

## BUILDING AND MONUMENTAL STONES OF THE UNITED STATES

Anyone who examines stones from existing buildings and monuments will at some point encounter a stone which they do not recognize. If they then go on to search for reference works to help them to identify not only the type of stone but its original source and even sources for replacements and repairs, they will most likely encounter some problems. The surveys and publications of the United States Geological Survey and the various state Geological Surveys will normally have described all of the stones and their sources in terms of counties, nearby towns, and even individual quarries. However, these publications may have appeared back in the nineteenth century, and there are hundreds of them. Clearly if one is starting with a totally unknown stone which comes from an old building in New York, for example, one cannot search every survey in the country for its source. There are no comprehensive works which are designed specifically for the needs of the restorer or conservator of buildings and monuments. The following schedules of names and descriptions are a first attempt at remedying this lacuna. Obviously such a short study cannot be comprehensive for all periods and for the whole of the United States, but it may be found to be helpful for the eighteenth and nineteenth centuries in the eastern part of the country. Seventeenth century stone sources were normally very small and very close to the building in which the stone was to be used. This could well mean that the "quarry" has never been identified let alone studied and the stone subjected to petrographic analysis.

## NAMES AND DESCRIPTIONS OF STONES

### Granites

Connecticut, New London County: Granite and gneiss. From 1643–1648, at East Lyme and Niantic the quarries produced an even-grained pinkish gray granite, marketed in the 1930s as "Golden Pink Niantic." At Groton the quarry produced a fine grained greenish gray granite; Millstone Quarry produced fine grained dark gray. Waterford granite is buff gray but light gray when hammered. It takes a fine polish and has been sold as "Connecticut White." Windham County produces a biotite granite gneiss quarried near Oneco. The "Oneco" granite is a fine-grained dark bluish gray stone.

Georgia, Elbert County: Elberton Granite, Elberton Blue, Elberton Gray, Oglesby Light Blue, Oglesby Dark Blue. Fine grained bluish gray biotite granite with

black and dark gray grains, also a light gray medium grain granite.

Massachusetts: Quincy Granite, Medium Dark and Extra Dark Quincy Granite. A hornblende pyroxene granite quarried in and around Quincy, the general color ranges from a medium or bluish gray, to a very dark bluish gray all with blue or blue black spots (from 1825 at Bunker Hill Quarry). An unusual variety is known as "Goldleaf" and is characterized by yellowish and reddish specks of iron oxide derived partly from the oxidation of the unusual mineral aenigmatite (a titanio-silicate of ferrous iron and sodium with aluminum and ferric iron). Quincy granites are unusual in that they do not contain mica.

Massachusetts: Rockport Granite, Moose-A-Bec Granite, Rockport. Hornblende granite of which the Rockport Gray and Sea Green are medium to coarse grained, hard, tough and durable taking a high polish; they are colored gray or olive green spotted with black. The Moose-a-Bec is a dark reddish gray, biotite granite with white and pinkish feldspars and smaller spots of black biotite. Example: Soldiers and Sailors World War Memorial, Pittsfield, MA.

Maine, Deer Island, Crotch Island: Goss Pink, Stonington Pink. Knox County: Vinalhaven Hurricane Island and Fox Island Granite. Coarse-grained gray biotite granite with pink to lavender; widely used for buildings and bridges. Contains orthoclase, microcline, oligoclase, smoky quartz, and biotite. Crotch Island quarry opened in 1870. Compressive strength 23,620 lb/in<sup>2</sup>. Example: St. John the Divine, New York.

Minnesota: St. Cloud, Rockville Pink, Minnesota Pearl and Cold Spring Rainbow Granite. A coarse grained red, pink, dark gray, or deep green background with swirling gneissic bands and knots of black. Takes and holds a fine polish. Weight 185 lb/ft<sup>3</sup>. Crushing strength 23,000 lb/in<sup>2</sup>. Modulus of rupture 3042 lb.

Minnesota: St. Cloud, Rockville Pink, Minnesota Pearl Pink Granite. Medium grained pinkish gray, red, and fine grained gray; and coarse grained pink with gray quartz and biotite granites. Weight 175 lb/ft<sup>3</sup>. Crushing strength 20,000 lb/in<sup>2</sup>. Modulus of rupture 2000 lb. SiO<sub>2</sub> 62.15%; Al<sub>2</sub>O<sub>3</sub> 19.41%; Lime 2.27%; Phosphorus 0.13%.

New Hampshire: Milford Granite. Fine, medium, and coarse grained light gray, and pink granites with coarse black grains; a quartz monzonite. Examples: Columbia University Campus such as base of Low Library, New York.

New Hampshire: Concord Granite. Fine to medium grained light gray biotite-muscovite granite with the soft brownish color of the muscovite. The potassium feldspar crystals are very small giving the granite a fine grain. A second variety known in 1927 as Swenson's Antique Granite was colored warm buff and gray and was said to be reminiscent of old ivory in color. Examples: Concord State House 1816–1819 and Old State's Prison, Concord, 1812. Essex County Hall of Records, Newark, NJ.

North Carolina: Mount Airy Granite. Medium grained even textured light gray to white biotite granite, used for buildings and monuments. Biotite has some tendency to segregate in streaks. Quarry opened 1889, first shipment 1890. Examples: columns capitals and panels, Municipal Building, New York. SiO<sub>2</sub> 70.70%; Al<sub>2</sub>O<sub>3</sub> 16.50%; Fe<sub>2</sub>O<sub>3</sub> 2.34%; MgO 0.29%; CaO 2.96%; Na<sub>2</sub>O 4.56%; K<sub>2</sub>O<sub>3</sub> .45%; FeS<sub>2</sub> 0.09%. Weight 165 lb/ft<sup>3</sup>. Crushing strength 23,068 lb/in<sup>2</sup>.

Rhode Island: Westerly Blue, Dark Pink, and Light Pink Granite. Fine grained gray, bluish gray, and brown granites, typically all with "pepper and salt" appearance caused by fine black grains. A medium coarse grained variety is colored a reddish gray speckled with black; this stone is a medium red when polished. From ca. 1847. Examples: Declaration of Independence Monument, Boston, MA.

Rhode Island: Westerly Granite. A very fine grained white granite when hammered but a clear dark blue when polished.

Virginia: Petersburg Granite. Medium grained gray; used for buildings and monuments.

Virginia: Richmond Granite. Fine grained, light gray biotite granite; used for buildings and monuments.

Vermont: Barre. Fine textured, medium grained white to light and medium dark gray biotite granite; used for all purposes. There is also a dark blue gray used for polishing only and a light gray for hammered work. The first quarries at Barre operated ca. 1814. The dark Barre granite consists of about 65% feldspars, 27% quartz, and 8% mica. This is the largest producer of granite in the United States.

### Marbles: Including Orthomarbles and Metamarbles

Alabama, Talladega County: Alabama Marble. A fine grained white marble with variations of more or less creamy color and two varieties with either fine pencil

like grayish veins or heavier veins of a greenish or dark gray with orange or pink clouded borders to the veins. Example: Interior, United States Custom House, New York, (Cass Gilbert) 1899–1907; and the Arkansas State Capitol.

Colorado, Yule Creek: Leadville Quarries, upper part medium grained white calcitic marble; lower part dolomitic (primarily 1886–1940). Examples: Tomb of the Unknown Soldier and the Lincoln Memorial.

Georgia, Tate District, Tate and Marble Hill: Murphy Marble. Medium to coarse grained predominantly calcitic white, rose to deep pink, veined and mottled with greenish black actinolite and hornblende. In 1927, the Georgia Marble Company advertised that their White and Silver Grey Georgia Marbles were unexcelled for sculpture work exposed to the weather, the marble being unaffected by even the most severe weather. Examples: New York Stock Exchange is Georgia White; Buckingham Fountain, Grant Park Chicago is Georgia Pink. Columns and monoliths 30 ft long by 4 ft diameter. CaCO<sub>3</sub> 98.96%; MgCO<sub>3</sub> 0.13%; Al<sub>2</sub>O<sub>3</sub> 0.22%; SiO<sub>2</sub> 0.61%; Loss 0.08%. Weight 165 lb/ft<sup>3</sup>. Water absorption after 24-hr immersion 0.028%.

New York: Catskill Marble. Fossiliferous limestone dark brown in color with crinoids. Very hard and dense. Used in buildings and engineering works.

New York, Dutchess County: South Dover, Dover White. Medium grained very white dolomitic marble used extensively for fine building work (by 1815).

New York: Tuckahoe. White coarse grained dolomitic marble. Once extensively used for building work.

Tennessee: Knoxville District, East Tennessee. A wide range of thick bedded Palaeozoic crystalline limestones which take a high polish and are known as Holston orthomarble; the predominant colors are pinks but there is a range from light gray and pinkish gray, via deep pink and red to a deep chocolate brown.

Usually used for interiors, the names of the Tennessee marbles are usually descriptive of the distinguishing features in a polished state, for example, Dark Cedar Tennessee (dark chocolate with fossil fragments), Appalachian Dark Chocolate, and Appalachian Roseal (fine grained grayish pink with splotches of white, pink, rich red, and black). Many varieties contain fossils which may range from indistinct fragments to very large straight shelled cephalopods as large as seven feet long. The United States Government opened the first quarries in 1838 for interior mar-

ble for the U.S. Capitol. In 1934 Bowles noted that Tennessee marble accounted for 35.5% of the total value of marble produced in the country.

Vermont: Clarendon marble. A number of varieties for both exterior and interior use, light in color generally with a white background with gray and green clouded and veined varieties; there is also a green veined cream and a cream with golden vein and blue. Example; Exterior, State Educational Building, Albany NY. Crushing strength 14,000 psi. Water absorption with immersion 0.01%.

Vermont: Pittsford District. Medium to coarse grain light bluish gray. Example: Scott Fountain, Belle Isle, Detroit made from single 65-ton block.

Vermont: Rochester Quarry. Serpentine marble, "Verde Antique" deep green with light green and almost white veining.

Vermont: Danby Quarry, Dorset Mountain. Close grained white with soft clouding of grey and green; occasional tints of light tan or "gold" (since 1907).

Vermont: Imperial Quarry Danby, Dorset Mountain. Close grained white with gray and beige markings; white with bold gray green veining (since 1907).

### Limestones

Indiana or Bedford Limestone. Termed Salem limestone by the geological surveys of Indiana and Illinois, and Spergen limestone by the U.S. Geological Survey, a calcarenite or detrital limestone composed of oolites, fossil shells, and carbonate detritus. The stone occurs in massive beds; and single blocks 60 ft, long, 12 ft high, and 4 ft thick are commonly available. This stone comprises 60% of the dimension limestone produced in the United States. Production commenced in 1929.

Indiana limestone is gray or bluish gray below groundwater level but pale buff to light grey as it is exposed and weathered. Stylolites or "crowsfeet" may occur. These resemble graph lines in appearance and are present along bedding planes and locally throughout the rock. They consist of black shaly bituminous matter and occasional pyrites and other ferruginous material. They are not usually large enough to cause weathering and staining problems. Brown staining may result from contact with alkalis and organic matter, for example, ferric hydroxide staining from concrete.

Bedford Blue: 1.15% SiO<sub>2</sub>; 1.91% Fe<sub>2</sub>O<sub>3</sub>; 53.25% CaO; 1.23% MgO; 42.40% CO<sub>2</sub>.

Bedford Buff: 0.77% SiO<sub>2</sub>; 0.63% Fe<sub>2</sub>O<sub>3</sub>; 3.0% Al<sub>2</sub>O<sub>3</sub>; 52.85% CaO; 1.18 MgO; 41.54% CO<sub>2</sub>.

Weight per cubic foot: 140.3–152.4 lb/ft<sup>3</sup>. Compressive strength: Buff 9012 psi; Blue 10,823 psi. Shear strength: Buff 1222 psi; Blue 1016 psi.

Tennessee: Holston orthomarl (see **Marbles**).

### Sandstones

Connecticut: Portland Brown Stone. A medium to fine textured Upper Triassic sandstone of uniform reddish brown color, with flakes of muscovite parallel to the bedding planes. Quarries at Portland opened in 1665. Examples: Morris-Jumel Mansion, ca. 1765, New York; Cooper Union Building, New York 1859; Church of the Ascension, Fifth Ave and 10th St. New York, 1841. Also quarried at Middletown, Middlesex County, CN. Crushing strength 13,980–15,020 lb/in.<sup>2</sup>. Specific gravity 2.35. Ratio of absorption 1:40. Silica 70.11%; alumina 13.49%; Fe<sub>2</sub>O<sub>3</sub> 4.85%; lime 2.39%; magnesia 1.44%; soda and potash etc. 7.37.

Massachusetts: East Longmeadow Sandstone. Upper Triassic sandstone evenly fine-grained brick red to reddish brown in color. Iron oxide cementing quartz grains. Examples: St. George's Church, Stuyvesant Sq. and East 16th St. New York, 1848; Bobst Library, New York University, 70 Washington Sq., New York, 1973.

New Jersey: New Jersey Brownstone. An Upper Triassic compact sandstone fine to coarse grained, thickly bedded with and without distinct lamination. The stone is arkosic with a cement of silica and sometimes iron oxide. The colors vary but include white-gray-brown and red. Examples: Trinity Church, Broadway and Wall St., New York, 1846; Villard Houses, Madison Ave. between 59 and 61 Sts., 1884. Quarries; Passaic, Belleville, North Arlington, Pleasantdale, Patterson, Little Falls and Osborne and Marsellis. The stone and hence the quarries extend in a belt 32 miles wide along the Delaware River above Trenton, and from the Palisades on the Hudson to the Ramapo River at Suffern NY.

New York: New York Bluestone, Genesee Valley Bluestone. A fine grained dense even gray-blue sandstone. Genesee Valley Bluestone is quoted in Sweet's in 1927 as having a crushing strength of 19,970 lb/in.<sup>2</sup>. Weight

150 lb/ft<sup>3</sup>. Silica 76.50%; alumina 14.75%; Fe<sub>2</sub>O<sub>3</sub> 6.35%; water 2.00%. The Genesee Valley Quarry opened in 1899 at Ambluco in Wyoming County, NY. Massive use for paving but also used for ashlar and bed courses. Extremely durable and wear resistant. An analysis for a sandstone from this region and known as Bigelow bluestone (also known as Ulster bluestone) by F.L. Nason and published by Dickinson in 1893 was as follows: Minerals: quartz and feldspar, quartz grains angular, some feldspar grains fresh and others almost completely decomposed; cementing material silica; no carbonate of lime and very little iron oxide.

New York, Catskills: Saugerties Bluestone. A fine grained dense, even gray-blue sandstone of the Upper Devonian period, with fine large slabs, some containing fossil brachiopods. Extensive quarrying for paving slabs for New York City all through the nineteenth century. The old quarries now contain Harvey Fite's famous monumental sculpture Opus 40 which was built 1939–1976. The grain structure is extremely fine and compact. Freshly broken surfaces are bluish gray but weathered surfaces oxidize to a grayish brown.

New York: Medina Sandstone. Upper Silurian fine-grained sandstone, quartz grains with minor amounts of kaolinized feldspar; colors gray to red and variegated. Locations: western New York with major deposits in Orleans County at Medina, also in Niagara County at Lockport, for example, and Monroe County at Brockport. The deposits extend into Canada where the stone was also extensively quarried.

New York: Potsdam Sandstone. An Upper Cambrian fine to medium grained sandstone with angular grains of clear quartz in a siliceous cement. The colors range from light pink to light red and reddish brown and there is also a variegated type. Sources: northern New York, Racquette River Valley, Lawrence County, northern Adirondacks. Potsdam Quarry since 1856.

Ohio, Cuyahoga County, Lorain County, northern Ohio: Berea, South Amherst Quarries. The Mississippian sandstone commonly occurs as fill in deep ancient channels cut in underlying shales. Some of the quarries at South Amherst are 235 ft deep. The colors and types vary but a typical Berea is light gray medium- to fine-grained protoquartzite with silica and some clay cement. Honey or buff colored variations exist with a coarser grain version with fine rust colored banding. In polluted environments rust-colored staining may be found to consist of individual rusting grains of ferric compounds (from ca. 1840.) Examples: carved stone-

work of the Ottawa Parliament Buildings, East Block, 1859; Oswego, NY, Custom House 1858.

Ohio: Massillon Sandstone, Middle Pottsville; Glenmont, Holmes County, Briar Hill; Ohio. The type consists of a wide variety of sandstones which tend to be cross-bedded and poorly sorted with grain sizes varying from fine to coarse. Typical dimensioned stone is buff to light ochre in color with darker rust colored and even dark red-brown fine irregular bands or veins. The latter are usually left in relief as the stone weathers. One variety of Briar Hill Sandstone is a warm Indian Red in color. Briar Hill Sandstone's chemical analysis is as follows: silicon dioxide 95.00%; aluminum oxide 2.75%; iron oxide 0.60%; calcium oxide 0.30%; magnesium oxide 0.25%; loss in ignition 1.10%. Absorption 6% by weight. Crushing strength 4000–6000 lb/in.<sup>2</sup>.

Pennsylvania: Pennsylvania Brownstone. An Upper Triassic, fine-grained, even textured, reddish brown to purplish brown sandstone with fine angular quartz grains in a cement of clay and iron oxide. Principal quarry was at Hummelstown, Dauphin County from 1867.

Pennsylvania: Delaware Valley Sandstone, Lumberton Quarry, Lumberville, Bucks County. A variety of sandstones with colors ranging from buff and light bluish gray to dark gray to brown. Lumberton Quarry has operated since 1852. Used as ashlar but also as split face fieldstone and rubble.

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## STONE CONSERVATION CASE HISTORIES

The following extracts from case histories and specification notes are taken from the files of the Center for Preservation Research, Columbia University, New York. They are included here to illustrate the form and contents of a series of typical conservation projects. They also illustrate precisely how typical technical problems are handled both in terms of techniques and materials, and how the specifications are written.\*

### A CHURCH IN NEW YORK

Purchase of scaffolding by the Church, in an amount determined by the dimensions of the Tower and Spire, could be extremely cost-effective. The Church should pay a contractor for dismantling and reerection as the project proceeds, but could sell the (now used) scaffolding upon completion of the work, recovering a considerable percentage of the cost. Consideration should also be given to the advance purchase of some materials, such as colored sands and replacement stone, that could become difficult to secure in the later years of the work.

Final contract documents should be distributed to a short list of qualified restoration contractors for negotiated bidding. Submittal requirements must include the identification of all proposed subcontractors, a list of references and of recent reviews, a proposed work schedule, and price. It may be appropriate to make an initial award (perhaps as early as summer, 1987) for a demonstration contract involving only 2 or 3 bays of the Church, or the Soldier's Monument, as an opportunity for full-scale field-testing of all methods. This would permit final reevaluation of many important as-

\* Frank G. Matero was the author of the original studies and specifications.

pects of the project, including coordination and supervision needs, contractor competence, safe storage, handling and disposal of commercial projects, impact upon Church operations, total cost, and visual aesthetics.

Proper execution of the full project, which we estimate as 3 to 5 years in duration, will require close collaboration of the Church and its consultants in the matter of supervision. Technical judgments will certainly need to be made at all stages of the work; there must be established a mechanism to do so quickly and intelligently. Complete familiarity with the condition of the Church, with earlier restoration efforts, and with the materials and techniques being utilized by the contractor is necessary for all persons involved in on-site decision-making.

## VII.2. Specific Operations

### VII.2.1. Cleaning

Preliminary cleaning tests were carried out on June 25, 1986, on the Monument in the northeast corner of the Churchyard. The Monument, built shortly after completion of the Church, is said to be of the Little Falls sandstone, and has a treatment history that is similar to that of the Church. Testing was done on the north face (see Appendix B, Fig. 17), and the northeast corner. Acidic products conventionally used for the cleaning of sandstone did not remove the soiling effectively, because of the presence of organic coatings (the earlier treatments) that prevent the cleaners from coming into direct contact with the stone surface.<sup>1</sup>

The most complete series of tests was done to evaluate the possibility of alkaline degreasing, followed by acidic cleaning.<sup>2</sup> Four commercially manufactured alkaline products were tested. These were:

Heavy Duty Paint Stripper (HDPS);  
Limestone Prewash (LP);

<sup>1</sup> Pressure washing without chemical treatment was also found to be ineffective. This surely would have been the case with water spraying, and with steam. Abrasive methods were ruled out as excessively damaging and dangerous. For a review of available techniques, see Ashurst, John, "Cleaning and surface repair," in *Conservation of Historic Stone Buildings and Monuments* (N.S. Baer, ed.). Washington: National Academy Press, 1982; also Weiss, Norman R., *Exterior Cleaning of Historic Masonry Buildings*. Washington: U.S. Dept. of the Interior, 1975.

<sup>2</sup> This two-step approach has become more common in recent years. We are currently involved in the cleaning of the General Electric Building, which is brick and terra cotta, by such a method. Earlier evaluation on sandstone and slate gravestones was done by us in the Trinity Churchyard, at King's Chapel Burying Ground, Boston, and the Ancient Burying Ground, Hartford. Some basic principles of chemical cleaning have been summarized by Heller, Harold L., "The chemistry of masonry cleaning," *Bulletin of the Association for Preservation Technology*, IX (2), 2-9 (1977).

766 Prewash; and  
T-792 Alkaline Prewash<sup>3</sup>

The stone surface was prewetted only for the Limestone Prewash. All application was by brush. Air temperature was about 65 F, with some wind. Application time was 1 hour. The products were fully rinsed with water @ 500 psi. Restoration Cleaner (RC), diluted 1 part water to 2 parts concentrate, was then applied by brush, reapplied (and scrubbed) after 5 minutes, then rinsed fully @ 500 psi. (This was repeated in small areas within some of the test panels.) Surface pH was measured to ascertain that complete neutralization had taken place.

Performance of all systems was generally good, with the LP slightly worse than the others. The cleaning effect is dramatic; no loss of stone, etching, efflorescence or discoloration was observed. There appeared to be some drying or absorption of the 766 and the T-792 after 20-25 minutes, which lead to a procedural modification in the second set of tests, carried out on the Church, on November 7, 1986.

These later tests were done at the junction of elevations 18 and 20, that is, the southeast corner of the Chapel, where surfaces of both the Little Falls and the East Longmeadow sandstones could be cleaned. Air temperature was approximately 50 F. The 766 and the T-792 were tested again, with prewetting of the walls for about 2 minutes. Both were applied for only  $\frac{1}{2}$  hour. (The HDPS and the LP were eliminated from the testing program for several reasons, including the greater difficulty of handling these products, especially on the higher elevations of the Church.) Another product, 859, an organic solvent-based stripper, was also tested here, with an application time of 15 minutes, and no prewetting.

All three were rinsed; the RC was then applied, diluted as in the earlier tests. After 5 minutes, a second application of the RC was made, then rinsed @ 500 psi.

Greater variation was seen in these tests, largely because of the shorter dwell time of the prewashes. In some areas, the 859 actually outperformed the other prewashes, but full interpretation of the several panels done in this location suggests that the T-792 may be the most generally useful product. It appears that prewetting will be possible with the T-792, which handled very well under these conditions. Supplemental use of the 859 for areas that resist cleaning seems feasible once such areas have dried.

Our recommendation, based on these test results, is that removal of surface coatings and heavy soiling can

<sup>3</sup> All are manufactured by ProSoCo, Inc., P.O. Box 1578, Kansas City, Kansas 66117. For product descriptions, see manufacturer's literature, including "Masonry cleaning weatherproofing and restoration products," and "Restoration products," both printed 1985.

be done by use of ProSoCo's T-792 Alkaline Prewash (prewetting, applied for 1 hour, rinsed @ 500-1000 psi with a broad fan nozzle, minimum 6 gpm flow rate), followed immediately by RC (diluted as described earlier, applied for 5 minutes, then re-applied, scrubbed and rinsed). Tarpaulins may need to be used to protect the public, especially at the east and west ends of the Church, where the work will be near property lines, and control of pedestrians is thus not entirely possible. Windows will also require protection with polyethylene sheeting and/or a strippable masking material; of special concern are the clerestory windows, which are not double glazed.

We believe that, in this instance, cleaning is of more than cosmetic value. Thorough removal of the soiled wax (and silicone) layer constitutes an important measure for the preservation of the stone, as it should effectively reduce moisture entrapment. It is, moreover, necessary to eliminate this coating prior to any further conservation treatment, most especially impregnation with a consolidant (see section VII.2.4. of this report)

## BURIAL GROUND PHASE I

### 5.2.2. ADHESIVE REPAIR AND REATTACHMENT

Fragmented markers should be repaired before pieces become lost. For smaller fragments a structural adhesive, such as a 2-part water insensitive polyamide epoxy resin, is adequate. For the majority of repairs at the Burial Ground, Sikadur Hi Mod Gel alone and in conjunction with threaded nylon pins was employed. In previous stone fragment repairs in other northeastern cemeteries, this has provided excellent bonding and continued performance.

For adhesive repair, fragments should be cleaned as described for masonry and dried thoroughly. For surface preparation, the contact edges should be swabbed with a suitable solvent system such as denatured alcohol followed by acetone to ensure clean, degreased, dry surfaces. All joints should be dry tested for fit before the adhesive is applied. Surfaces should be aligned with a straight edge to maintain original plane. The adhesive should be mixed in quantities readily applied within the setting time. It should be applied thinly and evenly to both surfaces to be joined, leaving an adequate margin ( $\frac{1}{4}$  in.) toward the outer edges to prevent surface exposure. The surfaces should be immediately joined and held in position until the initial set has occurred (approximately 15 minutes). It may be necessary to secure the individual pieces to be joined with clamps or other means to insure complete immobilization during the curing set. Any excess adhesive visible at the cracks should be mechanically removed in its gel state but before it hardens as it will discolor and degrade when exposed to sunlight.

On those stones where areas of loss exist along narrow



breaks, a fill of two parts white Portland Cement: one part hydrated lime (by volume) should be applied. The fill may be colored to match the stone by the addition of alkali-stable cement pigments in very small quantities (no more than 10% of the total binder component). Larger losses of stone along breaks require the addition of an appropriate aggregate to control shrinkage (see patching information below).

For most breaks, it is necessary to provide reasonable alignment by working on a horizontal support. Improperly aligned joints are unsightly. A sheet of plywood may be placed on sawhorses to provide a suitable work table on site. For tablets which have been deformed, temporary support of the deformation configuration must be constructed to achieve joint alignment and reduce stress at the joint. Masons' shims of various sizes are useful for this localized support.

For larger fragments or joints which require structural reinforcement, flexible threaded nylon or threaded stainless steel pins may be used, depending on the degree of strength or flexibility required. The diameter of the pin should not exceed one quarter the width of the stone. The length of the pin should be eight times the width of the drilled hole. Holes should be drilled with a masonry bit one-eighth inch larger than the diameter of the pin to be used. To determine the proper alignment of the pin holes, one edge is predrilled to the proper depth and its holes are filled with a colored chalk or crayon. Carefully assemble the adjacent section and the chalk will mark the respective location for pinning. These markings can then be rechecked using an adjustable scale such as that on a carpenter's combination square. The second section should be drilled to the proper depth and angle using an adjustable carpenter's angle for comparison, and then all holes should be cleaned of dust and debris with compressed air. Edges and holes should be swabbed with appropriate solvents such as denatured alcohol followed by acetone and allowed to dry. A dry assembly is essential to verify the hole placements and alignment of the fragments. Adhesive should be applied as described above and packed into holes before inserting pins, taking care to prevent excess from travelling to the surface of the stone.

Where original and replacement iron base pins were found, their removal or stabilization was considered essential for the future survival of the stones. This was achieved by either drilling the iron pins out and replacing them with threaded nylon rod as described above or by cleaning them down to bare metal (removing all corrosion) and priming them with a single-component, aluminum-pigmented moisture-cured urethane primer (Tnemec 50-330 Poly-Ura-Prime) before reuse. The latter option was only selected when removal was too difficult or dangerous to the stone and pins were found to be in relatively sound condition. Even broken tab assemblies were reattached by inserting nylon pins rather than recreating the same faulty design. Under

no circumstances were markers completely adhered to their raised bases with structural (epoxy) adhesives, as this was considered too rigid and irreversible.

### 5.2.3. CLEANING

The decision to clean should be based on a genuine necessity to clean as all masonry cleaning subjects the stone to potential hazards. A monument which is darkened with soiling and biological growth is not only disfigured but also susceptible to accelerated masonry deterioration and therefore requires cleaning. A lightly soiled monument with legible details however, may not require a major cleaning. All cleaning methods must be tested in a discreet location for each stone before full-scale treatment. The gentlest methods should be tested first and if acceptable, should be chosen so as to avoid unnecessary damage to the stone.

#### 5.2.3.1. Water Cleaning

Water cleaning is the gentlest, safest, and least expensive method of cleaning masonry especially for marbles and limestones. Most general surface soiling and some biological growth is easily removed with water. All open joints must be repaired to prevent penetration of quantities of water into the masonry. The water used should have a low metals content to avoid staining. Usually a potable water supply is adequate; however, the use of a particulate filter is advisable to secure against latent metallic staining.

Water can be applied at low pressure (up to 500–600 psi) and may be supplemented by gentle scrubbing with soft nonmetallic bristle brushes. However, cleaning with pressurized water and scrubbing should not be considered if the surface of the stone displays fragile condition.

Since black crusts, resulting from a carbonate stone's interaction with acid rain, are partially water soluble, they may be removed with a slow water misting soak. A perforated garden hose should be set up horizontally parallel to the surface to deliver water at city water pressure for 24 hours. Cleaning is done from top to bottom in this technique. As large amounts of water are used in this treatment, it is especially important that all joints and seams are watertight to prevent the introduction of water to the interior of the masonry and that drainage from the site is provided. Slight staining can sometimes develop on certain stones possessing iron-containing minerals which can react to form brown or yellow oxide stains.

#### 5.2.3.2. Chemical Cleaning

For organic stains below the surface of the stone which are not removed by a water wash, the application of a bleaching poultice has proven to be very effective on

porous stones such as marble. A low concentration solution of technical grade calcium hypochlorite (1.5–6%) is mixed into an inert clay body, such as kaolin and attapulgite clays. This paste is then spread over the stone or in localized areas to a thickness of no less than  $\frac{1}{4}$  in. and left on for 10–30 minutes. The paste is then removed using nonabrasive tools such as wood or rubber spatulas and the stone is rinsed thoroughly with clean water. No odor of calcium hypochlorite should remain after rinse.

Poultice applications may be repeated if staining remains.

#### 5.2.3.3. Abrasive Cleaning

Abrasive cleaning involving any grit or aggregate applied under pressure should not be used on soft stone types such as those found in the Burial Ground. This technique is considered too aggressive and can cause irreversible damage. It may lead to accelerated weathering by pitting the surface, thus opening the masonry to increased moisture penetration and atmospheric reactivity and subsequent deterioration.

#### 5.2.3.4. Metallic Stain Removal

For removal of iron staining resulting from the corrosion of pins and braces, a saturated solution of ammonium citrate with glycerin and buffered with ammonium hydroxide to a pH of 8.5 should be used locally in a poultice application as described above under chemical cleaning. In this case the poultice should be covered with plastic for 48 hours. After the plastic has been removed and the poultice has completely dried, the remaining material should be removed with dry brushing and nonabrasive tools. The area should then be thoroughly rinsed with clean water.

As above, poultice applications may be repeated if some staining remains.

### 5.2.4. CONDITION

Consolidation treatment should be carefully considered for individual stones only by a professional conservator. If consolidation is considered viable, it must be tested before a full-scale treatment program is attempted. Previous research and test data suggest the use of organo-silicates as promising stone consolidants. The model treatments done on site using an ethyl silicate (Conservare Stone Strengthener H and OH, manufactured by Wacker-Chemie and distributed by ProSoCo) have shown to increase abrasion resistance and water repellency without significantly reducing water vapor permeability or changing color and texture. Consolidation of friable fragments is necessary prior to reattachment in order to insure adequate joint adhesion at the break. In all cases consolidation should

be preceded by cleaning where a hydrophobic consolidation system is selected, as cleaning will be difficult later on. Mortar repairs must be installed prior to treatment and allowed to cure for 1–2 weeks before application of the consolidant.

For stones of manageable size, the first choice of application is the immersion method, however, for stones in place or of sufficient size and/or weight, a spray application method is satisfactory.

### 5.2.5. GROUTING

Conservators, masons, and others in the allied building trades are often confronted with the problem of stabilizing exfoliating or delaminating masonry and plaster. When details of historic fabric such as decorative carving, tombstone inscriptions, or painted mural surfaces are endangered, reintegration or reattachment is central to their conservation. Grouting—the injection of fluid mortars or synthetic adhesive materials at low pressure—has been successful as an effective, easily duplicated, safe and inexpensive technique for reintegrating detaching and unsound material, particularly when used for nonstructural historic masonry. The majority of commercially available grouting products today have properties which render them unacceptable for use on historic fabric including flexural, tensile, and compressive strengths which may exceed 2000–10,000 psi each.

Lower strength and more vapor-permeable formulations are available either commercially (Jahn M-40, from Cathedral Stone) or can be formulated using (by volume) 2 parts white portland cement: 1 part (Type S) hydrated lime: 3 parts aggregate (equal amounts of fine banding sand and ceramic eccospheres); either of these formulations are suitable, both are used and recommended by Center for Preservation Research for this type of grouting. Formulations should be premixed dry and then well mixed with water to the consistency of heavy cream. Cavities to be grouted are first cleaned of debris with compressed air and then water flushed. Cracks and fissures are dammed with nonstaining potter's clay and the grout injected by gravity through tubes or with low pressure syringes. After voids are completely filled and delaminations attached, the work is covered with wet burlap or plastic for slow cure. Capping of the grouted areas with mortar mixes (see Patching) where necessary is done to deter water infiltration and visually reintegrate the losses.

All masonry work should be executed under optimum weather conditions to ensure the success of the repairs. No work should be executed nor cured during freezing weather (below 40°F). To prevent too rapid drying in temperatures over 85°F, particularly of thin finishes such as mortar repairs and washes, masonry work may require repeated misting and protection from the sun with damp burlap sacking.

## A NEW YORK CHURCH

### 1. INTRODUCTION

The Center for Preservation Research (CPR) conducted an investigation of exterior stonework of a Church in New York, beginning in April 1986. The investigation was undertaken at the request of the Director of Administration, in preparation for up-coming restoration work. The Church was designed in the Gothic style popular for ecclesiastical architecture at the turn of the century. Construction was completed in 1914. The church has an asymmetrical form with a main tower at one corner. A parish house of the same materials and style adjoins the church.

Because of some difficulties recently encountered during exterior cleaning of the parish house, an in-depth investigation of conditions of the stonework of the church was requested. The investigation included a review of records of past preservation treatments, on-site and laboratory examination of materials, and small-scale tests of cleaning methods. The following report summarizes data obtained and provides recommendations for restoring the original appearance of the Church.

### 2. MATERIALS

The principal material used in the construction of the Church is Bowling Green limestone, an oolitic limestone from Warren County, Kentucky. Beds are generally 10–22 feet thick; freshly quarried stone contains oil (from petroleum deposits) which gives the stone a murky appearance. Upon exposure to the weather, the oil evaporates leaving the stone with a white or nearly white appearance. Oolites stand out conspicuously and are rounded or elongated in shape. The primary mineral is calcite. Occasionally iron pyrite is present.

Bowling Green limestone is known as "the aristocrat of limestones" because of its color, uniformity, strength, and ease of working. The stone is also known for its good weathering qualities; original tool marks are often retained long after construction.

Sculpture of the entries is of Indiana (Bedford) limestone. This stone consists mainly of somewhat rounded shell fragments cemented together with calcite. Its color and texture are similar to that of Bowling Green limestone.

### 3. PREVIOUS TREATMENTS

#### 3.1 Fluorosilicate Treatment

Church records state that in 1928–1929, Nicholson and

Galloway, Inc. applied a solution of "Magnesium-Silicon-Fluorite" to stonework of the Church for the purpose of hardening the stone. Church records suggest that soiling and discoloration of the stonework were present at the time of treatment.

The fluorosilicate or "fluote" treatment for preserving stone was first proposed by J.L. Kessler in France in 1883. Reports of the treatment were initially enthusiastic. A report from 1918 states that Kessler's method is "free from all objectionable features possessed by other methods proposed or adopted for preservation of building stones." The treatment was thought to harden the surface of the stone and impart resistance to frost damage. However, as early as 1921, others described difficulties encountered with the treatment: the formation of a hard surface film on treated stone resulted in subsequent flaking, scabbing, and scaling.

Success of the treatment is based on the reaction of magnesium fluorosilicate with calcium carbonate (calcite) of which this limestone is primarily composed.

Because the pH of the solution is low, the evolution of carbon dioxide gas accompanies its reaction with limestone. The calcium fluoride and silica are deposited as a superficial, often spongy, layer. Unfortunately, deterioration often continues underneath this crust. Today, conservators of art and architecture are generally negative about the long-term benefits of fluorosilicate treatment.

#### 3.2 Plexi-Seal Treatment

Proposals were made by Plexi-Seal Protection Corp. during 1971–1974 to apply a coating of Plexi-Seal to stonework of the church and parish house. According to product data, the coating used was a partially cross-linked polyester material. (In a recent telephone conversation, J.S. Wyner, the President of Plexi-Seal Protection Corp., stated that the coating also contained an acrylic resin.) Plexi-Seal is supposed to provide masonry substrates with a protective coating that will reduce damage caused by water intrusion. Correspondence indicates that the coating was applied to elements of the main tower, "frontal areas" of buttresses, the northwest rear wall at the third floor level, and to the parish house facade. In addition, a modified acrylic latex formulation of Plexi-Seal was added to mortar used in patching and repointing. Limitations of this type of treatment include its inability to achieve more than superficial penetration and the risk of drastically reducing water vapor permeability. With some building materials, the latter can result in damage from the entrapment of water and soluble salts. Fortunately, it does not appear that the Plexi-Seal coating has accelerated deterioration of the stonework of the Church.

However, the mottled appearance of stonework of the parish house after its recent cleaning appears to be the direct result of this "preservation" treatment. In addition, patching and repointing executed in the early 1970s is considerably darker than adjacent stonework. Discoloration of the Plexi-Seal coating strongly suggests that it is not resistant to ultraviolet radiation.

### 4. EXISTING CONDITIONS

The existing condition of exterior stonework was surveyed during several site visits. In those locations where closeup examination was not possible (e.g., upper areas of the main tower), inspection was made from the ground and roof levels with the aid of binoculars.

Stonework of the Church is generally in good condition. As surface erosion has been moderate, carved ornamental details are still relatively crisp and arrisses sharp in most locations. Tool marks are still visible in many locations. A notable exception is the limestone of the turret where weathering has been severe.

A number of vertical and diagonal cracks were noted along the water table level of the church. As was earlier stated, these are patched with a now-darkened cementitious material. Repairs to limestone blocks can also be seen from the turret roof. Discoloration of the patching material in this location is similar to that noted on the crack repairs at the water table level.

A further description of several exterior masonry conditions (general soiling, coating residues, and localized stainings) provided in the paragraphs below. Deterioration mechanisms are discussed.

#### 4.1. General Soiling

Dark soiling is present on exterior limestone in areas that are protected from direct contact with rainwater. This soiling pattern is typical for limestones and other calcareous stones. Although the condition was noted throughout, the pattern is perhaps most pronounced on the south elevation at street level. The mechanism resulting this condition is described below.

Acidic gases absorbed from the atmosphere by rainwater, cause it to be reactive with limestone and other calcareous stones. Sulfur dioxide, which (under typical atmospheric conditions) forms both sulfurous and sulfuric acid when dissolved in water, is perhaps the most destructive of these pollutant gases. In addition to the direct dissolution of calcium carbonate (calcite), the reaction of sulfur dioxide with limestone results in the formation of calcium sulfate dihydrate (gypsum) on the surface of the stone. As gypsum is more soluble in water than is calcium carbonate, the exposed surface becomes eroded when washed by the rain. Where this

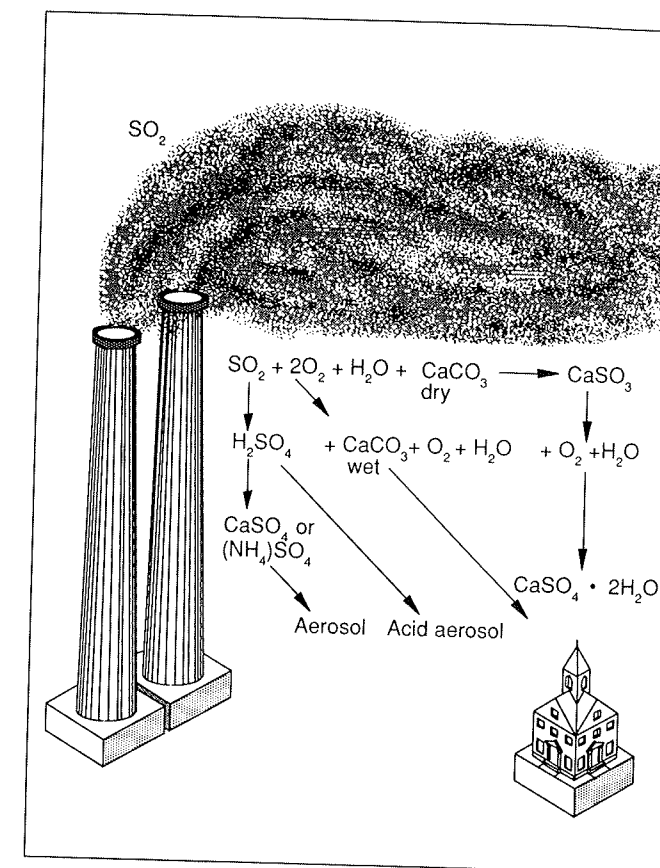


Figure 52. Air pollutants.

surface is protected from the flow of rainwater, the continued transformation of calcium carbonate into calcium sulfate dihydrate results in the formation of a "crust" of gypsum. Particulate matter becomes entrapped in the network of gypsum crystals, giving the surface of protected areas a blackened appearance.

At the Church, there is often an intermediate brownish-colored zone between the blackened gypsum crust and white, rainwashed stone. It is possible that this phenomenon is related to previous preservation treatments. In several locations leaching of calcium carbonate by rainwater has resulted in particularly heavy deposits of gypsum. Thick "framoidal" crusts can be seen at window tracery, decorative moldings of the entries, and ornamental carving of the turret.

Of particular note is alveolar erosion of the gypsum crust best seen at the turret. The reason for this differential deterioration is still uncertain. Possible causative factors are external conditions such as greater exposure to winds and heterogeneity of materials imposed by preservation treatments.

#### 4.2. Coating Residues

Much of the stonework of the parish house is somewhat discolored with streaking and mottling. It appears

that the recent cleaning of the parish house by Nicholson and Galloway, Inc. using the water method did not completely remove coating residues from the limestone surface. The appearance of the stonework as well as information from church records indicate that the residues are probably from the Plexi-Seal treatment of the early 1970s.

Stonework at the tops of buttresses and below the carved ornament of the turret display mottling that is similar in appearance of the dark-colored staining on brickwork at the northwest corner suggests the presence of a coating on the stonework above. Church records support the use of Plexi-Seal in these locations. Mottling, however, is not apparent on the main tower, where, according to Wyner, the coating was also applied.

Stonework of the entries also appears to have a coating residue. In these protected locations, mottling is less apparent. There is discoloration throughout with efflorescence visible above the doorway at the southeast entry.

#### 4.3. Localized Staining

Metallic staining present on exterior masonry is of two types. Blue-green copper stains are present below the flashing on the inner wall below the turret and at the tracery of the clerestory level at the north facade. Solubility of the copper corrosion products in rainwater has resulted in this staining.

The reddish-brown color of stains below air conditioning units on the south elevation of the church and parish house suggests its ferrous source. However, there is no obvious source of similar colored staining on the limestone at the southwest corner of the clerestory level. Here, the staining may be related to the mineralogical composition of the limestone.

#### 5. LABORATORY TESTS

Core drilling samples were obtained May 13 using 1¼" diameter carbide tipped bit. Locations were as follows:

- A. northwest corner at stair landing
- B. parish house turret, north side
- C. clerestory, south side below turret

Each sample was examined by Robert Koestler using a scanning electron microscope. Results of the examination are highlighted below.

Calcium fluoride and amorphous silica were seen on all samples, undoubtedly dating from the 1928–1929 treatment. Examination of the samples suggests that the treatment may have contributed to etching of calcite grains. The presence of silica deposits on the sur-

face of gypsum crystals of sample C indicates that the surface was somewhat weathered at the time of treatment. It appears that the Plexi-Seal treatment, seen on sample A, may have contributed to flaking of the surface crust.

#### 6. ON-SITE TESTS

After the review of records of previous treatments and a thorough inspection of existing conditions, locations representative of typical substrate conditions were designated for on-site testing. Small-scale tests of several cleaning methods were conducted *in situ* during May and early June. Because metallic staining is not visible from the street level, no on-site tests were carried out to treat this condition. Materials and methodologies are described below.

##### 6.2. General Soiling

###### 6.2.1. Chemical Cleaning Tests

Because of the difficulties encountered during the cleaning of the parish house stonework and the records of previous fluorosilicate and Plexi-Seal treatments, it was feared the water washing would not be effective in removing general soiling from limestone. Chemical cleaning tests were executed on the clerestory level of the street facade using both commercial products and custom formulations.

The following commercial products were applied according to the manufacturers' instructions:

Limestone Prewash, diluted 1 part concentrate to 3 parts water (ProSoCo, Inc.)  
T-792 Prewash (ProSoCo, Inc.)  
Limestone Restorer (Deidrich Chemical)

Dwell times were approximately 1 hour. After thoroughly rinsing the surface, Limestone Afterwash (ProSoCo, Inc.), prediluted 1:3, was applied. After 3–5 minutes, the surface was again thoroughly rinsed.

Results: With each of the above, there was some lightening of the surface. Complete removal of general soiling, however, was not effected in any of the test areas. In addition to the above commercial products, the following custom formulations were tested:

AB-57  
D-10

Each was applied as a poultice and covered with polyethylene for the first 48 hours. The poultice was then allowed to dry (approximately 72 hours) and removed with dry brushing followed by water rinsing.

Results: Removal of general soiling was good with AB-

57 and moderate with D-10. However, the success of AB-57 may be due in part to the reaction of EDTA with the limestone rather than the removal of soiling from its surface.

###### 6.2.2. Water Washing

Water washing is generally thought to be simplest, safest, and least expensive method for removing general soiling (gypsum crust) from limestones and other calcareous stones. The effectiveness of this method relies on the fact that the gypsum crust in which the dirt is incorporated is several times more soluble than is calcium carbonate. Thus, by partial dissolution, water loosens the gypsum crust and the material trapped within the network.

Water washing was tested at the southwest corner and at the north side of the passageway below the turret at the clerestory level of the street facade. A perforated garden hose using water at city pressure was aimed at soiling for approximately 24 hours.

Results: In both test areas, dark-colored soiling was successfully removed after a 24-hour water wash. In the passageway, some mottling was noticeable after drying was completed. The success of the small-scale tests suggests that the fluorosilicate treatment was probably applied to a weathered surface. (This determination is supported by the laboratory examination using the scanning electron microscope.) Water washing appears to penetrate the superficial crust of any surviving treatment residue, solubilizing the gypsum below.

#### 6.3 Coating Residues

Tests to remove coating residues were first carried out on the parish house at the first story level.

The following commercial products (all ProSoCo, Inc.) were applied according to the manufacturers' instructions:

Limestone Prewash  
T-792 Prewash  
509 Paint Stripper  
Heavy Duty Paint Stripper

Dwell times were approximately 1 hour. After thoroughly rinsing the surface, Limestone Afterwash (ProSoCo, Inc.), prediluted 1:3, was applied to all but the test where 509 Paint Stripper was used. After 3–5 minutes, the surface was again thoroughly rinsed.

Tests using the Limestone Prewash and the Heavy Duty Paint Stripper were also executed on the stonework of the southeast entry.

Results: At the parish house test areas, the yellow-colored mottling appears to be very resistant to chemi-

cal cleaning methods. The most effective product tested in this location was the Heavy Duty Paint Stripper.

At the southeast entry, the Heavy Duty Paint Stripper was only moderately successful after one application. In this location, however, removal of coating residues was easily accomplished using the Limestone Prewash. Success in the test area suggests that this product can be diluted for full-scale cleaning.

#### 7. RECOMMENDATIONS

##### 7.1. General Soiling

General soiling can be effectively removed from the stonework of most areas using the water wash method. Washing equipment should include manifolds, hoses and sprinkler heads capable of delivering a fine mist of water to *all* soiled surfaces. Equipment should be set up horizontally parallel to the topmost area of a wall. When washing is completed, the equipment should be lowered in a straight line to the lowest point. [Editor's note: all such equipment shall contain no ferrous materials which could corrode and cause rust staining.]

The time period required for the removal of general soiling (washing cycle) should be determined during on-site tests conducted by the contractor. After completion of the washing cycle, light brushing using natural bristle brushes or low pressure rinsing should be used to complete the cleaning operation.

In some areas, where soiling persists, supplemental cleaning may be required after water washing. Whenever necessary, chemical cleaning should be executed using the materials and procedures described in the section below (5.2. Coating Residues). To remove framboidal crusts, it may be necessary to supplement water washing with chemical and/or mechanical methods. The latter should be performed using blunt masonry chisels. Care should be taken to avoid damaging adjacent masonry surfaces.

As the water wash method necessitates the use of a considerable amount of water, it is important to guard against its intrusion to interior spaces. The contractor should inspect the condition of all interior surfaces before cleaning begins. Monitoring of the condition of materials should continue through full-scale operations. Cleaning should be *immediately* stopped upon any sign of dampness.

##### 7.2. Coating Residues

Chemical cleaning will be necessary in areas where coating residues persist. In addition to stonework of



the entries, it is expected that supplemental cleaning will be required on topmost areas of the turret and, possibly, on some elements of the main tower.

It is hoped that the Limestone Prewash can be used in a 1:3 dilution (concentrate to water). This may be possible if limestone surfaces are pre-washed with water just prior to chemical cleaning. Tests conducted by the contractor on stonework of the southeast entry will determine the feasibility of this modification. Chemical cleaning should be carried out by the procedure described below.

1. Prewet a 4' section of limestone
2. Brush apply Limestone Prewash (prediluted 1 part concentrate to 3 parts water) to prewetted wall surface.
3. After allowing the cleaner to remain on the surface for approximately 1 hour, immediately flood the entire section with water, removing all alkaline cleaner from the surface.
4. Immediately apply Limestone Afterwash (prediluted 1:3) and allow to remain on the surface for 3–5 minutes.
5. Immediately flood the entry section with water, removing all acidic cleaner from the surface. Complete rinsing operation using pressure washing equipment.

Cleaning should *not* be conducted when the air temperature is below 40°F. The contractor should follow the manufacturer's recommended procedures for protecting surrounding nonmasonry surfaces during all phases of the cleaning operations. Workers should utilize protective safety glasses, gloves, clothing, and so on, as specifically recommended by the manufacturer.

### 7.3. Metallic Staining

Should metallic staining become apparent after the completion of general cleaning operations, remedial treatment may be desirable in some locations. The following recommendations are based on recent experiences with removing metallic stains from calcareous stones.

For copper stains, a 20% solution of ammonium carbonate should be used in poultice application. The poultice should be covered with plastic and allowed to remain on the surface for approximately 48 hours. After drying is complete, all remaining poultice material should be removed with dry brushing. The area should then be thoroughly rinsed.

For iron stains, a solution of ammonium oxalate or ammonium citrate should be applied in the manner described above. In both cases, small-scale tests should precede full-scale operations.

## NOTES

1. Information about Bowling Green limestone was obtained from *The Building Stones of Kentucky* by Charles Henry Richardson (Frankfort, KY: The Kentucky Geological Society, 1923) and *Physical Properties of the Principal Commercial Limestones Used for Building Construction in the United States* by D.W. Kessler and W.H. Sligh (Technologic Papers of the Bureau of Standards, 21, No. 349, 497–590, July 23, 1927).
2. Cecil H. Desch, The Preservation of Building Stone, *J. Soc. Chem. Ind.* 37 (April 30, 1918): 118T.
3. Noel Heaton, The Preservation of Stone, *J. Roy. Soc. Arts* 70 (1921): 124–139.

## MUNICIPAL BUILDING MASONRY STONework

### Description

According to the drawings and specifications (see Appendix A) the stonework of the North and South Entrance Halls and the main stairwells was built as planned using a "Light Botticino marble dressed rubbed to a half polish." This light buff colored Italian marble became increasingly popular by the end of the century as evidenced by its widespread use in many public interiors of the period. Largely composed of calcium carbonate, its color is due to secondary mineral impurities—limonite or hydrous iron oxide. The veneer ashlar and all trimmings appear to have been installed as specified with metallic anchors to the backing wall and with dowels connecting adjoining pieces (top to bottom). All work was set in a white cement mortar with narrow  $\frac{1}{8}$ -in. bedding joints.

Accent stone was used in the lunettes above the arched elevator openings and in the floor pavement. Although the lunette fields were of a gypsum plaster imitation stone (see Plasterwork), the roundels within were built as specified with "grey and yellow sienna marble" dressed as the Botticino walls.

The floor pavement design called for a more complicated mix of different colored stone and cast bronze circular insets of the seal of the City. The design specified and built was a patterned background of "light and dark Pink Knoxville Marble," geologically a crystallized limestone with small circular and diamond-shaped inset panels of "Oriental and Verde Antique Vermont Marble." Larger square and circular panels placed along the center axis were to be of various granites, "Cape Ann, Ascutney Green, Jersey Pink, and Stoney Creek." This was all executed as planned with the exception of the cast brass inlays which were never installed.

Also as specified, the risers, treads, and platforms of

the entrance hall stairs were constructed of a "Pink Knoxville Marble" similar to the main pavement.

## CONDITION

Only a general qualitative survey of the stonework was made to identify the major problems and to assist in setting up a treatment test program. In general the stonework of both lobbies appears to be in good condition. Overall soiling, observed as a gritty yellowish to brown film, occurs on most surfaces, except where it has been harshly removed by recent chemical cleaning along the lower walls. Both soiled and cleaned surfaces are dull in luster. This soiling is most likely the combined result of greasy air-borne particulates from fossil fuel combustion (automotive exhaust and heating fuel), cigarette smoke, and body oils. The latter is most noticeable along the pier edges and lower walls of the stairwells due to high pedestrian traffic. No previous coatings appear to be present judging from a lack of surface anomalies; however, their presence sometimes can be difficult to ascertain.

An unusual white mottling of the Botticino marble occurring along hairline cracks, geological joints and veining, and construction joints is most prominent on the exterior walls, especially in the stairwells. This is most likely related to the transmission of water vapor or liquid through these openings and possibly the transport and deposition of water soluble salts. It is also possible these areas may appear lighter than the surrounding soiled surfaces because they have been kept clean by the migrating moisture. No salt fretting or spalling is evident except on the second floor landing of the South Hall stairwell.

In addition to these discolorations, localized stains from pressure tape adhesive, signage, chewing gum, and graffiti are also present. Previous fills, some of discolored adhesive resins, and many new losses from abrasion and impact are visible across much of the lower walls and arises. Isolated stress cracks exist as well.

## MASONRY TESTING PROGRAM

In July and November of 1989, a small-scale testing program was conducted on the stonework and plaster ceilings to ascertain the most appropriate methods for restoration.

Cleaning tests of approximately 6 × 12 in. were performed on heavily soiled Botticino marble in the south stairwell and on the lower panel of the Directory and on a representative stair riser and tread of "Knoxville

marble," all in the South Entrance Hall. Paint removal tests and restoration of the original plasterwork finish were also attempted in the northeast corner vault and lunette in the North Entrance Hall.

These tests and their results are outlined below:

- 0 No visible effect
- + Visible cleaning
- Negative or adverse effect

## TEST AREA: SOUTH WALL OF SOUTH STAIRCASE SOUTH ENTRANCE HALL

- X water scrub / 0
- 1 Ammoniated Triton X [20% 3M Ammonium hydroxide + 80% Triton X (Now Union Carbide) nonionic detergent (10 drops/gallon of water) / 0
- A Lacquer thinner  
cotton pad applied/0
- B Petroleum ether (technical grade)  
cotton pad applied/0
- C Denatured alcohol (technical grade)  
cotton pad applied/0
- D Sure Klean Marble Poultice with water (ProSoCo)  
dwell time: 48 hours with scrub rinse/—surface alteration
- E Sure Klean Marble Poultice (ProSoCo) with additive  
dwell time: 48 hours with scrub rinse/—surface alteration
- F Ammoniated Stripper (Manhattan Floor Supply)  
full treatment

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- + ISC Sure Klean Interior Stone Cleaner (ProSoCo)  
prewet, diluted 1 part concentrate: 2 parts water  
dwell time: 3–5 minutes, scrub and water rinse/ +
- Z Control

The results of these tests suggest that the surface soiling is most effectively removed with alkali and alkali-

solvent mixtures. Test panels F and I both displayed the best cleaning leaving the stone a cool buff color. Test panel E displayed an unacceptable rough texture and whitish color alteration. The results of test panel D appeared to be effective in removing surface grime, however, its application as a poultice would not be as efficient or cost effective as a single application of the Ammoniated Stripper (F) or 859 Stripper (I). The Liquid Marble Cleaner and the Interior Stone Cleaner

were not as effective in removing the white mottling as the Ammoniated Stripper (full strength and dilute) or the 859 Stripper.

In addition to the above cleaning tests, a small panel of Botticino marble was resurfaced with wet abrasive/acidic polishing by a professional stonemason. This technique both cleaned and restored a luster finish to the marble.