THE

DECAY OF THE BUILDING STONES

NEW YORK CITY.

DR. ALEXIS A. JULIEN.

(Reprint of papers read before the NEW YORK ACADEMY OF SCIENCES, January 29 and April 30, 1883)

At the meeting of the NEW YORK ACADEMY OF SCIENCES, January 29, 1883,

Dr. ALEXIS A. JULIEN read a paper on

"THE DECAY OF THE BUILDING STONES OF NEW YORK CITY,"

(with Lantern Illustrations from American and Foreign Architecture).

(Abstract).

The paper, which will be published in full by the Building-Stone Department of the Tenth Census of the United States, considers the building stones employed in New York City and its suburbs, *i.e.*, Brooklyn, Staten Island, Jersey City and Hoboken.

I. The buildings, their numbers and common materials.

The materials of general construction occur in the following percentage proportion to the total number of buildings in the cities stated in the table below:

	New York.	Brooklyn.	Staten Island.	Jersey City.	Hoboken.	Entire Metropolis.
No. of buildings..	100,193	75,526	7,725	20,880	6,284	210,608
Brick and stucco.	63.2	39.9	9.5	22.8	32.7	47.9
Frame...........	24.3	50.9	90.0	75.2	64.7	42.5
Stone...........	11.6	9.1	0.5	2.0	2.6	9.1
Iron............	0.9	0.1				0.5

In New York City proper, the several varieties of stone are used in the following proportion to the entire number of stone buildings:

Brown sandstone	78.6	Granyte	1.8
Nova Scotia and Ohio sandstones	10.6	Gneiss	0.9
Marble	7.9	Foreign sandstone	0.1
		Bluestone and limestone	0.1

In Brooklyn, the Connecticut brownstone is the variety predominating among the stone buildings (95.7 per cent), and is employed almost altogether for the fronts of residences. Very few iron buildings occur, but over three times as many stucco-fronts as in New York. The frame buildings predominate, particularly in the outskirts, *e.g.*, Long Island City (80.5 per cent).

In Staten Island, stone enters in very small proportion into the fronts of buildings, though commonly employed, as in New York and throughout this district, for the dressing of apertures, the walls of enclosures, and other masonry.

In Jersey City, the proportions of the materials are much as in Staten Island. The selection of the dark trap from the Heights behind the city, for the construction of many fronts or entire buildings, is a local feature of interest.

In Hoboken, the same general features prevail as in Jersey City.

The annual reports of the Committee on Fire Patrol of the New York Board of Fire Underwriters, for the years 1881 and 1882, have yielded the following statistics, which, so far as they go, closely approximate my own:

	Number of buildings.
South of Canal street	10,553
Between Canal and Fourteenth streets	26,700
Between Fourteenth and Fifty-ninth streets	33,815
Between Fifty-ninth street and Harlem River	18,746
Total	89,814

The materials of construction for this district, which does not include the 23d and 24th Wards, North of the Harlem river, are reported as follows:

Brick, with stone trimmings, and, in part, with stone facings	64,783
Brick and frame	3,616
Frame	21,415

II. *The Building Stones, their Varieties, Localities, and Edifices Constructed of Each.*

An exceedingly rich and varied series is brought to our docks, and the number and variety are constantly increasing. A few of the more important may be here mentioned.

Freestones (Carboniferous Sandstone), commonly styled "Nova Scotia Stone," or "Dorchester Stone," in various shades of buff, olive-yellow, etc., from Hopewell and Mary's Point, Albert, N. B., and from Wood Point, Sackville, Harvey, and Weston, N. B., Kennetcook, N. S., etc. A very large number of private residences in New York and

Brooklyn, etc., the fences, bridges, etc., in Central and Prospect Parks, many churches, banks, etc.

Freestone (Mesozoic Sandstone), commonly styled "brownstone," from East Longmeadow and Springfield, Mass., but chiefly from Portland, Conn., in dark shades of reddish-brown, inclining to chocolate. This is the most common stone used in the fronts of private residences, many churches, Academy of Design in Brooklyn, etc.

Freestone (Mesozoic Sandstone), "brownstone," from Middletown, Conn. Trinity Church, Brooklyn, etc.

Red Sandstone (Potsdam Sandstone), Potsdam, N. Y. Several residences, buildings of Columbia College, etc.

Freestone (Potsdam Sandstone), "brownstone," Oswego, N. Y. Part of Masonic Temple in 23d street.

Freestone (Mesozoic Sandstone), "brownstone," in several shades of light reddish-brown, orange-brown, etc., and generally fine-grained, from Belleville, N. J. Very many of the best residences and churches, *e.g.*, cor. 60th and 64th streets and Madison avenue, etc.

Also, varieties of the same "brownstone" from Little Falls, N. J. (Trinity Church, New York), from the base of the Palisades (part of the wall around Central Park), etc.

Freestone (Lower Carboniferous Sandstone), commonly styled "Ohio Stone," from Amherst, East Cleveland, Independence, Berea, Portsmouth, Waverly, etc., Ohio, in various shades of buff, white, drab, dove-colored, etc. Many private residences and stores, the Boreel building, Williamsburgh Saving Bank, Rossmore Hotel, etc.

Freestone (Mesozoic Sandstone), often styled "Carlisle Stone," from the English shipping port, or "Scotch Stone," from Corsehill, Ballochmile and Gatelaw Bridge, Scotland; in shades of dark red to bright pink. Fronts of several residences, trimmings of Murray Hill Hotel, the "Berkshire" building, etc.

Also, varieties from Frankfort-on-the-Main, Germany, etc.

Blue Sandstone (Devonian Sandstone), commonly styled "Bluestone," from many quarries in Albany, Greene, Ulster and Delaware counties, N. Y., and Pike county, Penn. The trimmings of many private residences and business buildings, walls and bridges in the Parks, part of Academy of Design in 23d street, Penitentiary on Blackwell's Island, house at 72d street and Madison avenue, etc.

Freestone (Oolite Limestone), "Caenstone," from Caen, France. Fronts of several residences in 9th street, trimmings of Trinity Chapel, the reredos in Trinity Church, New York, etc.

Limestone (Niagara Limestone), Lockport, N. Y. Lenox Library trimmings of Presbyterian Hospital, etc.

Limestone (Lower Carboniferous), styled "Oolitic Limestone," from Ellitsville, Ind. Several private residences, (*e.g.*, cor. 52d street and Fifth avenue), trimmings of business buildings, etc.

Also, varieties of limestone from Kingston and Rondout, N.Y., Isle La Motte, Lake Champlain, Mott Haven, and Greenwich, Conn., etc. Part of the anchorages of the Brooklyn Bridge, walls in Central Park, etc.

Granyte, Bay of Fundy, N. S. Columns in Stock Exchange, etc.

Red Granyte, Blue Hills, Me. U. S. Barge Office.

Gray Granyte, East Blue Hills, Me. Part of towers and approaches of New York and Brooklyn Bridge, etc.

Granyte, Spruce Head, Me. Part of towers of Brooklyn Bridge, bridges of Fourth Avenue Improvement, Jersey City Reservoir, etc.

Gray Granyte, Hurricane Island, Me. Part of New York Post Office and of towers and approaches of Brooklyn Bridge, etc.

Granyte, Fox Island, Me. Basement of Stock Exchange, etc.

Granyte, Hallowell, Me. Trimmings of St. Patrick's Cathedral, Jersey City Heights, etc.

Granyte, Round Point, Me. Seventh Regiment Armory, etc.

Granyte, Jonesborough, Me. Welles' building, panels in Williamsburgh Savings Bank, etc.

Granyte, Frankfort, Me. Part of towers and approaches of Brooklyn Bridge, etc.

Granyte, Dix Island, Me. New York Post Office, part of *Staats Zeitung* building, etc.

Also, varieties from Calais, Red Beach, East Boston, Clark's Island Mt. Waldo, Musquito Mountain, Mt. Desert, Ratcliff's Island, etc., Me.

Granyte, Concord, N H. Booth's Theatre, German Savings Bank etc.

Granyte, Cape Ann, Mass. Dark base-stone and spandrel stones of towers and approaches of Brooklyn Bridge, etc.

Granyte, Quincy, Mass. Astor House, Custom House, etc.

Granyte, Westerly, R. I. Part of Brooklyn anchorage of Brooklyn Bridge.

Granyte, Stony Creek, Conn. Part of New York anchorage of Brooklyn Bridge.

Also, varieties from St. Johnsville, Vt., Millstone Point, Conn., Cornwall, N. Y., Charlottesburg, N. J., Rubislaw and Peterhead, Scotland, etc.

Gray Gneiss, New York Island and Westchester County, N. Y. A, large number of churches, Bellevue Hospital, the Reservoir at 42d street, etc., and the foundations of most of the buildings throughout the city.

Gray Gneiss, Willett's Point and Hallett's Point, Kings County, N. Y. Many churches in Brooklyn, the Naval Hospital, etc.

Marble, Manchester, Vt. Drexel & Morgan's building, church corner 29th street and Fifth avenue, etc.

Also, many varieties from Swanton, West Rutland, Burlington, Isle La Motte, etc., Vt. The "Sutherland" building at 63d street and Madison avenue, residences at 58th street and Fifth avenue, etc.

Marble, Lee, Mass. Turrets of St. Patrick's Cathedral, etc.

Marble, Stockbridge, Mass. Part of old City Hall, New York.

Marble, Hastings, N. Y. The University building, etc.

Marble, Tuckahoe, N. Y. Part of St. Patrick's Cathedral, residence on the corner of 34th street and Fifth avenue, etc.

Marble, Pleasantville, N. Y., styled "Snowflake Marble." Greater part of St. Patrick's Cathedral, Union Dime Savings Bank, many residences and stores, etc.

Also, many varieties from Canaan, Conn., Williamsport, Penn., Knoxville, Tenn., Carrara and Sienna, Italy, etc.; used generally, especially for interior decoration, etc.

Trap (Mesozoic Diabase), from many quarries along the "Palisades," at Jersey City Heights, Weehawken, etc. Stevens' Institute, Hoboken, N. J., Court House on Jersey City Heights, old rubble-work buildings at New Utrecht, etc., on the outskirts of Brooklyn, etc.

Trap (Mesozoic Diabase), styled "Norwood Stone," from Closter, N. J. Grace Episcopal Church, Harlem.

Also, varieties from Graniteville, Staten Island, N. Y., and Weehawken, N. J.

Serpentine, Hoboken, N. J. Many private residences, masonry, etc., in Hoboken. Also, varieties from Chester, Penn.

In addition to the edifices referred to above, many public buildings of importance are constructed of stone, *e.g.:* prisons in the city and on the islands, bridges in the Parks and over the Harlem river, in which sandstone, limestone, granyte and gneiss are used.

The sewers are constructed of gneiss from New York Island and vicinity, as well as of boulders of trap, granyte, etc., from excavations.

The Croton Aqueduct, the High Bridge, the Reservoirs in the Central and Prospect Parks and at 42d St., in which gneiss from the vicinity and granyte from New England were used.

The walls, buildings, bridges and general masonry in the Parks are constructed of the following varieties of stone:

Freestone (sandstone), from Albert, Dorchester, and Weston, N. B.

Brownstone, from Belleville and the base of the Palisades. N. J.
Bluestone and "mountain graywacke," from the Hudson River.
Limestone, from Mott Haven and Greenwich, Conn.
Granyte, from Radcliffe's Island, etc., Me.
Gneiss, from New York, Westchester and Kings counties, N. Y.
Marble, from Westchester county, N. Y.

The fortifications in the Harbor and entrance to the Sound, constructed of granyte from Dix Island, Spruce Head, etc., Me., gneiss from the vicinity, brownstone from Conn., etc.

The stonework of the New York and Brooklyn Bridge, as I am kindly informed by Mr. F. Collingwood, the engineer in charge of the New York Approach, is constructed of the following materials:

Granyte, from Frankfort, Spruce Head, Hurricane Island, East Blue Hill, and Mt. Desert, Me., Concord, N. H., Cape Ann, Mass., Westerly, R. I., Stony Creek, Conn., and Charlottesburg, N. J.

Limestone, from Rondout and Kingston, N. Y., also from Isle La Motte and Willsboro Point, Lake Champlain, and vicinity of Catskill, N. Y.

In the Anchorages, the corner-stones, exterior of the cornice and coping, and the stones resting on anchor-plates, consist of granyte from Charlottesburg and Stony Creek, in the New York Anchorage, and from Westerly, in the Brooklyn Anchorage. The rest of the material is entirely limestone, mainly from Rondout, largely from Lake Champlain. In the Towers, limestone was chiefly employed below the water line, and, above, granyte from all the localities named, except Charlottesburg, Westerly and Stony Creek. In the Approaches, the materials were arranged in about the same way as in the Towers. Additional particulars are given concerning the quantity, prices, tests of strength and reasons for selection of the varieties of stone.

For roofing, slate is largely employed throughout these cities, being mainly derived from Poultney, Castleton, Fairhaven, etc., Vt., and Slatington, Lynnport, Bethlehem, etc., Penn.

For pavements, the boulders of trap and granyte from excavations have been widely used in the "cobblestone" pavements. The trap (or diabase) of the Palisades across the Hudson, immediately opposite New York City, and from Graniteville, Staten Island, is used in the "Russ" and Belgian pavement; also, granyte from the Highlands of the Hudson, from Maine, etc., in the "granyte block" pavement in both New York and Brooklyn; large quantities of crushed trap from Weehawken and Graniteville, for the macadamized streets and roads in the Parks and outskirts; and also wood, concrete and asphalt in various combinations.

For sidewalks and curb-stones, the material generally employed is the flagstone, a thinly bedded blue sandstone or graywacke from the interior of the State, the Catskill Mountains, and from Pennsylvania; also, granyte, chiefly from Maine. In the older streets, a mica-slate from Bolton, Conn., and micaceous slaty gneiss from Haddam, Conn., were once largely used, and may still be occasionally observed in scattered slabs.

Additional facts were given concerning the ruling prices for the varieties of stone, tables presenting all the determinations obtainable, in reference to the crushing strength of the varieties used in New York, lists of the dealers in building and ornamental stones, etc.

III. *Durability of Building-Stones,* in New York City and vicinity.

All varieties of soft, porous and untested stones are being hurried into the masonry of the buildings of New York City and its vicinity. On many of them the ravages of the weather and the need of the repairer are apparent within five years after their erection, and a resistance to much decay for twenty or thirty years is usually considered wonderful and perfectly satisfactory.

Notwithstanding the general injury to the appearance of the rotten stone, and the enormous losses annually involved in the extensive repairs, painting, or demolition, little concern is yet manifested by either architects, builders, or house owners. Hardly any department of technical science is so much neglected as that which embraces the study of the nature of stone, and all the varied resources of lithology in chemical, microscopical, and physical methods of investigation, wonderfully developed within the last quarter century, have never yet been properly applied to the selection and protection of stone, as used for building purposes. Much alarm has been caused abroad in the rapid decay and fast approaching ruin of the most important monuments, cathedrals, and public buildings, but in many instances the means have been found for their artificial protection, *e.g.*, the Louvre and many palaces in and near Paris, France, St. Charles church in Vienna, Austria, the Houses of Parliament, etc., in London, England, etc.

In New York, the Commissioners of the Croton Aqueduct Department complained, twenty years ago, of the crumbling away of varieties of the gneiss used in embankments; the marbles of Italy, Vermont, and of Westchester County, soon become discolored, are now all more or less pitted or softened upon the surface (*e.g.*, the U. S. Treasury), and are not likely to last a century in satisfactory condition (*e.g.*, the U. S. Hotel); the coarser brown sandstones are exfoliating in the most offensive way throughout all of our older streets and in many of the newer (*e.g.*, the old City Hall); the few limestones yet brought into use are beginning to lose their dressed surfaces and to be traversed by cracks (*e.g.*, the Lenox Library); and even the granytes, within a half century, show both discoloration, pitting (*e.g.*, the Custom House), or exfoliation (*e.g.*, the Tombs). To meet and properly cope with this destructive action, requires, first, a clear recognition of the hostile external agencies concerned in the process. These belong to three classes, chemical, physical, and organic.

The chemical agencies discussed were the following: sulphurous and sulphuric acids, discharged in vast quantities into the air of the city, by the combustion of coal and gas, the decomposition of street-refuse and sewer-gas, etc.: carbonic, nitric, and hydrochloric acids; carbolic, hippuric, and many other organic acids, derived from smoke, street-dust, sewer vapors, etc.: oxygen and ozone, ammonia, and sea-salt.

The mechanical and physical agencies discussed were the following: frost: extreme variations in temperature, amounting in our climate to 120° F. in a year, and even 70° in a single day: wind and rain, most efficient on fronts facing the north, northeast, and east: crystallization by efflorescence: pressure of superincumbent masonry: friction: and fire.

The organic agencies consist of vegetable growths, mostly confervæ, etc., within the city, and lichens and mosses, without, and of boring molluscs, sponges, etc.

The internal elements of durability in a stone depend, first, upon the chemical composition of its constituent minerals and of their cement. This involves a consideration of their solubility in atmospheric waters, *e.g.*, the calcium-carbonate of a marble or limestone, the ferric oxide of certain sandstones, etc.: their tendency to oxidation, hydration, and decomposition, *e.g.*, of the sulphides (especially marcasite) in a roofing-slate or marble, the biotite and ferruginous orthoclase in a granyte or sandstone, etc.: the enclosure of fluids and moisture, *e.g.*, as "quarry-sap," in chemical combination as hydrated silicates (chlorite, kaolin, etc.) and iron-oxides, and as fluid-cavities locked up in quartz, etc.

The durability of a stone depends again upon its physical structure, in regard to which the following points were discussed: the size, form, and position of its constituent minerals; *e.g.*, an excess of mica-plates in parallel-position may serve as an element of weakness: the porosity of the rock, permitting the percolation of water through its interstices, especially important in the case of the soft freestones and leading to varieties of discoloration upon the light-colored stones, which were described in detail: the hardness and toughness, particularly in relation to use for pavements, sidewalks, and stoops: the crystalline structure, which, if well-developed, increases the strength of its resistance: the tension of the grains, which appears to explain especially the disruption of many crystalline marbles: the contiguity of the grains and the proportion of cement in their interstices: and the homogeneity of the rock.

Again, the durability of a rock may depend upon the character of its surface, whether polished, smoothly dressed, or rough-hewn, since upon this circumstance may rest the rapidity with which atmospheric waters are shed, or with which the deposition of soot, street-dust, etc., may be favored: also upon the inclination and position of the surface, as affecting the retention of rainwater and moisture, exposure to northeast gales and to burning sun, etc.

IV. *Methods of Trial of Building-Stone.*

In such methods, two classes may be distinguished, the natural and the artificial.

The former embrace, first, the examination of quarry-outcrops, where the exposure of the surface of the rock during ages may give some indication of its power of resistance to decomposition, *e.g.*, the dolomitic marbles of New York and Westchester counties, some of which present a surface crumbling into sand: and, secondly, the examination of old masonry. Few old buildings have survived the changes in our restless city, but many observations were presented in regard to the condition of many materials, usually after an exposure of less than half a century.

Another source of information, in this regard, was found in the study of the stones erected in our oldest cemeteries, *e.g.*, that of Trinity Church. There could hardly be devised a superior method for thoroughly testing, by natural means, the durability of the stone, than by its erection in this way, with partial insertion in the moist earth, complete exposure to the winds, rain, and sun on every side, its bedding-lamination standing on edge, and several of its surfaces smoothed and polished and sharply incised with dates, inscriptions, and carvings, by which to detect and to measure the character and extent of its decay. In Trinity Church-yard, the stones are vertical, and stand facing the east. The most common material is a red sandstone, probably from Little Falls, N. J., whose erection dates back as far as 1681, and which remains, in most cases, in very fair condition. Its dark color, however, has led to a frequent tendency to splitting on the western side of the slabs, *i.e.*, that which faces the afternoon sun. Other materials studied consisted of bluestone, probably from the Catskills, black slate, gray slate, green hydromicaceous schist, and white oolitic limestone, all in good condition, and white marble, in a decided state of decay.

The artificial methods of trial of stone, now occasionally in vogue, whenever some extraordinary pressure is brought upon architects to pay attention to the durability of the material they propose to employ, are, from their obsolete antiquity, imperfection, or absolute inaccuracy, unworthy of the age and of so honorable a profession. They usually consist of trials of solubility in acids, of absorptive power for water, of resistance to frost, tested by the efflorescence of sodium-sulphate, and of resistance to crushing. The latter may have the remotest relationship to the elements of durability in many rocks, and yet is one on which much reliance of the architectural world is now placed. Sooner or later a wide departure will take place from these incomplete and antique methods, in the light of modern discovery.

Reference was made to certain experiments by Prof. J. C. Draper on the brownstone and Nova-Scotia stone used in this city, by Dr. Page on a series of the building-stones, and by Profs. J. Henry and W. R. Johnson on American marbles, in some cases with conflicting results, which were probably due to the limited number and methods of the experiments.

V. Means of Protection and Preservation of Stone.

We have here to consider certain natural principles of construction, and then the methods for the artificial preservation of the stone used in buildings. Under the first head, there are four divisions.

Selection of stone. As it is universally agreed that the utmost importance rests upon the original selection of the building-material, it is here that all the resources of lithological science should be called in. Only one investigation, aiming at thorough work, has ever been carried through, that of the Royal Commission appointed for the selection of stone for the Houses of Parliament. But the efforts of these able men were restricted by the little progress made at that time in the general study of rocks, and were afterwards completely thwarted by the discharge of the Committee and by the delivery of the execution of the work of selection to incompetent hands. There will be hereafter, from investigations made in the light of modern researches, no excuse for such annoying results and enormous expenses as those which attended the endless repairs which have been required, since a period of four or five years after the completion of the great building referred to.

Seasoning. The recommendations of Vitruvius, 2000 years ago, have been observed at times down to the day of Sir Christopher Wren, who would not accept the stone, which he proposed to use in the erection of St. Paul's Cathedral, in London, until it had lain for three years, seasoning upon the seashore. Since then little or no attention appears to have been paid to this important requirement by modern architects, in the heedless haste of the energy of the times. Building-stone, even for many notable edifices, is hurried from the quarries into its position in masonry, long before the "quarry-sap" has been permitted, by its evaporation, to produce solid cementation in the interstices of the stone.

Position. The danger of setting up any laminated material on edge, rather than on its natural bedding-plane, has been widely acknowledged; yet it is of the rarest occurrence, in New York City, to observe any attention paid to this rule, except where, from the small size or square form of the blocks of stone employed, it has been really cheapest and most convenient to pile them up on their flat sides.

Form of projections. The principle is maintained by all the best English and French architects that projections (*i.e.*, cornices, sills, lintels, etc.) should be "throated," that is undercut in such a way as to throw off the dripping of rainwater, etc., from the front of the building; but in New York this principle is almost universally neglected. It was pointed out that the severity of our climate even requires the further care that the upper surface of projections should be so cut as to prevent the lodgment or long retention of deposits either of rainwater or snow. It is immediately above and below such deposits that the ashlar of our fronts is most rapidly corroded and exfoliated, an effect evidently due mainly to the repeated thawing and solution, freezing and disintegration, which are caused by the water, slush and snow, which rest, often for weeks, upon a window-sill, balcony, cornice, etc. Thus from the initial and inexcusable carelessness in the construction and form of the projections, and, later, the neglect of the houseowner, due to ignorance of the results involved, to remove the deposits of snow, etc., as fast as they accumulate on the projections, is derived a large part of the discoloration of the marble, Nova Scotia stone, or light colored granyte, and especially the exfoliation of the brownstone beneath the window-sills, balconies, etc., by the water alternately trickling down the front and freezing, by day and by night, for long periods.

The artificial means of preservation are of two classes, organic and inorganic. The former depend on the application of some organic substance in a coating or on the injection of fatty matters; but, as the substances are with greater or less rapidity oxidized, dissolved, and carried away by the atmospheric fluids, the methods founded on their use have been properly denounced by many authorities as only costly palliatives, needing frequent repetition, and therefore exerting an influence toward the destruction of delicate carving. The following were discussed: coal-tar: paint, which has been used in New York for many residences, as in Washington for the Capitol and in London for Buckingham Palace, etc., but lasts only a few years and often even permits the disintegration to progress beneath it: oil, often used in New York, but as objectionable as paint: soap and alum-solution: and paraffine, beeswax, rosin, tallow, etc., dissolved in naphtha, turpentine, camphine, oil, etc.

The preparations of an inorganic nature, which have been proposed and used abroad, have in some cases met with success; but the exact nature of their action, and the conditions to which they are each suited, are yet to be investigated, especially with reference to the entirely different climate by which the stone in our city is being tried. The processes which have been proposed, and in some cases practically used, involve the application of the following substances: waterglass, in connection with salts of calcium or barium, or bitumen: oxalate of aluminium: barium solution, in connection with calcium superphosphate or ferro-silicic acid: copper salts, used by Dr. Robert in Paris to stop the growth of vegetation on stone, etc. There is certainly a call for processes by which, at least, those stones which are used in isolated, exposed, and unnatural positions, may receive artificial protection, such as the stone-sills and lintels of windows, stone balusters, projecting cornices, and ashlar-stone set up on edge. It will doubtless be found that only those stones, which possess a coarse porous texture and strong abscrptive power for liquids, will be found particularly available for protection by artificial preservatives, and that such stones should indeed never be used in construction in a raw or crude state. In the spongy brown and light olive free-stones, a marble full of minute crevices, and a cellular fossiliferous limestone, a petrifying liquid may permeate to some depth, close up the pores by its deposits, and encase the stone in solid armor; while, upon a more compact rock, such as a granyte or solid limestone, it can only deposit a shelly crust or enamel, which time may soon peel off. The carelessness with which stone is selected and used, and the ignorance in regard to its proper preservation, when the decay of a poor stone becomes apparent, have led to an increased use of brick and terracotta, much to be deplored; durable stones are to be obtained in great variety, methods for the preservation of the porous stones can easily be devised, and stones of a fire-proof character do exist in this country in abundance.

In conclusion, three suggestions were offered: 1st, that householders invoke the magic use of the broom on the fronts of their residences as carefully as upon the sidewalks: 2d, that house builders insist upon the undercutting of all projections, and the exclusion of brackets or other supports to sills and cornices, which only lead to the oozing of water and a line of corrosion down the ashlar: 3d, that house repairers recut the projections in this way, whenever possible, and entirely avoid the use of paint, oil, or other organic preservatives.

At a meeting of the New York Academy of Sciences, April 30, 1883, another paper was read by Dr. ALEXIS A. JULIEN,

ON THE DECAY OF BUILDING STONE, PART II,

with illustrations from the old cemeteries of New Utrecht, Flatbush, etc.

(Abstract).

The present and increasing magnitude of building operations in this city and vicinity must serve as an apology for bringing the subject of the decay of stone a second time before the Academy this season. The various suburbs and vacant districts have been gradually approaching a character sufficiently settled to justify the erection of entire and numerous blocks of private residences, huge buildings for business offices in the lower part of the city and for family flats in the central and upper wards, besides large numbers of public edifices, storage houses, manufactories, etc. The failure of stone to resist fire in the business district, and the offensive results of discoloration or serious exfoliation, which the poor durability of many varieties of stone has rendered manifest in all parts of the city, have already largely diminished its proportionate use, in reference to brick. Nevertheless great quantities of stone of many kinds are yet introduced, as ashlar or the trimmings of apertures, into the buildings now in progress, and will soon be further employed, if the present activity in building be continued, not only in the private enterprises already mentioned, but others of more lasting and public importance; *e.g.*, the projected improvements and additions in connection with our water supply, as aqueducts and reservoirs; the new bridges proposed over our rivers; the replacement of our rotting wooden docks by more permanent structures; and perhaps, we may hope, the huge pedestal to support the Statue of Liberty on an island in our harbor. As the kinds of building-stone brought to this market for these purposes are increasing in number and variety, and their selection and mode of use, as it seems to me, are irregular and indiscriminate, whether from the ignorance or the carelessness likely to prevail in a busy money-getting community, it would appear proper that a voice of warning should now be heard, from a member of the Academy of Sciences, calling attention to the dangers involved in the use of bad stone or the bad use of good stone; in the enormous waste and expense soon required for repairs in our severe climate; or, in the consequent disuse of stone in favor of brick, by a natural reaction, to the injury of the beauty and comfort of our city.

There are three classes in the community to which such a warning is addressed:

1. A considerable number of house-owners, to whom it seems to come too late, since they have already expended tens of thousands of dollars in temporary repairs, patching and painting decayed stone, and many of whom have doubtless made rash vows to use hereafter, in construction, brick, iron, terracotta, wood—anything but stone.

2. House-owners, not yet aware of the coming dilapidation, and who can yet take precautions to delay or prevent its arrival—or others about to build, and who have implicit faith in the eternity of building-stone, since it comes from the "everlasting rock," or at least in a duration which will last their lifetimes—and, also a certain proportion of builders and architects willing to learn, and who have much to learn, since the practical scientific study of building-stones is yet to be made.

3. And lastly, the architects, builders and contractors, who know all about the subject, or who do not care what happens to the houses they build—and that large part of our population who never expect to own any houses. To all these the decay of the stone in this city is a matter of indifference, and the quotation recently presented

from an encyclopedia of architecture, "no modern building will stand a thousand years"—few of them, indeed, over a century or two, in fair condition—is only a matter of jest.

The following additional facts, observed in reference to the decay of stone in this city, have been gathered partly by observation in our streets, and partly by a study of the tomb-stones in the old cemeteries at New Utrecht and Flatbush, on the southern and northeastern outskirts of the city of Brooklyn, L. I., and in that of St. Paul's Church, at the corner of Broadway and Fulton street, in this city. In my last paper I presented observations on the stones in the churchyard of Trinity Church, built in 1841–6 (the first building having been erected on that site in 1696). St. Paul's Chapel was erected 1766, and, although this structure is older than that of Trinity, its cemetery is much more recent in its origin.

BROWN SANDSTONE.

In addition to the varieties already described, there is one quite recently introduced into this city from Hammelstown, Penn., in a building on Fifth avenue above 41st street. It has been largely used in Philadelphia, and is said to resist the weather very well.

The causes of the general decay of brown-stone may be definitely connected with some of the agencies which were detailed in my former paper.

Erection on edge of lamination.—Instances are very rare in this city where the stone has been laid "on its bed," with a deliberate regard to its durability: *e.g.*, a few houses on Fifth avenue above 51st street, the new wings of the Astor library, etc. On the other hand, from mere convenience in construction, many buildings, especially of our older churches, are fortunately so constructed, the blocks having been small and square and conveniently so laid. In some instances, (*e.g.*, the church on the southeast corner of 35th street and Fifth avenue), blocks occur in both positions and in both are affected by incipient decay; in others (*e.g.*, the church on southwest corner of 21st street and Fifth avenue), the blocks, although all on bed, are often deeply decayed. In the old City Hall, erected in 1812, the north face, although on the side usually least affected by decay, presents the brownstone of its ashlar set on edge and exfoliating in entire sheets, often traversed by fissures across the lamination, parallel to the joints. Notwithstanding these warnings, most of our newest edifices exhibit the same faulty construction: *e.g.*, the sandstone (from Massachusetts) in the trimmings and even partly in the pillars of the Union League Club on Fifth avenue, the fine new residences in the upper part of Madison avenue, the trimmings, etc., in the huge new buildings for "flats" and business offices throughout the city, often nine to eleven or more stories in height, in whose walls the crushing force exerted upon this soft stone must be excessive.

Sea-salt in the atmosphere.—A comparison of the forms of decay of stone observed in the cemeteries within this city and in those nearer the ocean, *e.g.*, at New Utrecht, yielded no evidence of any results, attributable to this agency, in greater action at the latter locality. Thus, too, in England, the sandstone of Sandysfoot Castle, near Weymouth, which has been washed by salt spray since the time of Henry VIII., remains as perfect as ever.

Heat of the sun.—There can be no doubt that this is one of the agencies which most severely attack our brown-stone. On the cross streets, the west sides of stoops become decayed and ragged, long before the eastern; so also the southern before the northern sides, on our north and south avenues. The ashlar at the base of the steeple of the church at 37th street and Fifth avenue is beginning to decay on the south side, but not on the north or east sides (the west side not being visible). The slender balusters of the balustrades of balconies and along the sides of stoops are commonly constructed of soft sandstone, with the lamination vertical and its plane set irregularly, either parallel or at right angles to that of the house front; the ill-judged exposure of the soft stone in such a way has led to the common mutilation of the carved work by exfoliation on the side exposed to the sun, *i.e.*, on the west side of the stoop-balustrades in the cross streets, and on the south side along the avenues.

Lichens.—It has been stated that these abound upon the brown-stone within the city, but, though found upon trees, I have never discovered them encrusting hewn stone within the city. Thus they never occur in the churchyards of Trinity church and St. Paul's chapel, though found abundantly in those of New Utrecht and Flatbush; *e.g.*, three species were distinguished upon a single tombstone (Rutgert Denyse, 1795) at New Utrecht. On their removal, the surface of the stone beneath is not found corroded, but only retains a fresh color.

Imperfect pointing.—The admitted energetic agencies of decay—frost, solution, hydration, etc.—have been largely favored by the imperfect and hasty construction of the masonry throughout the city, its joints when new often admitting a trowel. A cement-mortar of poor quality is largely employed and, soon dropping out, the joints are often allowed to remain open for years. The atmospheric attack is thus made, as it were in flank, directly through the exposed edges of the outer laminæ of the stone, and the decay rapidly affects the stone to a considerable depth, several inches in many cases, and even throughout the entire block, although the exfoliation may appear superficial.

Cemetery at New Utrecht.—Two varieties of sandstone were found commonly employed here, the stones standing vertically and facing the east.

1. Fine-grained and compact, warm red to reddish brown in color, apparently derived from Little Falls, N. J. The stones dated from 1830 back to 1785, and are in excellent condition, especially in proportion to compactness and fineness of grain (*e.g.*, C. Van P., 1796).

2. Red, often fine-grained, and generally laminated, the laminæ being one-eighth to one-half inch in thickness, with alternations of reddish shades of color. The stones date from 1854 back to 1820, and have weathered very poorly, splitting first near the west face of the stone and finally throughout, often with fissures cutting the stone across the lamination and parallel to the edges (*e. g.*, W. B. 1826).

A light gray graywacke also occurs (S. B., 1852), but is thinly laminated and split in fine cracks throughout.

Cemetery at Flatbush.—The same varieties are here employed and the stones stand in the same position. Those of the compact variety date from 1800 back to 1754, and are in excellent condition (*e.g.*, Marrytie D., 1797.) Those of the laminated structure date from 1826 back to 1754 and are generally in wretched condition (*e.g.*, Adriantie L., 1761), especially on and near the top and edge and the west face. Sometimes, however, the lamination has not allowed any decay (*e.g.*, Geljam C., 1754). In both cemeteries, however, the decay at its worst has split up the stone, but has little affected the sharpness of inscriptions.

St. Paul's Churchyard.—One variety of fine-grained sandstone predominates, dating from 1813 back to 1768. The finest-grained and most compact are often in perfect condition (J. J., 1768), but many coarser or more laminated stones, and sometimes fine and compact stones, are very badly split, and show exfoliation near the ground (A. Van B., 1813)—sometimes with fissures across the stone (J. A., 1813). The splitting begins, as usual, near the west face and near the edges.

LIGHT-COLORED SANDSTONES.

Nova Scotia Sandstone.—In regard to this name, I have indicated already, but it is fair to explain more fully here, that it originated many years ago, when grindstone-dealers obtained their supplies from some small surface-quarries located in and near Nova Scotia. As that stone was of a yellow color, the stone-trade has persisted ever since in calling every light-colored stone coming from anywhere in that section, "Nova

Scotia stone." However, 95 per cent. of the imported stone is derived from New Brunswick (probably 85 per cent. from Dorchester, N. B.), and the remainder from Nova Scotia and other points. The popular name has been applied to light-colored stones of every quality, quarried at various points of Eastern Canada, over a wide section of country, hundreds of square miles in extent, and variously worked out at tide-level, under tide-water from exposed reefs running out into the sea, or, as at Dorchester, N. B., from a hillside 900 feet high and a quarter of a mile from tide-water. The small quarries usually work out only such stones as they can obtain from outcropping ledges and boulders, and these are apt to be of bad and varying color, more or less full of iron and other defects; for example, the surface-quarries of Hillsboro, N. B., long since abandoned, used in the houses in 42nd street near Madison avenue, in Second avenue near 55th street, some of the bridges in Central Park, etc. At the quarries of Dorchester, N. B., it is stated that from 35 to 50 feet of inferior rock and debris are first stripped off to reach the sound rock which is sent to this market. The introduction of this stone into the city as a building material has been too recent to allow any measure of its durability. A little exfoliation may be however distinguished near the ground-line, and on the sides and posts of stoops, in many cases. Also, in panels, under heavy projecting mouldings, cornices, etc., where the sun has no chance to reach and dry up the dampness, the stone moulders away slightly over the surface. In the cemeteries it is rarely or never used; in one example, possibly of this material, in St. Paul's churchyard (W. J. M., 1841), the decay is plainly beginning around the carvings. The discoloration of good varieties of the stone would be very slow to affect vertical surfaces, properly protected by drips; but on sloping, horizontal, or shaded surfaces, especially near the street-level, street-dust is sure to lodge and cling, all the more after the surface becomes roughened by a slight disintegration; while the rough usage to which the stone of balustrades and stoops is always subjected in a busy street, renders this, as well as all other soft varieties of freestone, liable to chipping as well as offensive discoloration (*e.g.*, in the courses, trimmings, and posts of the church on the corner of 42d street and Madison avenue, etc.) and unsuitable for use near the ground-line.

Ohio Sandstone.—The buff variety from Amherst is said to contain "97 per cent of pure sand." Buildings constructed of this material in this city since 1857 (*e.g.*, on the corner of Barclay street and Broadway, on the corner of Howard and Crosby streets, etc.), show no decay, but only discoloration. In other instances (*e. g.*, rows of houses on 50th street, west of Fifth avenue, on Madison avenue between 34th and 43d streets, etc.) the blackened discoloration and frequent chipping of edges of the soft stone are quite offensive. On the other hand, it must be admitted that a stone which cleans itself, by the disintegration of its surface, the grains dropping out and so carrying away the dirt, as in the poorer and softer varieties of brown-stone or of Nova Scotia stone, is by that very action still more objectionable from its want of durability; and the discoloration of the Ohio stone is offset, at least in part, in the best varieties, by their hardness and promise of durability.

Medina sandstone.—This material is of recent introduction (*e.g.*, Baptist church on 57th street, west of 6th avenue), and its true durability cannot yet be estimated.

Bluestone (graywacke).—This stone is yearly coming into more general use, and, though somewhat sombre in tone and difficult to dress, seems likely to prove a material of remarkable durability. In one building in 24th street, between Madison and Fourth avenues, its condition appears to be excellent, after fifteen years exposure, perfectly retaining the tool-marks. The variety reported to come from the Wyoming valley (*e.g.*, in the building on the north side of Union Square) is really derived, as I am informed by Prof. H. L. Fairchild, from Meshoppen, Penn.

In this connection, we may refer to the experiments made by Dr. Hiram A. Cutting, of Vermont, on a series of American sandstones, in regard to specific gravity, weight, absorptive power, and resistance to fire. The results on varieties like those used in New York City are quoted in the following table (*The Weekly Underwriter*, 1880, Vol. XXII., p. 288):

LOCAL NAME.	*Locality.*	*Specific Gravity.*	*Weight of one Cubic Foot, lbs.*	*Ratio of Absorption.*	*Heated at 600° F.*	*Heated at 800° F.*	*Heated at 900° F.*	*Heated at 1000° F.*	*Heated at Higher Temperatures.*
Freestone......................	Portland, Conn......	2.380	148.7	1+27	Not Injured.	Not injured.	Friable.	Tender.	Ruined.
Freestone......................	North of England...	2.168	135.5	1+27		"	Cracks badly.	Spoiled.	
Montrose Stone................	Ulster County, N. Y.	2.661	166.3	1+314		"	Not injured.	Slight injury	Stands well.
Freestone......................	Belleville, N. J......	2.350	146.8	1+27		"	Cracks.	Friable.	
Freestone......................	Nova Scotia........	2.424	151.5	1+240		"	"	"	
Carboniferous Sandstone........	Br. Philips, N. S....	2.353	147.0	1+19		"	Crumbles.	Cracks and crumbles.	
Freestone......................	Dorchester, N. B....	2.363	147.7	1+26		Cracks.	Cracks and crumbles.	"	
Berlin Stone..................	Cleveland, O........	2.210	*138.1	1+22		Not injured.	Slight cracks		Stands well.
Berea Stone....................	Berea, O............	2.254	*140 8	1+20		"	"	Crumbles.	"
Amherst Stone.................	Amherst, O.........	2.200	*137.5	1+18		"	Changes color.	Friable.	"
Brownstone....................	Hammellstown, Pa..	2 346	146.6	1+28		"	Cracks.	Crumbles.	
Potsdam Sandstone............	Beauharnois, Quebec	2.512	157.0	1+38		"	"	"	

* It is claimed that these figures understate the true weight, which is said to approximate 155 pounds.

LIMESTONE.

The coarse fossiliferous stone from Lockport owes its rapid disintegration within ten years, wherever used in this city, in part to its careless arrangement in masonry. Thus, in the building of the Lenox Library, at 70th street and Fifth avenue, about 40 per cent of the material is set on edge, *e.g.*, the alternate receding courses of the ashlar, trimmings of apertures, gate-posts, etc.; so also, in part, in the stone used in the Presbyterian Hospital. The oolitic stone from Ellitsville, Indiana, shows an almost immediate and irregular discoloration, said to be produced by the exudation of oil. The oolite from Caen, France, has also been used in many buildings, and, unless protected by a coating of paint, has shown decay in several instances. Mr. G. Godwin, of London, has stated (Soc. of Arts, 1881,) that "the Caen stone which was sent to this country (England) could not now be depended on and ought not to be used for external work." The extensive decay of this, with other oolitic and magnesian limestones, in the walls of Westminster Abbey, has recently caused great alarm and will necessitate the renewal of its outer masonry at enormous expense.

One of the most thorough investigations, in regard to the porosity of a series of American building-stones, was made by Dr. T. S. Hunt in 1864, and with the following conclusion (Chem. and Geol. Essays, p 164):

"Other things being equal, it may probably be said that the value of a stone for building purposes is inversely as its porosity or absorbing power." From the results given on 39 specimens, the following may be here quoted as pertinent to stones used in New York City:

No. of Specimens.	Absorption Percentage.
1. Potsdam sandstone, hard and white.	0.50— 3.96 (usually about 1)
2. Medina sandstone	3.31— 4.04
3. Ohio sandstone	9.59—10.22
3. Caen limestone	14.48—16.05

Of course the proviso, "other things being equal," covers a great deal of important ground, including the solvency of the material of a stone in the acidified rain-waters of a city. Some of the most impervious and non-absorbent readily decompose; while others, which are porous or even cellular, may afford an excellent resistance to decay. But judged in regard to both points, porosity and solvency, the Caen stone may be safely rejected hereafter as unfit for our climate.

MARBLE.

The dolomitic marble of Westchester County has been largely employed in our buildings, and some idea of its character for durability may now be gained. A fine-grained variety was used in the building of the U. S. Assay Office in Wall street; its surface is now much discolored, and the edges of many of the blocks show cracks. A variety of medium texture was employed in the hotel at the corner of Fulton and Pearl streets, erected in 1823; the surface is decomposed, after the exposure of exactly sixty years, with a gray exterior, in a crust ⅛ to ¼ inch in thickness, soft and orange-colored in section. Many crystals have fallen out of the surface on the weathered eastern face, producing a pitted appearance. A very coarse variety has been used in the Bank-building at Thirty-second street and Broadway, in large part being set on edge; very many of the blocks are more or less cracked, even in the highest story. In the U. S. Treasury building, in Wall street, a rather coarse dolomyte-marble, rich in tremolite and phlogopite, was used, the blocks being laid on bed in the plinth and most of the ashlar, but largely on edge in the pillars, pilasters, etc.; in the latter case vertical fissures commonly mark the decay, but even elsewhere a deep pitting has been produced by the weathering out of the tremolite. The marble used in many other prominent buildings has been improperly laid, *e.g.*, in both of the buildings of the City Hall, the Drexel building at the corner of Broad and Wall streets, the Academy of Design at 23d street and Fourth avenue, etc.

Cemetery at New Utrecht.—Here a very fine white marble is used in many stones, perhaps that of Carrara—a few stones dating about or a little before 1800. These are in excellent condition, but on the east face are much roughened.

Another variety is a tremolitic dolomyte-marble, white, fine to coarse in texture, probably from Westchester County. It is in fair to good condition, but the weathered tops, sides, and east faces of the stones are in a pulverulent state. Sometimes the west face is the one roughened, and the stone is split near it.

Stones of a white veined marble, perhaps from Vermont, date from 1853 back to 1828. They are in good condition, but the east face is pulverulent.

A blue marble (C. Groenendyke, 1797) and a black and white marble (N. G., 1795) are in excellent condition, but the eastern faces of the stones are decidedly roughened, the inscriptions remaining sharp and distinct.

Flatbush Cemetery.—Marble here predominates in two varieties. The stones of a fine white marble (Italian?), date from 1859 back to 1809. They are generally in good to excellent condition, but their surfaces are more or less roughened, becoming pulverulent when dating from 1836. That of 1809 (N. R. C.), a horizontal tablet, is blackened by a minute lichen, *lepra antiquitatis* (also J. V., 1800).

The stones of a coarse tremolitic dolomyte-marble date from 1847 back to 1818. They weather grayish and become much roughened over the east face, top and sides, and sometimes over a third of the surface down the west face. Fissures in the edges of the stone begin after about 30 years exposure. The polish has survived for about 40 years on the faces of some stones of this class, even when the edges are disintegrated. Near the ground for a foot the polish remains even much longer, *e.g.*, the double stone of Femetie and Peter Stryker (1730).

St. Paul's Churchyard.—The stones here date from 1851 back to 1798, and consist of a coarse white marble. It weathers grayish white, and becomes roughened. Only a small proportion of the stones are split. About one-tenth have their inscriptions entirely obliterated, and this fact, due doubtless to the acid rain-waters of the city, was not observed in the suburban cemeteries; in one case (A. W., 1851) it has been largely affected in a little over 30 years.

The horizontal tablets, supported on masonry, which has partially settled (*e.g.*, J. G., 1821), generally show a slight curvature in centre only in part possibly produced through solution by standing rain-water.

Dolomieu first made the observation on an Italian marble, called Betullio, that it possessed a degree of flexibility allied to that of the itacolumyte of Brazil. Gwilt states (Encyc. of Arch., p. 1274):

"Some extremely fine specimens of white marble are to be seen in the Borghese Palace at Rome, which, on being suspended by the centre on a hard body, bend very considerably. It is found that statuary marble exposed to the sun acquires, in time, this property, thus indicating a less degree of adhesion of its parts than it naturally possessed."

In the white marble-veneering of the facade of St. Marks, Venice, the same effect has been observed by Mr. C. M. Burns, Jr., in the lower half of a slab of veined marble, two inches thick, on the south side of the northernmost of the five portals, just behind the columns and about five feet from the pavement. The slab is eleven feet and two inches long, and one foot and six inches wide; it is hung to the backing by copper hooks driven into the brickwork, but the lower part, for a distance of five feet and seven inches, bulges out two and three-quarter inches from the backing. "The exposure is directly westward, and I found that it became decidedly warm in the afternoon sun, while the backing would be likely to keep its temperature lower. Though the outer surface is somewhat weatherworn, I could not find the slightest tendency to fracture in any part." (*The Am. Arch. and Build. News*, 1882, p. 118).

Also at the palace of the Alhambra, in Grenada, Spain, one of the two doors that have been christened "La Mezquita," exhibits an ancient facing of three slabs of marble, the upper resting as a lintel upon the two others, which form uprights, eleven feet in height, nine inches in width, and only two and one-half inches in thickness. At eighteen and one-half inches from the top of the door, the slab on the right begins to curve and to detach itself from the wall, attaining the distance of three inches at about three feet from the bottom. From a subsidence of the material of the wall, an enormous thrust has been exerted upon the right, and the marble, instead of breaking or of rupturing its casings, has simply bent and curved as if it were wood (*La Nature*, 1882.)

I have also been informed at Sutherland Falls and other quarries near Rutland, Vermont, that the bending of thin slabs of marble, exposed to the sunshine in the open air and accidentally supported only at the ends, has been there repeatedly observed.

Fleurian de Bellevue discovered a dolomyte possessed of the same property in the Val-Levantine, of Mt. St. Gothard. Dolomieu attributed the property to "a state of desiccation which has lessened the adherence of the molecules of the stone," and this was supposed to be confirmed by experiments of De Bellevue, who, on heating inflexible varieties of marble, found that they became flexible.

This change, however, cannot be connected with the remarkably small content of water existing in marbles, but with a peculiarity of their texture, which has been briefly discussed by Archibald Geikie (Proc. Roy. Soc. Edinb., 1880), in an interesting investigation on the decay of the stones used in Scotch cemeteries. He has pointed out that the irregular and closely contiguous grains of calcite, which make up a white marble, are united by no cement, and have apparently a very feeble coherence.

It appears to me probable also that their contiguous crystallization has left them in a state of tension, on account of which the least force applied, through pressure from without or of the unsupported weight of the stone, or from internal expansion by heat or frost, produces a separation of the interstitial planes in minute rifts. Such a condition permits a play of the grains upon each other and considerable motion, as illustrated in the commonly observed sharp foldings of strata of granular limestones, without fractures or faults. In such cases, also, I have observed that the mutual attrition of the grains has been sometimes sufficient to convert their angular, often rhomboidal, original contours into circular outlines, the interstices between the rounded grains being evidently filled up by much smaller fragments and rubbedoff particles; *e. g.*, in the white marble of the anticlinal axis at Sutherland Falls, Vt.

These results are confirmed by the appearances, familiar to all lithologists, in the study of thin sections of marble, the latent interstices between the grains of calcite having been often developed by the insinuation of films and veinlets of iron-oxide, manganese-oxide, etc. While a polished slab of marble, fresh from the stone-yard, may not be particularly sensitive to stains; after it has been erected and used as a mantelpiece over a fire-place, its increased absorbence for ink, fruit-juices, etc., becomes strongly marked. On this property are founded the processes, always preceded by heat, for the artificial coloring of marbles.

In the decay of the marble, largely Italian, in the atmosphere of Edinburgh, Geikie has recognized three phases:

1. Loss of polish, superficial solution, and production of a rough, loosely granular surface. This is effected, Geikie states, by "exposure for not more than a year or two to our prevalent westerly rains." The solution of the surface may sometimes reach the depth of about a quarter of an inch, and the inscriptions may become almost illegible in sixteen years.

In our own dry climate, however, these results do not appear. The polish often survives ten years in our city cemeteries, and even for over half a century near the ground, in the suburban cemeteries; in one instance, at Flatbush, it has remained intact for over 150 years, on the tombstone of F. and P. Stryker, dated 1730. Inscriptions are decipherable in St. Paul's churchyard back to the date of 1798, but about one-tenth are illegible or obliterated; the latter effect was never seen in a single instance on the suburban stones, and is evidently due to the acid vapors in the rain-waters of the city.

2. Incrustation of the marble with a begrimed blackish film, sometimes a millimeter in thickness, consisting of town-dust, cemented by calcium sulphate, and thorough internal disintegration of the stone, sufficient, after a century, to cause it to crumble into powder by very slight pressure.

Neither the crust nor any deep disintegration has been observed in the oldest marble-tombstones in the cemeteries of New York; their absence is plainly attributable to the inferior humidity of our atmosphere and the absence of smoke from soft coals.

3. Curvature and fracture, observed in slabs of marble, firmly inserted into a solid framework of sandstone. This process consists in the bulging out of the marble, accompanied with a series of fractures, and has been accomplished by expansion due to frost. Tombstones are never constructed in this way, in our cemeteries; but the curvature of

horizontal slabs, observed in St. Paul's churchyard, produced by the sagging of the supporting masonry beneath the centre of the slab, is simply indicative of the flexibility of the material.

Geikie states: "The results of my observations among our burial-grounds show that, save in exceptionally sheltered situations, slabs of marble, exposed to the weather in such a climate and atmosphere as that of Edinburgh, are entirely destroyed in less than a century. Where this destruction takes place by simple comparatively rapid superficial solution and removal of the stone, the rate of lowering of the surface amounts sometimes to about a third of an inch (or roughly 9 millimetres) in a century. Where it is effected by internal displacement, a curvature of 2½ inches, with abundant rents, a partial effacement of the inscription, and a reduction of the marble to a pulverulent condition, may be produced in about forty years, and a total disruption and effacement of the stone within one hundred. It is evident that white marble is here utterly unsuited for out-of-door use." My own conclusions, from observations in New York, is that, in the cemeteries within the city, the polish on vertical slabs is usually destroyed in about ten years; that the inscriptions are only in small part effaced within thirty to fifty years, and are for the most part perfectly legible on the oldest tombstones, dating 1798; and that, although the reduction of the surface to a loose granular condition may reach the depth of ten millimetres, the actual lowering of the surface seldom exceeds five or six millimetres, the internal disintegration is never sufficient to affect sensibly the strength of the stone during the periods of exposure which have been noted, and a slight flexure, perhaps to the amount of twelve or fifteen millimetres, sometimes affects the centre of horizontal slabs, two metres in length.

In the cemeteries without the city, the polish may often survive near the ground, on the faces of vertical slabs, for over one hundred and fifty years; the granulation of the surface rarely exceeds a depth of three or four millimetres; and all the inscriptions remain perfect on the oldest vertical tombstones, suffering partial effacement only on horizontal slabs.

Although these facts show the far greater durability of marble in our dry and pure atmosphere, the frequent obliteration of inscriptions, the general, and often rapid, granulation of the surface, and the occasional fissuring of slabs, show that the decay of marble—in the varieties hitherto long used in New York City—is steady, inevitable, and but a question of time; and with Geikie, I, too, am convinced that, if unprotected, such materials are utterly unsuited for out-of-door use, at least for decorative purposes or cemetery-records, within the atmosphere of a city.

GRANYTE.

The bluish variety from Quincy, Mass., has been used in many buildings and rarely shows as yet many signs of decay. In the U.S. Custom House on Wall street, most of the huge blocks appear laid "on bed," but, nevertheless, show some pitting in places, by the attack and partial removal of the larger grains of hornblende. In the church at Fourth street and Lafayette Place, erected in 1830, a little exfoliation has been produced by street-dust on the faces of some steps. In the Astor House, at Barclay street and Broadway, no decay was observed.

In the fine-grained granyte from Concord, N. H., employed in the building on the southeast corner of Twenty-third street and Sixth avenue, many of the blocks are set on edge, but the only change yet seen is that of discoloration by street-dust and iron-oxide from the Elevated Railway.

The light-colored and fine-grained granyte of Hallowell, Me., has been used for the construction of the City Prison, the Halls of Justice or "Tombs," in Centre street. This stone consists of a white feldspar, which predominates, a greyish-white quartz, which is abundant, and a considerable quantity of a silvery white mica, thoroughly intermixed. The rock possesses several properties—fineness of grain, homogeneity of structure, and freedom from iron, as shown by the color of the feldspar—likely to render it durable; the only unfavorable conditions are the predominance of feldspar and the laminated structure. The rock is a granitoid gneiss, with lamination often clearly marked; these markings at once show to the eye that most of the blocks are set, not on bed, but irregularly on edge.

The building is square and occupies an entire block. On a study of the weathering, the south face was found to present an exfoliation to the depth of one-eighth to one-fourth of an inch at many points, up to the very summit of the building, particularly on the sides of the pillars at the southeast entrance, on the ashlar near the southwest gate, under and over the cornice and string pieces. In some places the stone was loosened or peeled off in sheets of the area of a square foot. The west front presents much exfoliation all over the surface, though always thin; it seems to begin chiefly along and near the joints. In places, fragments have separated from the corners of the blocks. The north front exhibits very little exfoliation; so also the east front, in a few small scattered spots.

The exfoliation appears to be the result directly of the sun's heat, exerted most intensely on the southern and western sides of the building. An examination of the disintegrated material shows but little decomposition; a little kaolin may be distinguished in films, but the bulk of the feldspar, the weakest constituent, remains with bright facets, without change in color or lustre. It is by no means characteristic of the "maladie du granit," first described by Dolomieu and later studied by Dr. T. Sterry Hunt; but here the action seems to be mainly and simply a disintegration of the grains, initiated by expansion under the sun's heat, during the summer, and developed by the expansion caused by frost during the winter. An architect of the city recently stated that "he had built several large granite offices and considered Quincy granite the most durable of all building material. He thought the weathering of granite would hardly amount to one-thirty-secondth of an inch in a hundred years. According to that calculation many buildings might hope for a longer span than the thousand years spoken of by the professor."

However, it is a well-known fact that the weathering of granyte does not proceed by a merely superficial wear, which can be measured or limited by fractions of an inch; but by a deep insinuation along the lines of weakness, between grains, through cleavage-planes, and into latent fissures. Thus, long before the surface has become much corroded or removed, a deep disintegration has taken place by which large fragments are ready for separation by frost, from the edges and angles of a block. When directly exposed to the heat of the sun, an additional agency of destruction is involved, and the stone is suddenly found ready to exfoliate, layer after layer, concentrically. As yet we have little to guide us in the estimation of durability in years, since the best known granyte monuments are those which have been exposed to the exceptionally mild climate of Egypt; but even there some exfoliation has been noticed, *e. g.*, on the inner walls of the so-called Temple of the Sphynx.

In the cemeteries within the city and on Long Island, much granyte is now used in slabs and monuments, but its introduction has been everywhere of too recent a date to afford any measure of its durability. Geikie remarks: "traces of decay in some of its feldspar crystals may be detected, yet in no case that I have seen is the decay of a polished granite surface sensibly apparent after exposure for fifteen or twenty years. Even the most durable granite will probably be far surpassed in permanence by the best of our silicious sandstones. But as yet the data do not exist for making any satisfactory comparison between them.

GNEISS.

The oldest building in this city, in which this material has been used, appears to be that of St. Matthews Lutheran Church, on the northeast corner of Broome and Elizabeth streets, erected in 1841. The stone is the micaceous gneiss, in part hornblendic, from excavations on the island, with trimmings, string-pieces, etc., of brown stone, the latter, as usual, being in a state of decay. On the west front, the gneiss is in excellent condition, occurring in small blocks, mostly laid on the bedding-plane. In the south front, many of the quoins are set on edge and are much decayed along the joints, sometimes with splitting or exfoliation, fracture of corners, and irregular chipping out of the surface to the depth of one-half to one inch below the level of the projecting cement-joints.

GENERAL CONCLUSIONS.

If a rough estimate be desired, founded merely on these observations, of the comparative durability of the common varieties of building-stone, used in New York city and vicinity, there may be found some truth in the following approximative figures for the "life" of each stone, signifying by that term, without regard to discoloration or other objectionable qualities, merely the period after which the incipient decay of the variety becomes sufficiently offensive to the eye to demand repair or renewal.

	Life, in Years.
Coarse brownstone	5–15
Laminated fine brownstone	20–50
Compact fine brownstone	100–200
Bluestone	Untried, probably centuries.
Nova Scotia stone	Untried, perhaps 50–200
Ohio sandstone, (best silicious variety), perhaps from 1 to many centuries.	
Limestone, coarse fossiliferous	20–40
Limestone, fine oolitic (French)	30–40
" " (American)	Untried here.
Marble (*Dolomyte*,) coarse	40
" " fine	60–80
Marble, fine	50–200
Granyte	75–200
Gneiss	50 years to many centuries.

Within a very few years past, it has become frequent to introduce rude varieties of rusticated work into the masonry of buildings in this city, or to leave the stone rough and undressed in huge blocks, especially in the basement or lowest stories, where it is under close and continuous inspection, and the results of its decay will be disguised by its original rough surface. Although there are certain large buildings in which such a massive treatment of stone may be appropriate, its common use, with stones of known feebleness or lack of durability, is a disingenuous evasion of responsibility and a mere confession of ignorance, want of enterprise, and despair, in regard to the proper selection of building material and in regard to its protection.

Finally, it may be pointed out that many of the best building stones of the country have never yet been brought into this city; *e. g.*, silicious limestones of the highest promise of durability, allied to that employed in Salisbury Cathedral: refractory sandstones, like some of those of Ohio and other Western States, particularly fitted for introduction into business buildings in the "drygoods district," storage houses, etc., where a fire-proof stone is needed; and highly silicious varieties of Lower Silurian sandstones, such as occur near Lake Champlain, quartzytic and hard to work, like the Craigleith stone of Edinburgh, but possessing the valuable qualities of that fine stone, in resisting discoloration, notwithstanding its light color, and in remarkable resistance to disintegration.

As it is, we have many and need many varieties of stone for our various objects, but do not know how to use them. It is pitiable to see our new buildings erected in soft and often untried varieties of stone, covered with delicate carvings of foliage and flower-garlands, which are almost certain to be nipped off by the frost before the second generation of the owner shall enter the house. It is now time for one who loves stone to express his indignation at the careless and wasteful way in which a good material is being misused.

DISCUSSION.

Mr. F. Collingwood remarked on the durability of the stone (Trenton limestone) used in Montreal, and on the general need of well established rules for the selection of stone. He suggested for investigation, the subject of the effect of internal moisture on cements, *i. e.*, whether the slow percolation of rain-water through the cement in the joints of masonry, *e. g.*, in an arch, is likely to injure the integrity of the structure, producing serious damage by the disintegration of the cement.

A Visitor, a practical builder, stated that at present, in New York, the struggle of competition tended to produce satisfaction with temporary effects, and the mere question of cost was at the bottom of the hasty selection and cheap construction. Nevertheless, as nice workmanship in stone could be seen, and was being executed in New York to-day, as in any other place in the world. He asked for further explanation, and felt it due to the trade to say that stones were generally treated badly from ignorance rather than from intention. It was the duty of those who know all about these things, to inform those who had to build and work the stone all about its properties and capabilities, and then some good result might ensue. He himself felt the necessity of further knowledge on this important subject, and was sure that most of those in the trade felt as he did.

On invitation, Dr. T. STERRY HUNT observed that frost was the main agent of the disintegration of stone in our climate, often suddenly succeeding the moistening of the material by long rains, and thus producing violent expansion and crumbling. In England, no such extremes occurred. However, in visiting York Minster, a few years ago, he found the workmen engaged in repairing the magnesian limestone at one of the gates. He had climbed up the ladder, and, on examination of the stone, found a remarkable disintegration near the middle, to the depth of one or two inches, by which bars of the rock projected, marking the less absorbent layers.

As to the granytes, that of Hallowell, Me., and that vicinity, is only a granytoid gneiss, and not as compact as a true granyte; its exfoliation he knew to be a mere disintegration, favored by the greater porosity of its texture. The material of the granyte obelisk in Central Park is one likely to offer great resistance to disintegration and chemical decay, as the similar obelisks at Rome and Paris seem to show little or no effect of weathering.

The subject was further discussed by Messrs. BERG, TROTTER, and by the PRESIDENT, who expressed a cordial welcome to practical men to attend the meetings of the Academy, and to contribute to their interest through the valuable materials acquired by their experience.