America's Castle: The Evolution of the Smithsonian Building and Its Institution, 1850–1878: Washington, D.C., Smithsonian Institution Press, 180 p.

Hannibal, J.T., 1995, Use of trace fossils in determining provenance of dimension stone: An example from Ohio, *in* Maniatis, Y., Herz, N., and Basiakos, Y., eds., The Study of Marble and Other Stones Used in Antiquity: ASMOSIA III: London, Archetype, p. 253–258.

Hannibal, J.T., 2015, The Man in the urn: The geological contributions of Joseph Stanley-Brown, geologist, financier, and presidential aide: Earth Sciences History, v. 34, no. 1, p. 102–123, doi:10.17704/1944-6187-34.1.102.

Hannibal, J.T., and Bolton, D.W., 2015, this volume, Building stones of Baltimore, the Monumental City, *in* Brezinski, D.K., Halka, J.P., and Ortt, R.A., Jr., eds., Tripping from the Fall Line: Field Excursions for the GSA Annual Meeting, Baltimore, 2015: Geological Society of America Field Guide 40, doi:10.1130/2015.0040(14).

Hannibal, J.T., Scherzer, B.A., and Saja, D.B., 2007, The Euclid bluestone of northeastern Ohio: Quarrying history, petrology, and sedimentology, *in* Shaffer, N.R., and DeChurch, D.A., eds., Proceedings of the 40th Forum on the Geology of Industrial Minerals: Bloomington, Indiana, Indiana Geological Survey Occasional Paper 67, p. 70–81.

Hockman, A., and Kessler, D.W., 1957, A Study of the Properties of the U.S. Capitol Sandstone: National Bureau of Standards 4998, 29 p.

Hord Coplan Macht et al., 2012, Grant Memorial Investigative Condition Assessment Report for the National Park Service: National Mall and Memorial Parks (NAMA) 151838, Task Order No. P11PD21880, 132 p.

Jacob, J.M., 2005, The Washington Monument: A Technical History and Catalog of the Commemorative Stones: National Park Service, 234 p., www.nps.gov/parkhistory/online_books/wamo/stones.pdf.

Kaese, D.S., and Lynch, M.F., 2008, Marble in (and around) the city: Its origins and use in historic New York buildings: Common Bond, v. 22, no. 2, p. 7.

Knopf, E.B., and Jones, A.I., 1929, The geology of the crystalline rocks of Baltimore County, *in* Maryland Geological Survey, Baltimore County: Baltimore, Johns Hopkins, p. 97–217.

Lathram, E.H., and Thiel, G.A., 1946, A comparison of the physical properties and petrographic characteristics of some limestones and dolomites of southeastern Minnesota: Journal of Sedimentary Research, v. 16, no. 2, p. 72–85.

Latrobe, B.H., 1809, An account of the freestone quarries on the Potomac and Rappahannoc Rivers: American Philosophical Society Transactions, v. 6, p. 283–293, doi:10.2307/1004804.

Lee, K.Y., and Froelich, A.J., 1989, Triassic-Jurassic Stratigraphy of the Culpepper and Barboursville Basins, Virginia and Maryland: U.S. Geological Survey Professional Paper 1472, 67 p.

Leigh, C., 2009 (December 8), An ultramodern building shows signs of age: The Wall Street Journal, www.wsj.com/articles/SB10001424052748703558004574581890709007 56.

Lewis, M.D., and MacDonald, W.H., 1997, Assuring the durability of stone facades in new construction, *in* Labuz, J.F., ed., Degradation of Natural Building Stone: Reston, Virginia, ASCE, Geotechnical Special Publication No. 72, p. 116–138.

Livingston, R.A., Grissom, C.A., Giaccai, J., Little, N., Vicenzi, E.P., Freedman, W., and Aloiz, E., 2014, Black crusts on urban sandstone: Natural or anthropogenic? Goldschmidt Meeting 2014 [abs.]: Sacramento, California, p. 1501.

Matero, F.G., and Teutonico, J.M., 1982, The use of architectural sandstone in New York City in the 19th century: APT Bulletin, v. 14, no. 2, p. 11–17.

McCarthy, B.E., and Ginell, W.S., 2001, Deterioration of the U.S. Capitol Building Aquia Creek Sandstone Columns at the National Arboretum, Washington, D.C.: Los Angeles, Getty Conservation Institute, 45 p.

McGee, E.S., 1989, Mineralogical Characterization of the Shelburne Marble and the Salem Limestone Test Stones Used to Study the Effects of Acid Rain: U.S. Geological Survey Bulletin 1889, 45 p.

McGee, E.S., 1996, Investigation of the Column Capital Volute Failure at the Jefferson Memorial: U.S. Geological Survey Open-File Report 96-518, 42 p.

McGee, E.S., 1999, Colorado Yule Marble: Building Stone of the Lincoln Memorial: U.S. Geological Survey Bulletin, v. 2162, 45 p.

McKee, H.J., 1969, Historic American Building Survey: U.S. General Post Office, 18 p., lcweb2.loc.gov/master/pnp/habshaer/dc/dc0200/data/dc0290data.pdf.

McKee, H.J., 1973, Introduction to Early American Masonry: Stone, Brick, Mortar and Plaster: Washington, D.C., National Trust for Historic Preservation, 92 p.

Meccheri, M., Molli, G., Conli, P., Blasi, P., and Luca, V., 2007, The Carrara marbles (Alpi Apuane, Italy): A geological and economical updated review: Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, v. 158, no. 4, p. 719–736, doi:10.1127/1860-1804/2007/0158-0719.

Merguerian, C., and Merguerian, J.M., 2014, Field Trip Guidebook Isham and Inwood Parks, NYC for Lamont-Doherty Earth Observatory Manhattan Prong Workshop: Palisades, New York, Lamont Doherty Earth Observatory, Columbia University, 59 p.

Merrill, G.P., 1910, Stones for Building and Decoration: New York, Wiley, 551 p.

Merrill, G.P., and Matthews, E.B., 1898, The Building and Decorative Stones of Maryland: Maryland Geological Survey, 241 p.

Mossotti, V.G., Eldeeb, A.R., Reddy, M.M., Fries, T.L., Coombs, M.J., Schmiermund, R.L., and Sherwood, S.I., 2001, Statistical Compilation of NAPAP Chemical Erosion Observations: U.S. Geological Survey Open-File Report 98-755, 208 p.

Mumford, L., 1955, The Brown Decades: A Study of the Arts in America 1865–1895: New York, Dover, 266 p.

National Capital Planning Commission, 2014, Memorials & Museums Master Plan, Washington, v. 2015, National Capital Planning Commission, www.ncpc.gov/ncpc/Main(T2)/Planning(Tr2)/2MPlan.html.

National Geodetic Survey, 2015, 2013–2014, Survey of the Washington Monument: Washington, D.C., National Oceanic and Atmospheric Administration, 100 p.

National Park Service, 2010, National Mall Plan: Summary: Enriching Our American Experience: Envisioning a New Future: Washington, D.C., U.S. National Park Service, 44 p.

Nelson, W.A., 1924, Marble Deposits of East Tennessee: Tennessee State Department of Education Bulletin 28, 264 p.

O'Connor, J.V., 1989a, The District of Columbia, *in* Moore, J.E., and Jackson, J.A., eds., Geology, Hydrology, and History of the Washington, DC Area: Alexandria, Virginia, American Geological Institute, p. 3–9.

O'Connor, J.V., 1989b, A geologic walk through Rock Creek Park (northern section), *in* Environmental, Engineering, and Urban Geology in the United States: Washington, D.C., American Geophysical Union, Trip Number T209, p. 3.

Obata, G., 1991, Issues relative to the Mall in designing the National Air and Space Museum, *in* Longstreth, R., ed., The Mall in Washington, 1791–1991: Washington, D.C., National Gallery of Art, p. 304–315.

Olsen, P.E., 1980, Triassic and Jurassic formations of the Newark basin, *in* Manspeizer, W., ed., Field Studies in New Jersey Geology and Guide to Field Trips: 52nd Annual Meeting of the New York State Geological Association: Newark, Rutgers University, Newark College of Arts and Sciences, p. 2–39.

O'Neil, E.F., 1995, Repair and Maintenance of Masonry: Case Histories, Technical Report REMR-CS-46: U.S. Capitol: U.S. Corps of Engineers, 105 p.

Ottesen, C., 2011, A Guide to Smithsonian Gardens: Washington, D.C., Smithsonian Institution, 163 p.

Owen, R.D., 1849, Hints on Public Architecture: New York, Putnam, 119 p.

Park, W.C., and Schot, E.H., 1968, Stylolites: Their nature and origin: Journal of Sedimentary Petrology, v. 8, no. 1, p. 175–191.

Pattison, W.D., 1957, Beginnings of the American Rectangular Land Survey System, 1784–1800: Chicago, The University of Chicago Press, 250 p.

Patton, J.B., and Carr, D.D., 1982, The Salem Limestone in the Indiana Building-Stone District: Indiana Department of Natural Resources Geological Survey Occasional Paper 38: Indiana State Geological Survey, 37 p.

Peck, G., 2013, The Smithsonian Castle and the Seneca Quarry: Charleston, South Carolina, The History Press, 141 p.

Penczer, P.R., 2007, The Washington National Mall: Arlington, Virginia, Oneonta Press, 128 p.

Pliny, 1968, Natural History, ed. and trans. by H. Rackham and E.E. Eichholz: Cambridge, Massachusetts, Loeb Classical Library.

Purdum, W.D., 1940, The history of the marble quarries in Baltimore County, Maryland: College Park, University of Maryland, 13 p., www.archive.org/details/TheHistoryOfTheMarbleQuarriesInBaltimoreCountyMaryland.

Quinn Evans Architects, 2013, National Air and Space Museum: Exterior Envelope Study, Smithsonian Office of Facilities Engineering and Operations (OFEO) Project No. 1206101, 943 p.

Reed, J.C., and Obermeister, S.F., 1989, The foundations of a nation's capital, *in* Moore, J.E., and Jackson, J.A., eds., Geology, Hydrology, and History of the Washington, DC Area: Alexandria, Virginia, American Geological Institute, p. 27–50.

Reps, J.W., 1967, Monumental Washington: The Planning and Development of the Capital Center: Princeton, New Jersey, Princeton University Press, 221 p.

Robbins, E.I., and Welter, M.H., 2001, Building Stones and Geomorphology of Washington D.C.: The Jim O'Connor Memorial Field Trip: GSW Field Trip Guide No. 62001, Geological Society of Washington, 67 p., www.gswweb.org/fieldtrips.html.

Robertson, C.J., 2006, Temple of Invention: History of a National Landmark: London, Scala, 106 p.

Robertson, M.-R., 1989, Building blocks, *in* Moore, J.E., and Jackson, J.A., eds., Geology, Hydrology and History of the Washington, DC Area: Alexandria, Virginia, American Geological Institute, p. 62.

Ruane, M.E., and Rivero, C., 2012 (August 6), A renovated reflecting pool: The Washington Post, Washington, D.C.

Sanford, R.F., 1980, Textures and mechanisms of metamorphic reactions in the Cockeysville marble near Texas, Maryland: The American Mineralogist, v. 65, p. 654–669.

Savage, K., 2009, Monument Wars: Washington, D.C., the National Mall, and the Transformation of the Memorial Landscape: Berkeley, California, University of California Press, 390 p.

Scott, P., and Lee, A.J., 1993, Buildings of the District of Columbia: New York, Oxford University Press, 463 p.

Shadidi, S.G., Pakzad, S.N., Ricles, J.M., Martin, J.R., Olgun, C.G., and Godfrey, E.A., 2014, Behavior and damage of the Washington Monument during the 2011 Mineral, Virginia, earthquake, *in* Horton, J.W., Chapman, M.C., and Green, R.A., eds., The 2011 Mineral, Virginia, Earthquake, and Its Significance for Seismic Hazards in Eastern North America: Geological Society of America Special Paper 509, p. 235–252, doi:10.1130/2015.2509(13).

Sharp, L.I., 1985, John Quincy Adams Ward: Dean of American Sculpture: Cranbury, New Jersey, Associated University Presses, 300 p.

Siegesmund, S., and Durrast, H., 2011, Physical and mechanical properties of rocks, *in* Siegesmund, S., and Snethlage, R., eds., Stone in Architecture: Properties, Durability: Heidelberg, Springer, p. 97–225, doi:10.1007/978-3-642-14475-2_3.

Southworth, S., Brezinski, D.K., Orndorff, R.C., Repetski, J.E., and Denenny, D.M., 2008, Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and Virginia: U.S. Geological Survey Professional Paper 1691, 157 p.

Stinnard, M., 2005 (1 February), Natural stone reflects Indian culture: Stone World, www.stoneworld.com/Articles/83351-natural-stone-reflects-indian-culture.

Sykes, J., 1986, [U.S. Capitol] Laboratory Report, Project 486-020, Kansas City, KS, ProSoCo, Inc., 21 p.

Torres, L., 1976, Tuckahoe Marble: The Rise and Fall of an Industry in Eastchester, New York, 1822–1830: Harrison, New York, Harbor Hill Books, 91 p.

Torres, L., 1985, "To the Immortal Name and Memory of George Washington": The United States Army Corps of Engineers and the Construction of the Washington Monument: Washington, D.C., U.S. Government Printing Office, 145 p.

The Trust for the National Mall, Campaign for the National Mall, Washington, D.C., 2015, http://nationalmall.org/turf-phaseii.

Vandenbusche, D., and Myers, R., 1970, Marble, Colorado: City of Stone: Denver, Golden Bell Press, 229 p.

Voynick, S., 2015, Colorado's Yule quarry: Rock and Gem, v. 45, no. 5, p. 52–56.

Waffe, C.B., 2001, A prime meridian for the United States: Journal for the History of Astronomy, v. 32, no. 107, p. 157–159.

Weiss, N.R., Ennis, M.T., and Schnabel, L., 1987, Exterior Masonry Study of the Old Patent Office Building, Washington, DC: New York, Center for Preservation Research, Columbia University Graduate School of Architecture and Planning, 38 p.

Wells, D., Egan, J.A., Murphy, D.G., and Paret, T., 2015, Ground shaking and structural response of the Washington Monument during the 2011 Mineral, Virginia, earthquake, *in* Horton, J.W., Chapman, M.C., and Green, R.A., eds., The 2011 Mineral, Virginia, Earthquake, and Its Significance for Seismic Hazards in Eastern North America: Geological Society of America Special Paper 509, p. 199–233, doi:10.1130/2015.2509(12).

Wessel, D.P., 2011, Case study: Field observations on the effectiveness of zinc strips to control biocolonization of stone, *in* Charola, A.E., McNamara, C., and Koestler, R.J., eds., Biocolonization of Stone: Control and Preventive: Washington, D.C., Smithsonian Institution Scholarly Press, Smithsonian Contributions to Museum Conservation No. 2, p. 109–112.

Williams, G.P., 1977, Washington, D.C.'s Vanishing Springs and Waterways: U.S. Geological Survey Circular 752, 19 p.

Withington, C.F., 1981, Building Stones of Our Nation's Capital: Washington, D.C., U.S. Geological Survey, 44 p.

Wolanin, B., 2003, The conservation treatment history of the Peace Monument, Washington, D.C., *in* Weathering the Test of Time: The Preservation of Marble Monuments and Architectural Landmarks [abs.]: Washington, D.C., Association for Preservation Technology, Washington, D.C., Chapter, 3 p.

Wones, D.R., and Goldsmith, R., 1988, Intrusive rocks of eastern Massachusetts, U.S. Geological Survey Professional Paper 1366-I, *in* Hath, N.L.J., ed., The Bedrock Geology of Massachusetts: U.S. Geological Survey Professional Paper 1366-E–J, p. I31–I33.

Wrabel, F.A., 2008, The Northern Central Railroad and Parkton: History Trails, v. 40, no. 1–2, p. 1–19.

Manuscript Accepted by the Society 11 August 2015