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NEW YORK STATE MUSEUM OF NATURAL HISTORY.

REPORT

ON

With the Compliments of

James Hall,

ALBANY, N. Y., U. S. A.

STATE GEOLOGIST.

By JAMES HALL.

[EXTRACTED FROM THE THIRTY-NINTH ANNUAL REPORT OF THE N. Y. STATE MUSEUM.]

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REPORT ON BUILDING STONES.

By Prof. JAMES HALL

The following report on building stones was communicated to the Commissioners of the New Capitol in 1868. The report was called for before it could be properly completed, and much material intended for incorporation, was never finally prepared for publication. At that time the author was promised further facilities for continuing and completing the work, but these were never granted, and the report, in its very incomplete and unsatisfactory condition, has remained as originally published. The small number of copies at that time issued was quite insufficient to supply the demand; and the author has been frequently solicited to republish the report. This has been postponed from time to time, in the hope of being able to add matter of interest, and especially some tables of the comparative strength and resistance to crushing force. But these data still remain as they were recorded in 1868; and there is no prospect of being able to resume a work which, if properly carried out, would be of important economic value.

The report is herewith communicated as originally presented. It forms a part of the work accomplished by the author since assuming the charge of the State Museum of Natural History in 1866. It may very properly be regarded as the result of museum work. It is illustrated by the museum collections of marbles, building stones, etc., chiefly in the material occupying the shelves along the sides of the entrance-hall of the State Museum on State street.

January, 1886.

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GENERAL ABSTRACT OF CONTENTS OF REPORT.

PRELIMINARY ADDRESS.

I. Granites, including Sienite, Gneiss or Gneissoid and Sienitic Rocks; their Geological position and Geographical distribution.

II. Marbles or Metamorphic crystalline limestones, their Geological position and Geographical distribution.

III. Limestones not Metamorphic, compact or sub-crystalline; their Geological position and Geographical distribution.

IV. Sandstones or freestones, and their varieties; their Geological position and Geographical distribution within the State of New York.

V. On the selection of Building Stones, and the cause of their decay.

VI. General composition and comparative durability of Building Stones.

VII. Modes of determining the character and strength of Building Stones.

VIII. Causes affecting the durability of Building Stones, which are inherent in the Stone itself.

IX. Causes affecting the durability of a Stone, which are accidental, or due to artificial or extraneous conditions.

X. Results of trials of the strength of various Stones with tables of comparison for other Stones. Incomplete.

XI. Catalogue of the principal Stones in Collection, which have been submitted to the Commissioners for their inspection, or collected during the examination.

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PRELIMINARY REPORT.

[Communicated to the Commissioners of the New Capitol in 1868.]

Hon. Hamilton Harris,
Chairman of New Capitol Commissioners:

Dear Sir — According to instructions received from yourself and Hon. J. V. L. Pruyn in June, 1867, I proceeded to examine the quarries of building stone within the limits of the State of New York, and also those in adjacent States from which materials had been, or were proposed to be offered for the building of the New Capitol.

To this object I devoted the greater part of my time during the remainder of the season, returning from my last journey on the 4th of December; leaving the investigation, however, very far from being completed. During this time I visited many of the quarries within the State of New York and others in the State of Massachusetts, and some in Connecticut, Vermont, New Hampshire, Maine, and Ohio.

In order to have before you the tangible results of this investigation, I have brought to Albany, and deposited in the Geological Rooms, specimens from the greater part of the quarries examined. In nearly all cases the specimens were freely contributed by the proprietors of the quarries, and some of them in the most liberal and handsome manner, as I shall have occasion to mention in the course of my report. Other specimens have likewise been promised for the collection, from quarries examined, and from others not visited. The materials now arranged in the Hall of the Geological Rooms, though far from complete, constitute a valuable and instructive series of building stones; from among which, I believe, satisfactory selections may be made, not only for the construction of the New Capitol, in its foundations and superstructure, but they will serve as a guide for architects and others in the selection of materials for other purposes.

I had hoped to be able to finish my observations upon the quarries, and the general distribution of building material, during the present season; but other duties have prevented this, and I would respectfully suggest that some further examination, particularly in some parts of New York, be authorized by the Commissioners before the Report shall be considered complete. I venture to suggest this,

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believing that a more acceptable service could not be rendered to the building and economic interests of the State; and the New Capitol Commissioners have an opportunity of rendering this service to the general welfare of the community, while fortifying themselves with all available information to govern their own action in the selection of materials, not only for the exterior walls, but for interior use and decoration.

For the latter object, I would very earnestly recommend that specimens from all formations yielding marble, or of limestone bearing a good polish, be used in some part of the New Capitol work. With this object in view, I have already procured specimens of some of these stones, but the collection in this department is scarcely begun.

I have already recommended to you certain localities from which foundation stones may be obtained. In this statement, I think I omitted, or did not definitely specify, the locality of gneiss or granite in the Highlands on the Hudson river, of which the quarries at Breakneck and Butter hill offer good examples.

As a preliminary to our inquiries after *proper building stone*, we may first consider what are the materials with which we have to deal. The rocks or varieties of rocks offered in nature, and from which we are compelled to make our selections, may be named under the following heads:

1. GRANITES, including SIENITE, GNEISS, etc.
2. MARBLES, *or* METAMORPHIC CRYSTALLINE LIMESTONES.
3. LIMESTONES, *not metamorphic, compact or subcrystalline.*
4. SANDSTONES *or* FREESTONES, *and* their varieties resulting from admixture of clay or carbonate of lime, etc.

In the first place, it should be understood that under each of these heads there is an almost infinite variety in *texture*, *color*, *power* of *resistance* to *pressure*, *durability*, etc.; that the substances named are very widely distributed, and that they vary in different and distant localities; that a *sandstone* is rarely a purely siliceous rock, or a *limestone* a purely calcareous or calcareo-magnesian rock; other materials foreign to their strict constitution, according to the usual designation, enter into their composition, and, for the most part, to the injury of the mass. In the purely sedimentary rocks, which have undergone no subsequent change, the sandstones are more or less permeated by argillaceous matter or clay, which constituted a part of the original sediment, and which may be uniformly mingled throughout the entire mass, or may form thin layers or seams separating the harder layers. In either case it is a dangerous ingredient; for no rock with clay seams can long be exposed to the weather, without a greater or less degree of separation or disintegration; and when any considerable amount of the same material is distributed through the mass, its ready absorption of water renders it equally dangerous to the stability and integrity of the whole. Placed beneath the surface, and beyond the reach of frosts, the conditions are different, and such rocks last for an indefinite period of time.

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The same remarks hold true with regard to limestones; and there are few limestones that are not marked by partings of shale or clay, which, in the course of time, weather into open seams, causing those unsightly appearances so common in structures of this kind.

In the granite and crystalline limestones, other causes, as the want of cohesion among the particles, presence of destructive agents or liability to chemical changes, and seams or patches of foreign matter, are symptoms to be guarded against. It is not because a rock offered as a building stone is a *granite*, a *marble*, a *limestone*, or a *sandstone*, that it is good or bad; but this characteristic is to be sought in other conditions, and the objectionable feature may be accidental or adventitious.

One other condition should be remembered. These materials used for building are not promiscuously distributed over the country, but are restricted to certain geological formations, and can only be found within certain limits. Although we find granite, gneiss, and various sienites, with crystalline limestone, in the mountainous regions of Northern New York, it would be quite absurd to look for rocks of this kind in the Catskill mountains. We find white and variegated marbles in the region skirting the Highlands on the east, and extending through Western Connecticut, Massachusetts and Vermont; but no well informed person expects this material in the Helderberg mountains, or in the hills of the southern counties of New York. Investigation has shown that certain kinds of rock, or rocks of similar but very distinct characteristics, are confined to certain geological formations, and do not occur out of these; and again, that these formations have certain limits which are already defined and well understood. Geology has so well defined these matters, and the association of certain rocks and minerals, that when told that a known geological formation covers a portion of country, we know what kind and character of rocks and other mineral products to expect.

In a State where the geological structure is so well known as that of New York, I think I may be allowed to speak of the various building materials under the heads of the several geological formations to which they belong, or in which they occur; thus conveying general information, while treating of the *special subject*.

All the Granites, *granitic*, *sienitic*, or *gneissoid* rocks of the State are confined either to the northern portion, known as the Adirondack region, from the name of the high mountain range in its central part; or to the Highland region along the Hudson river, which is of the same geological age as the northern portion, and all belonging to the Laurentian System.

In the northern part of the State, Crystalline limestone, of various colors, is associated with granitic or gneissoid rocks; the same is true, in a less degree, of the granitic region of the Highlands.

The White and Variegated Marbles, so much in general use, belong to a different geological age and constitute a distinct belt of

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formation, running to the eastward of the Highlands generally, and occupying portions of Westchester and Dutchess counties in New York, and thence extending into Connecticut and Massachusetts. The ordinary gray or dark-colored bluish limestones and the various colored sandstones have a much wider distribution, but are still limited to certain belts of country.

Treating these in their order, we may arrange and discuss them as follows:

I.

GRANITES, INCLUDING SIENITES, GNEISS, OR GNEISSOID AND SIENITIC ROCKS; THEIR GEOLOGICAL POSITION AND GEOGRAPHICAL DISTRIBUTION.

The term granite, in its strict signification, means a crystalline rock composed of quartz, felspar and mica in intimate mixture, the separate minerals being composed of crystalline grains. It is a very common condition of the granitic rocks, that the mica may be absent, and in its stead we have hornblende, and in this form the rock is termed a sienite.* On the other hand, the presence of mica in thin scales, forming lamination, or rendering the lines of bedding visible by coloration or otherwise, produces what we term *gneiss;* though some geologists would apply the term *gneiss* to all stratified granitic rocks.

The proportion of mica in gneiss is not necessarily larger than in some of the granites; but the faces of the thin laminæ being arranged parallel to the lines of bedding and the freest line of cleavage, causes it often to appear in larger proportion.†

Quartz, felspar and hornblende without mica or with a very small proportion of this mineral constitute some of the best granites; while in the lighter gray or whitish gray granites, the quartz, or quartz and felspar, are the chief component parts, and there is little either of hornblende or mica. The grains or aggregations of these minerals may sometimes be so large that each one presents its distinctive mineralogical or individual character, becoming so coarsely crystalline as to be unfit for building purposes.

GRANITES OF NEW YORK.

In the lower portion of the Adirondack region, or the Laurentian System bordering Lake Champlain and extending from Saratoga to Clinton county, the rocks consist mainly of a gray gneissoid granite, which is sometimes traversed by coarser crystalline veins, and sometimes nearly or entirely losing its gneissoid character from the small proportion of mica, but always regularly stratified. The latter character is presented in the exposures at Little Falls and other places;

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* The Egyptian sienite or syenite, according to DELESSE, contains mica.

† A distinction has sometimes been made between gneiss and granite, that the one is stratified and the other not. This does not hold true; for nearly all, if not all, the granites that are extensively quarried are stratified, and I believe all of them cleave in one direction more freely than in another, while the other free line of cleavage or breaking is rectangular to the first.

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while the true compact gneiss is seen at the quarries in Saratoga county, and the partial or entire absence of the mica characterizes the rock at many localities farther to the north. This gray gneissoid rock graduates downward, through alternating beds of variable character, into a hornblende rock, and becomes a compact dark-colored sienite extremely hard and tough in its character.

The same general features prevail in the granite rocks in the Highlands as exposed along the Hudson river, the strata being tilted at a high angle. In many places, however, the lines of bedding become obscure, the mica is to a great degree absent, and the rock assumes the character of a true granite. The principal points of exposure, where the gneiss or granite of the Highlands has been quarried, are at Butter hill, on the west side of the river, and at Breakneck on the east side. In some portions of the mass, at both of these localities, the rock loses in a measure its gneissoid character, and presents a comparatively even admixture of the component parts. At both localities the rock is penetrated by trap dykes, which have affected the beds adjacent to them; and these, together with other causes, have produced a more than ordinarily fractured or jointed condition of the rock.

In the higher part of the Laurentian series, and in localities more inaccessible to means of transportation, we have the highly felspathic granites of the central portion of the Adirondack region. These are usually coarsely crystalline and of a dark color, but weathering to a lighter hue. They have nowhere been brought into use for building purposes; and not being within the limits of reasonable cost of transportation, it is scarcely worth while to indicate their localities more particularly.

GRANITES OF NEW ENGLAND.

The granites examined beyond the limits of the State belong to an entirely different geological age from those of New York, and present a different aspect in the aggregation of their component parts. They moreover differ among themselves, in a very extreme degree, both in color and texture; varying from the dark-colored compact sienite of Quincy and the neighborhood, through the lighter-colored varieties of the same locality and that of Chelmsford and other places, to the greyish-white varieties like that of Rockport on Cape Ann. All the quarries that I have examined along the coast are free from mica; and when hornblende is not present, we have the quartz and felspar only. The dark colors are usually due to the presence of hornblende; the reddish or brownish colors, to the colored felspar; and some of the quarries offer a granite of quartz, brownish felspar and dark hornblende, giving thus within these ranges a considerable variety of color, due either to the original color of the substances, or to the proportions in which they are mingled in the mass.

The principal quarries that came under my observation were those of Quincy and Weymouth, Rockport on Cape Ann and Dix island

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in Maine, with others of less importance. The collection embraces specimens from each of these places. All of the granites (sienites) quarried along the coast are durable stones; a character determined as well from their abundant use in building, as also from their exposed surfaces in nature, which have withstood the action of weathering for centuries without perceptible disintegration.

The granites of the interior of New England, as of Concord and Fitzwilliam in New Hampshire, Hallowell in Maine, Medfield in Massachusetts, Westerly in Rhode Island, and of Barre, Berlin and other places in Vermont, are compounds of quartz, felspar and mica. They are, for the most part, light-colored and fine grained. The felspar predominates, and they are easily wrought and bear fine working.

The Concord granite, which is now so largely in use, occupies a long hill near the town of Concord in New Hampshire, which has a direction or range from north-east to south-west. It is quarried at several places on this hill, within a moderate distance from the town and railroad. The rock presents distinct lines of bedding with an apparent dip to the north-west, as indicated by seams or laminæ of different color, and also by the splitting of the rock both in the line or *rift* (so termed by the workmen), and in the direction perpendicular or vertical to the lines of bedding.*

The beds of this granite are unequal in thickness, varying from one to three or four, or even five or six feet, which can be split in any desired lengths. The texture is pretty even, with some coarser beds, with occasionally some blotches of coarser or finer, or lighter or darker material.

The granite of Fitzwilliam, a locality some forty miles west of Concord, occupies a hill having a direction from north-east to south-west, with the dip apparently to the north-east. In texture and quality it is very similar to that of Concord, the prevailing beds perhaps a little thinner, the thickest being four feet. The rock is easily worked, and can be dressed with great facility.†

A mile northward of the principal quarries the rock is somewhat coarser in texture, but of similar light gray color, readily worked, and making a handsome building stone. The granite of Hallowell in Maine is similar in texture to that of Concord and Fitzwilliam.

There is also a light-colored granite in the town of Medfield in Massachusetts, from which the Court-house in Dedham has been built. In color and texture, this granite differs but little from the Concord granite, being perhaps a little coarser. The Court-house was erected more than forty years ago; and considering the time and the less perfect dressing of the stone as compared with work of the present day, the building still presents a very fine appearance.

The granites of Barre, Berlin and other places in Vermont, are of

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* In splitting the blocks vertically to the bedding, I am informed by the foreman of the quarry, Mr. Roe, that they open much more readily in lines east and west and north and south, than in any direction oblique to these.

† I am informed that the statues on the Horticultural Hall in Tremont street, Boston, are from the Fitzwilliam granite, the structure itself being of Concord granite.

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a whitish-gray color, with the component parts very distinctly granular and evenly mixed throughout, containing less mica than the Concord and Fitzwilliam granites, and producing one of the finest building materials in the country, possessing a fine color, strength and durability.

II.

MARBLES, OR METAMORPHIC CRYSTALLINE LIMESTONES; THEIR GEOLOGICAL POSITION AND GEOGRAPHICAL DISTRIBUTION.

Crystalline limestones are everywhere interstratified with the gneiss rocks of the Laurentian System, but usually forming a very small proportion of the entire mass. These limestones frequently contain a large proportion of other minerals, as serpentine, augite, etc.; often producing a marble of variegated character which is quite ornamental. When free from these materials, it is often grayish or bluish-gray, and generally coarsely crystalline.

Limestones of this age follow the line of outcrop of the gneiss of the same system, appearing to the northward in Saratoga county, and extending thence with more or less continuity through Warren, Essex and Clinton counties. In St. Lawrence and Jefferson counties, the crystalline limestones of the same age are more extensively developed, and have there been known and used for a long time. The same limestones likewise occur in Lewis county. In some localities these limestones are cut and wrought as a marble; but generally they have only a local use, though some of them with the serpentine admixture may yet prove of general commercial value.

The white and variegated marbles of commerce are mainly confined to the geological formation known as the Quebec group, which underlies a belt of country extending from Canada through Vermont, the western part of Massachusetts and Connecticut; thence into the eastern part of New York, through New Jersey, Pennsylvania, Maryland, etc.

The marbles of this group are largely quarried in Westchester county; and the quarries of Tuckahoe and Scarsdale, and other points, furnish large quantities of the material for buildings in New York city and elsewhere. The rock is rather coarsely crystalline, but compact and durable. The same marble, on the west side of the synclinal axis, is quarried at Hastings and at Sing Sing, and also at several places in Dutchess county.

The formation is abundantly developed in Litchfield county, in Connecticut, and at Stockbridge, Sheffield, Egremount, Barrington, Alford and other places in Massachusetts.

In its northern extension, the same formation furnishes the marbles of Vermont, at Rutland, Southerland Falls, Brandon and other places.

Neither to the eastward nor to the westward of this formation are there any extensive beds of white or variegated marble, and the great sources of this material for building and ornamental purposes is to be sought in this range of rocks.

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III.

LIMESTONES NOT METAMORPHIC, COMPACT OR SUBCRYSTALLINE; THEIR GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION.

The limestones used in building, or for foundations, canal locks, bridge abutments and other solid masonry, are very widely distributed, and in great variety within the State of New York.

In their geological order, we have the *Chazy limestone*, the *Trenton limestone group* (embracing the *Birdseye*, *Black river* and *Trenton limestone* proper), the *Niagara limestone*, the *Lower* and *Upper Helderberg limestone groups*, and the *Tully limestone*.

These limestones vary from a dark bluish-black or black color to bluish-gray, gray, or sometimes reddish or brownish-gray.

1. The oldest of these, the CHAZY LIMESTONE, as its name indicates, occurs at Chazy in New York. It forms the island known as Isle la Motte, and other islands in Lake Champlain, and extends likewise into Vermont and Canada. It exists in heavy beds, and is largely quarried for different purposes, as will be mentioned hereafter.

2. The TRENTON LIMESTONE GROUP, in one or more of its members, occurs both on the east and west shores of Lake Champlain, and is extensively quarried at Willsborough and other places. The same rock occurs at Glens Falls and in the neighborhood of Saratoga Springs. It likewise extends along the Mohawk valley from the neighborhood of Hoffman's Ferry to Little Falls, and is quarried at Amsterdam, Tribes Hill, and other places. At Little Falls the continuity of the limestone formation is interrupted by the southern extension of the Gneiss formation, but it comes in again to the south and west beyond this, and is extensively quarried at Jacksonburgh on the south side of the Mohawk river. The same formation extends, by the way of Trenton Falls, through Lewis and Jefferson counties, everywhere offering quarries for building-stone and for lime.

3. The NIAGARA LIMESTONE, though extending further to the eastward, acquires little force or thickness till we reach Monroe county, where it has a considerable thickness on the Genesee river, and some of the beds of the formation are valuable as quarry-stones. It is only in the neighborhood of Lockport, however, that the lower beds of this formation become important as a building stone. The principal working beds are a light gray stone, varying in some instances to a brownish color from the admixture of organic remains. The same limestone occurs at Niagara Falls and vicinity, extending thence through Canada West to Lake Huron. The upper parts of the formation are of a brownish, or often of an ashen gray color, with irregular bedding and of unequal texture, as well as marked by cavities and crystalline masses of calc-spar, selenite or compact gypsum, celestine, etc. The stone of this part of the formation is adapted only to the heavier and coarser masonry, and care is required in its selection to secure a strong and durable stone.

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4. **The Lower Helderberg limestone** formation, in its most easterly extension within New York, appears in the Helderberg mountains and extends west as far as Herkimer county. The lower beds of the formation afford a very excellent building stone of a dark-bluish color, which, when polished, is nearly black. It is principally quarried at Schoharie and Cobleskill; it is likewise worked at Carlisle and Cherry Valley, and to a small extent at points west of the latter place. The middle portion of the group consists of a gray or bluish-gray subcrystalline limestone, but affords no beds of great value for building material. The upper member of this formation is a gray subcrystalline limestone, sometimes variegated with brownish spots from organic remains. It is quarried both for a building stone for rough masonry, and likewise for a marble, bearing a pretty good polish, and the variety of color from the fossils gives it a handsome appearance.

5. **The Upper Helderberg limestone** formation consists principally of two members, the **Onondaga** and **Seneca** limestones. The former was so named from its having been extensively quarried in Onondaga county; and the latter, from its greater development in Seneca county.

This formation, or group, extends through the State of New York from the Hudson river westward to Black Rock on the Niagara. Constituting the higher limestone of the Helderberg mountains, it approaches the river, and continues in its outcrop along the river counties as far as Kingston in Ulster, where one of its members is largely quarried for various building purposes. The Onondaga limestone is worked at various points along its outcrop; but the principal quarries are in the county of Onondaga, to the southward of Syracuse. From this neighborhood, the stone was used for building some of the locks on the Erie canal in its original construction, and has been extensively used in the enlarged canal, as well as in the buildings of Syracuse. The upper member of the formation is quarried at Springport in Cayuga county, and largely in the neighborhood of Seneca Falls. From this point through the western counties one or both the members of this group are more or less extensively quarried, and used in building, or for door and window caps and sills, foundations, and other masonry.

6. The **Tully limestone** constitutes a belt of formation of from one to twenty-five feet in thickness, lying above the shales of the Hamilton group and below the Genesee slate. The geographical extent of this formation is very limited, having no great thickness or importance to the east of Cayuga county, and almost entirely disappearing on the west within the limits of Ontario county. It is mentioned here among the sources of building material, but it is rarely in such a condition as to be reliable for this purpose.

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IV.

SANDSTONES OR FREESTONES, AND THEIR VARIETIES; THEIR GEOLOGICAL POSITION AND GEOGRAPHICAL DISTRIBUTION WITHIN THE STATE OF NEW YORK.

1. The POTSDAM SANDSTONE formation is the lowest member of the unaltered stratified rocks. The formation consists of numerous beds of varying thickness, and of a gray, white, buff or red color. The rock is naturally fine-grained and compact, and in many localities furnishes a strong durable material. The beds are usually thin, but generally sufficiently thick for the ordinary purposes of construction.

In its eastern extension, this formation occupies a considerable area in Washington county, and is especially conspicuous in the neighborhood of Whitehall. It occurs at numerous places along the west side of Lake Champlain, and is especially developed in the neighborhood of Keeseville. In some parts of Clinton county the rock is too friable for any economical use beyond furnishing sand for glass-making. In Franklin county, at Malone, the rock has been extensively quarried and used for building and flagging stones for many years past. At Potsdam, and other places in St. Lawrence county, the stone is of a reddish brown color, close-grained and compact in texture. The rock continues of similar character in Jefferson county on the north side of the Black river valley. Its commonly striped or variegated color offers an objectionable feature for general use in building.

2. SANDSTONES AND ARGILLACEOUS SANDSTONES OF THE QUEBEC AND HUDSON RIVER GROUPS. Certain parts of both of these groups of rocks furnish building stones of greater or less value. The greater part of the stone known as *blue stone* (the Malden *blue stone* belongs to a different formation and has a different character), along the Hudson and Mohawk valleys is derived from one or other of these formations. The higher beds of the Hudson river group have also been quarried in Oneida, Oswego and Lewis counties, but they are not extensively used.

The quarries along the Mohawk river below Schenectady have furnished a large quantity of this blue stone, for foundations, water tables, and for entire buildings. Where the strata are but little disturbed and lie nearly horizontally, the beds are easily worked, and the blocks are readily dressed. The rock can be quarried in regular masses and of any required dimensions. In the valley of the Hudson, the rock is so much disturbed that the strata are broken, and do not readily afford the means of furnishing large quantities of regular formed blocks for masonry. Nevertheless they are largely used for foundation stone, and many thousands of tons are annually quarried along the river. At and below Poughkeepsie, the stone of this character, quarried along the river, is of the Quebec group. The strata all consist of an argillaceous sandstone, very compact and strong, but breaking irregularly. Those which break into large masses are very strong, and make excellent foundation stones; but I believe none of the beds are used for dressed stone.

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The two formations lie side by side along the Hudson river valley, extending northward through Washington county and into Vermont and Canada.

To the westward, the Hudson river group extends along the Mohawk valley, and thence in its upper members through Lewis and Oswego counties; overbearing in its upper part some heavy-bedded gray sandstone which is available for foundations and rough masonry, but I am not aware that it has been much used in the superstructure of buildings.

3. THE MEDINA SANDSTONE formation, from its eastern extension in Oswego county to the Nigara river, furnishes building stone in some of its beds, which, in some localities, is good and reliable, while in other parts of the same formation it becomes rapidly disintegrated upon exposure to the atmosphere. It is quarried at Fulton and other places in Oswego county, and at a few points in Wayne county. It has been heretofore quarried on the Genesee river below Rochester; but the more reliable quarries are at Holly, Albion, Medina and Lockport; and again it crops out in the bank of the Niagara river above Lewiston, where it can be worked with facility. The formation furnishes valuable flagstones in the neighborhood of Lockport.

4. SANDSTONES OF THE CLINTON GROUP. The Clinton group is made up of a series of shales, thin beds of limestone, and impure shaly sandstone with more perfect beds of the latter. In Herkimer county, on the south side of the Mohawk river, there are some beds of brown sandstone in this group which are worthy of attention. The material is mainly siliceous and the texture good. So far as known, these beds are limited within the width of the county. In the same neighborhood, and lying above the brown beds, there is a considerable thickness of gray siliceous sandstones of the most durable character. So far as known, the rock has not been quarried to any considerable extent, and its economic value is, therefore, not fully known. In other parts of the Clinton group, there are thin flaggy beds which are used for rough building or foundation stones.

5. THE ORISKANY SANDSTONE, though a good and valuable stone in some of its strata, does not occur in such thick or extensive beds as to render its use very extensive, and, except locally, it is unknown as a building stone.

6. FREESTONES OR ARGILLACEOUS SANDSTONE AND FLAGSTONE OF THE PORTAGE GROUP AND UPPER PART OF THE HAMILTON GROUP. In Eastern New York, the upper part of the Hamilton group and lower part of the Portage group yield an abundance of the finest flagstone yet known in any part of the country. Some of these beds become thick enough for building purposes; and the fine "*blue stone*" of the Malden quarries on the Hudson river (now much used), is from the lower part of the Portage group. In Central New York, the upper part of the Portage group yields an abundance of fine-grained argillaceous sandstone, which is not always durable. In the extreme

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western counties of the State, however, some of the beds are durable, and make a valuable building stone.

The extension of the same formation into Ohio yields the famous fine grained standstone of Berea, and the gray freestone of Amherst and vicinity; the latter of which is now so largely used for building in New York and Philadelphia, Cleveland and Buffalo, and which enters into the construction of the Houses of Parliament at Ottawa.

This sandstone, like all others of the same class of rocks, is very variable in its character at different points along the outcrop of the formation; owing chiefly to the greater or less proportion of argillaceous matter contained in the mass, and sometimes the almost entire absence of that material. The latter condition exists in some of the beds at Berea, but more particularly in those of Amherst and neighborhood.

7. THE SANDSTONE AND ARGILLACEOUS SANDSTONE OF THE CHEMUNG GROUP are very irregularly distributed over the southern counties of the State. The beds fit for building-stone are usually intercalated between shaly beds, and sometimes continuous for many miles; while the coarser masses are not frequently lenticular in form, thinning away in every direction, or ending in thinly laminated beds which are unfit for building stone, but may be used for flagstones.

The stone varies in different localities and in different beds, from fine sandy layers of a light gray color, to more or less of an argillaceous character with a dark olive-brown color. It is not possible to trace any set of beds continuously through the country, and the rock can scarcely come into general use for building purposes. In certain localities, the arenaceous beds will prove of great value to the immediate neighborhood.

8. NEW RED SANDSTONE. Within the State of New York, this rock is limited to the county of Rockland; extending from Haverstraw along the river, beyond the limits of the State into New Jersey. The same sandstone has a wide area in the Connecticut river valley, and it is from this region that we chiefly know it in its uses as a building stone. Within the State, the stone has been quarried at Haverstraw, and on the river bank below; though it has not been extensively used from these localities, so far as I know. The quarries in New Jersey have been more extensively worked; and from the stone there obtained, some fine structures have been erected. The same formation extends through Maryland, where it has furnished material for the erection of the Smithsonian Institution and other buildings in Washington.

The *brown stone*, in its varieties, is well known in all the Atlantic cities, and has been more extensively used than any other in the country.

I have sketched, in a hasty manner, the general geological and geographical distribution of the principal building stones which may be brought before you for consideration. The portions of the

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country occupied by these have been roughly traced in different colors upon the map accompanying this report, so far as it covers the ground. I shall hope to have an opportunity of completing this work, and presenting such a map as will illustrate the important points relating to the subject of materials for construction and ornamentation.

V.

ON THE SELECTION OF BUILDING STONES, AND THE CAUSES OF THEIR DECAY.

In the selection of building stones for the exterior walls of a building, *color*, *texture*, and *durability* are objects of the first importance; and all of these ought to be combined, to render the structure perfect. Too little attention has been given to the subject of building stones; while on the one hand we are largely using a brown stone, which gives a sombre, cheerless aspect to the structure, the opposite extreme has been sought in the white marble, or that which is more nearly white in color. In contrast with these we have the red glaring color of brick; and it is only partially that this offensive aspect is palliated by painting of neutral tints. In a few eastern cities and towns we find the light gray granites now used in preference to the brown freestone, the white marble, or the dark granite, which have been much in use in past years.

No one can fail to experience the sensation of relief afforded by the structures, of light-colored granites in the city of Boston, or those of the buff or dove-colored limestone in the city of Chicago, or of the light gray freestone of many buildings in Cleveland and other places and of the buff-colored brick of Milwaukee. In these cases we have not the excessive reflection of light, or the glare which comes from white buildings whether of marble or of painted brick; nor the sombre, cheerless expression of the darker stone, caused by its great absorption of light. It is only necessary to consider the effects produced by the structures of these different materials upon one's own sensation, in order to determine what are the most agreeable tints, or those which please the eye and produce a cheerful impression upon the mind.

In the majority of structures, the necessities of locality, cheapness, or other causes compel the erection of structures from materials most accessible; but these considerations are not imperative in the cases of an important public building.

In many cases where the rock is homogeneous throughout and the color uniform and satisfactory, it is only to be inquired whether the coloring material is such as will produce decay or disintegration of the particles. When the general color is produced by the aggregation of different materials of distinct coloration, the character of each one is to be considered, and its effect upon the whole; and it is important to have such material comparatively fine-grained, and

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the different parts as uniformly mingled together as possible. As a general rule, it is only in the darker stones that the coloring matter has any tendency to disintegrate the mass.

In the selection of building stones, the simple presentation of a sample is not enough. The rock in place should be examined in the outset; for in its natural outcrop it has been exposed to the action of the weather, in all its influences, for many thousands of years. One of the principles taught in elementary geology is that the soft and decomposing rocks appear in low rounded or flattened exposures, or entirely covered by the soil or their own debris, forming no conspicuous feature in the country; while on the contrary the harder rocks stand out in relief, producing marked and distinguishing features in the landscape. It not unfrequently happens that the geologist, having familiarized himself with the succession and character of the rocks of a particular locality or neighborhood, by seizing the features and character of the prominent beds, is able to trace them in succession along the escarpment or mountain range as far as the eye can reach, and to approach them from any distant point with assurance that he has not been deceived.

The strata which make these features in the landscape are the ever-enduring rocks, which have withstood the action of the atmosphere through a period a thousand times longer than any structure of human origin. One cannot doubt that if properly placed in any artificial structure, they would still withstand the action of the elements. These escarpments, in their natural situation, may be coarse, rough and forbidding, more or less dilapidated or unequally dilapidated from the effects of time; but as they there present themselves, we shall be able to see their future in any structure exposed to the same influences.

It is true, however, that no artificial structure or position will ever subject the stone to the same degree of weathering influence to which it is exposed in its natural position, but the same changes in degree will supervene upon any freshly exposed surfaces. In its natural position the bed has been encased in ice, washed by currents, saturated with rains and melting snows, frozen and thawed, and exposed to the extreme of summer heat without mitigation. The rock which has withstood these influences is quite equal to withstand the exposures of a few centuries in an artificial structure. Yet there are occasionally modifying influences and conditions which have sometimes subdued the permanence of a durable stone, and given preference to others less durable. It therefore becomes necessary to carefully examine all these conditions, and to determine not only from the rock in place, but also from its physical constitution, whether it will meet the requirements of the structures proposed.

It not unfrequently happens, in working a quarry, that layers are reached which have not been exposed to the weather, and it is then necessary to test the strength and power of endurance of the stone. This may be done by repeated exposure to freezing and thawing, by

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testing the strength or power of resistance to pressure, etc. The exposure to freezing and thawing will not only determine its power of resisting the action of the weather, but will determine also whether such foreign ingredients as iron pyrites may exist in the mass. Chemical analysis may be resorted to for the purpose of comparison with specimens of known composition and durability; but chemical analysis alone cannot determine, without other testing experiments, the strength or power of endurance of the stone.

In some countries, and in certain localities in our country, the evidence obtained from ancient structures is available in determining the durability of the stone which has been used. Yet it would seem that this information has been of little avail in many places, where the rebuilding of edifices is repeated every century. Experience in many cases does not teach the lesson anticipated; and when a dilapidated structure is pointed out, the argument is made that "these stones were not well selected," or they were obtained "at the first opening of the quarry, and were not as good as now furnished." And again, as already remarked, there are few cases in which parties are permitted to select the material without prejudice, the influence of interest, or the absence of important information. Examples are everywhere before us of the improper selection of materials for buildings, and these examples do not deter from their use in the erection of others. When good material is abundant and accessible, it will be used; in other situations, comparatively few durable structures are likely to be erected.

VI.

General Composition and comparative Durability of Building Stones.

All the stones used in building, under whatever name they may be known, are composed of a few essential elementary minerals; these are:

1. Silica or Quartz;
2. Alumina-Clay or Argillaceous Matter;
3. Carbonate of Lime;
4. Carbonate of Magnesia.

Beyond these, except in crystalline rocks, the presence of other material is almost non-essential to the composition of the stone, often accidental or adventitious, and usually injurious to the integrity of the mass. The ultimate chemical composition of a stone has little to do, as a general rule, with its character for durability; nor will a chemical analysis determine the value of a stone for building purposes.

Physical Conditions of the Aggregates of the several named Substances.

1. The silica or quartz may occur as a mechanical aggregation of

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particles of sand simply cohering among themselves, or by the intervention of some argillaceous, ferruginous, or calcareous matter acting as a cement; or lastly through a partial solution and cementation of the siliceous particles themselves. In the latter case, and where the mass is pretty purely siliceous, the process may have gone so far as to give a vitreous rock known as quartzite. In many cases, however, the siliceous or arenaceous deposits present great inequalities of texture, from the aggregation of coarse particles or small pebbles among the finer materials, always to the injury of the strength and durability of the mass. Under certain other conditions, these mixtures become crystalline rocks of various character.

2. The clay, or argillaceous matter by itself or with a small admixture of silica, and often more or less of carbonate of lime, becomes a slate or shale rock, but quite unfit for building stone; and as a general rule, any rock in which argillaceous matter predominates is unfit for a durable building stone.

3. Carbonate of lime and magnesia, or the former alone, constitutes extensive beds of solid and durable stone, but which is often deteriorated by the presence of argillaceous matter. In many limestones, the mass consists of an aggregation of fine particles which have been deposited in the form of a fine calcareous mud. Other and often very extensive beds are visibly composed of the debris of shells and other organic bodies, cemented together by the finer particles of calcareous mud, or often by the partial solution of calcareous matter. Under the influence of subsequent conditions, these simple mechanical aggregations of calcareous matter, or the calcareous magnesian deposits, become crystalline marbles of various colors.

In the purely siliceous stones, or quartzites, the mass is too hard and brittle for easy working or comely shaping of the pieces; an admixture of clay or argillaceous matter being essential to the possibility of working stone whose basis is silica. When, however, this argillaceous material becomes excessive, the stone is liable to rapid disintegration from the action of the weather. While the silica absorbs but an extremely small quantity of water, the clay will absorb largely; and this, on freezing, will destroy the stone more or less rapidly. Some of the argillaceous sandstones, on drying in a hot sun and then being suddenly wetted, will crack and crumble into pieces. The same effect is often produced by the sudden freezing of large blocks which have been freshly quarried, and which still retain their water of absorption.

When the argillaceous matter is evenly and intimately mingled with particles of silica or quartz, and not in too large proportions, the stone will last a long time, and will disintegrate but slowly; but when the argillaceous material is in *seams* or *laminæ* of deposit, it is far more injurious, and every such seam in a block of stone must sooner or later lead to its destruction. The manner of this is very simple. The clay seam absorbs water, and, holding it while freezing, the seam expands; if disintegration does not immediately follow, the seam is widened so that it admits more water on the next

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occasion; and so on successively with alternate freezing and thawing until an unsightly crevice is produced, which constantly widens and encroaches more or less on the adjacent parts till the stone is destroyed.

This condition occurs in the gray or light-colored freestones, as well as in the brown ones; but in the brown freestone or sandstone, there is a further cause of destruction. The coloring matter, which is also in part the cementing matter of the grains of sand, is ferruginous, the siliceous grains are covered with peroxide of iron, and this substance is intimately combined with the argillaceous matter of the mass which cements the particles. Experience has everywhere proved that the brown sandstones or freestones are not durable stones; their destructibility is not only due to the presence of argillaceous matter, but to the oxide of iron; for the gray or neutral-tinted stones, of the same composition otherwise, are much more durable.

As an evidence of the rapid decomposition of the red or brown sandstone when the siliceous element is deficient, we may sometimes find a large area, which, when broken up, decomposes so rapidly that it becomes in a few years an arable soil. The same is essentially true in some parts of the Medina sandstone. In order to demonstrate this fact, it is only necessary to examine any building of brown stone which has been erected for a period of twenty-five years. The State Library building is an example in point. The Capitol and the Albany Academy have been longer erected, and were originally of better material than the Library building. The basement of the old City Hall in New York is an example of the same kind, where the brown stone, from its inherent destructibility and from the presence of clay seams, presents a dilapidated appearance; and other examples might be mentioned. In Europe the same condition exists, and many old buildings of the red or brown sandstone are falling in ruins.

In the lighter-colored sandstones, we have mainly to guard against clay seams and too large a proportion of argillaceous mixture in the mass. Beyond this, the presence of iron pyrites is to be looked for. This mineral is present in so many rocks of this character, especially those with a bluish or greenish olive tint, that it is to be suspected in all such stones. It should be remarked, moreover, that iron pyrites (sulphuret of iron), when in visible grains, nodules or crystals, is not so dangerous or destructive to the rock as when disseminated in fine or imperceptible grains through the entire mass. This mineral, however, may be so disseminated and not prove entirely destructive, since in some stones it decomposes from the first exposure to the weather, staining the exterior of a rusty hue, and thus continuing to exude as an oxide of iron so long as any of it is reached by the moisture of the atmosphere; at the same time the free sulphuric acid unites with the lime or magnesia, if either be present, or to some extent with the alumina in the absence of the other substances; and this chemical change may sometimes

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go on for a long time, without seriously affecting the texture of the stone, producing no important result beyond the unsightly appearance. Generally, however, the decomposition of the pyrites produces the gradual destruction of the stone.

We have in the State of New York a class of argillaceous sandstones largely in use as building stones, and which are less known in any other State. They are of the character of rocks formerly known as "*Graywacke*," and the name might be usefully retained to designate the argillaceous sandstones of the Hudson river group, the Hamilton, Portage and Chemung groups. These beds of the Hudson river group are known as *blue stone*, which is a compact argillaceous sandstone consisting of variable proportions of these materials.

The name *blue stone* is equally applicable to the heavy-bedded compact arenaceous layers, and the thin-bedded slaty layers, which are largely used in the foundations of ordinary buildings. Much of the heavy-bedded slaty rock of this character, which is quarried along the Hudson river valley, belongs to the Quebec group; but I am not at this time aware of any quarries in the same formation, which furnish dressed building stone.

In the Hudson river group, this rock occurs in many localities, in very regular beds which are cut by vertical joints presenting clean, straight faces, and are thus laid in the building. The composition of these stones (that is, in the proportions of silica and alumina) often varies in the distance of a few rods; but, if well selected and laid on its natural bedding, it makes a durable building material. Much of it, however, becomes stained from the decomposition of iron pyrites, which after a length of time, either leaves the surface of a permanently rusty brown color, or the decomposition goes on till the rock crumbles or scales off in thin laminæ. Sometimes the faces of the joints are coated by thin laminæ of carbonate of lime, arising from the solution and infiltration of calcareous matter; and this forms a permanent coating, which resists all further change from atmospheric influences. It is of the greatest importance that these stones be carefully selected, or otherwise they soon become disintegrated.

The flagstones, so abundantly supplied from the upper part of the Hamilton group and lower part of the Portage group, are among the most enduring of the compounds of silica and alumina. The material is a fine-grained compact argillaceous sandstone of a blue or grayish-blue color, which, when free from seams, is scarcely influenced by the action of the weather. These beds are not only used for flagstones in most of the Atlantic cities, but in Albany, Troy, and other towns along the river and elsewhere, this stone is used for door-steps and caps, window-sills and caps, water tables, etc. The stone is very strong and durable, sometimes slightly staining from the decomposition of iron pyrites, but rarely or never undergoing disintegration from that cause.

The blue stone of Malden on the Hudson river, which has of late come into use for ashlar, door-steps and sills, pillars or pilasters, window-sills and caps, water tables, etc., is obtained from some

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heavier beds in the Portage group along the base of the Catskill mountains. The stone has great strength and durability, wearing very slowly when used for steps, and possessing the great merit of retaining a certain degree of roughness of surface. The dark color may be regarded as the only objectionable feature.

In the central and western part of the State, the Portage sandstones are of a lighter color, usually more friable than those of the eastern outcrops. Many of the beds are of a greenish or olive-gray color, occurring both in flaggy and heavier courses, which are easily dressed and present a very good appearance. The frequent presence of iron pyrites, causing both staining and disintegration, offers an objection to their extensive use. In the western counties, however, some of the beds are nearly gray, having lost the greenish or olive color almost entirely, and at the same time have less argillaceous matter in their composition, with scarcely a trace of iron pyrites. The stone from these beds has a very uniform gray color, a fine texture, and if quarried and dried before exposure to the frost, is a very durable stone.

In Ohio, the arenaceous beds of the Portage group furnish the friable gray sandstone from which grindstones are largely manufactured, and from which more recently large quantities of building stone have been furnished. The cohesion of the particles is slight, and the stone is very brittle on first quarrying, but becomes stronger and harder on exposure, and, if properly selected, resists the effects of the atmosphere in a remarkable degree. The strong cohesion of the particles, therefore, is not always a requirement for durability, though it is for strength, either as resisting direct pressure or the effect of tensile force.

It should not be forgotten, however, that neither all the beds of this stone, nor all parts of the same bed, are uniform in texture, composition or durability, and it will not be surprising, if in its indiscriminate use it may sometimes prove unsatisfactory as a building stone.

The argillaceous sandstones of the Chemung group are generally or comparatively free from iron pyrites, and range in color from gray to olive or dark olive-brown. When quarried and exposed to drying before freezing, they are comparatively durable stone; but they cannot be safely quarried during winter, or exposed to freezing soon after quarrying. Building stones from this group, within the State of New York, have long been used, and new quarries have been opened at many points, though the stone has usually but a local importance. The more important structures erected from this stone are the buildings of the Cornell University at Ithaca.

MANNER OF LAYING.

Sandstones or freestones, and all the varieties of argillaceous sandstones, should be laid in the building according to the natural bedding of the rock, so that the wear of the elements may act upon the exposed edges of the laminæ. Since it is impossible to have any great

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thickness of stratified stone, especially sandstone, entirely uniform and homogeneous in texture, or without interlamination of shaly matter, it follows that by turning the blocks upon their edges, we shall in one case have the face of a harder or coarser layer, and in another of a softer layer of the same rock, thus exposing the wall to unequal weathering. Not unfrequently the face of the stone is the line of the soft shaly parting, and the effects of this practice may often be seen in the scaling off of an entire surface of a block of ashlar for several square feet in extent. Such examples may be seen in some of our buildings, which have been erected within the past twenty-five years. Had these blocks been laid in an opposite direction, the edges of the shaly seams only would have been exposed, and their destruction would have been comparatively slow. The sandstones separate usually with great freedom along the line of bedding, and thus offer great facilities for dressing the surface in the direction of the laminæ; and from this cause, and the desire to present as large a surface as practicable in each block, has arisen the practice of setting them upon their edges. A block of stone may, however, be split in the same direction, through one of its more sandy layers, and the objections urged may not be so palpable.

An equally reprehensible practice is the cutting of step-stones from blocks with distinct shaly partings, which produce exfoliation and consequent inequality of the surface.

MODE OF DRESSING.

In the use of argillaceous sandstones, as well as some other rocks, there are some considerations as to the mode of dressing which should not be forgotten. There are some stones which, if dressed elaborately, disintegrate rapidly upon the surface. This comes from the crushing of the material under the tool;* the natural texture and cohesion of the particles being thus broken up, it absorbs more water, and on freezing, decays rapidly and becomes unsightly. Many stones that are unfit for finely dressed work are nevertheless quite durable if rough dressed; that is, by dressing the joints close and a smooth space along the edge, while a greater part of the face is left roughly broken without tool-work of any kind. During wet weather, the moisture will collect at the numerous projecting points or edges, and much of it drops off which will be absorbed by a smooth dressed face of stone. The effect of freezing is much less destructive under such conditions. Moreover, a moderate degree of weather-wearing on such surfaces is less conspicuous than on finely dressed stone. The dressing of the stone in the University buildings at Ithaca is a good example of this kind of work.

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* The term *deadening* of the surface is used by the workmen to designate this condition.

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LIMESTONES AND MARBLES.

In limestones and marbles, the conditions of durability and causes of destruction, as a general rule, differ little from those of sandstone. There is nevertheless one point of distinction, which may be noted in the outset. In all the marbles and older stratified limestones — that is, of the Silurian, Devonian or Carboniferous age — the want of cohesion among the particles, or a friable condition of the rock, may be regarded as fatal to its durability as a building stone; while on the other hand, as has been observed, some of the friable sandstones harden by exposure to the weather. In the calcareous deposition termed *travertin,* however, which is a deposit of modern origin, the mass, on first exposure, is soft and friable, and is frequently cut into blocks of the required shape and dimensions by the axe or saw; after being laid up in the wall it hardens and becomes quite indestructible. Some limestones are said to possess this power of hardening upon exposure.

In almost all limestones, as well those which are unaltered as those which have been metamorphosed, and are known as marbles *par excellence,* there is a considerable amount of argillaceous matter, either present in seams parallel to the lines of bedding, or disseminated through the mass. In the dark-colored uncrystalline or compact fine-grained limestones this matter is evenly distributed through the mass, and, when only in small proportion, produces no noticeable effect. Some of the varieties of this kind of limestone will stand the exposure of a century, without any essential or injurious change. The compact fine-grained blue limestones without seams are therefore among the most durable stones we have.

In the gray or bluish-gray subcrystalline limestones the argillaceous matter, instead of being distributed throughout the mass, is usually present in the form of seams which are parallel to the lines of bedding, or distributed in short interrupted laminæ. These seams, whether continuous or otherwise, are fatal to the integrity of the stone; and there is scarcely a limestone structure in the country, of twenty-five years' standing, which is not more or less dilapidated or unsightly, from the effects of absorption of water by the clay seams, and the alternate freezing and thawing. When laid in the position of the original beds, which is the usual mode, the separation by the clay seam is slower; but when used as posts or pillars, with the lines of bedding vertical, the change goes on more rapidly.

In the dressing of limestone, the tool crushes the stone to a certain depth, and leaves the surface with an interrupted layer of a lighter color, on which the cohesion of the particles has been partially or entirely destroyed; and in this condition the argillaceous seams are so covered and obscured as to be scarcely or at all visible, but the weathering of one or two years usually shows their presence.

The usual process of dressing limestone rather exaggerates the cause of dilapidation from the shaly seams in the material. The clay being softer than the adjacent stone, the blow of the hammer or other tool breaks the limestone at the margin of the seam, and drives forward into the space little wedge-shaped bits of harder stone. A careful examination of dressed surfaces will often show the limestone along the seam to be fractured, with numerous thin wedge-shaped sliv-

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ers of the stone which have been broken off, and are more or less driven forward into the softer parts. In looking at similar surfaces which have been a long time exposed to the weather, it will be seen that the stone adjacent to the seam presents an interrupted fractured margin; the small fragments having dropped out in the process of weathering. Limestones of this character are much better adapted to rough dressing, when the blows are directed away from the surface instead of against it, and when the entire surface shall be left of the natural fresh fracture. By this process the clay seams have not been crushed, nor the limestone margining them broken, and the stone withstands the weather much longer than otherwise. The attempt at fine hammer-dressing is injurious to any stone; for the cohesion of the particles is necessarily destroyed, and a portion of the surface left in a condition to be much more readily acted upon by the weather.

The gray, sometimes brownish-gray, subcrystalline limestone, which is not metamorphic, is usually composed of fragments of organic remains more or less comminuted, with the interstices filled with fine particles of the same, or with an impalpable calcareous mud. In such rocks, the fragments of fossils being crystalline, withstand the weathering action, while the intermediate portions wear away, leaving a rough and sometimes unsightly surface. The disintegration from this cause is slow; and in the absence of clay seams, a structure of this kind of stone may remain a long time without material deterioration.

One of the best limestones of this character, and perhaps the best in the country in relation to freedom from clay seams, is the encrinal limestone of Lockport, which, at that point, constitutes a portion of the lower part of the Niagara limestone. The Onondaga limestone, in the quarries south of Syracuse, is one of the most useful and serviceable of these limestones, and when free from clay seams, is equal to any other limestone in color, quality and durability. In some portions of the Onondaga beds to the westward, and in some similar beds of gray limestone in the Lower Helderberg group, the mass requires firmness; and the want of compactness or close coherence among the particles allows the infiltration of water, which, charged with carbonic acid, acts still further to lessen their cohesion.

In some of the Lower Silurian limestones, the entire mass of the dark-colored beds is completely penetrated by irregular ramifications of siliceous matter, which, in their position and relations, seem as if they may have been fucoidal or spongoid bodies growing upon the bottom at the time of the deposition of the calcareous deposits. The beds of this character furnish a strong and durable material for rough masonry and foundations, and some of the beds bear dressing with satisfactory results.

In the process of metamorphism, the limestones have become more or less changed to a white, bluish or grayish-white color, or to variegated white and gray. The seams of argillaceous matter which mark the line of bedding in ordinary limestones have undergone some chemical change, and have become chloritic, talcose or micaceous, of a greenish, bluish or variegated color, but nevertheless still retaining the same relations to the calcareous part of the mass as in their normal condition. Although they are no longer a clay or shale, but have undergone some chemical change, these parts are nevertheless usually softer and weather more rapidly than the surrounding calcareous portions; or

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if not entirely weathering out, some parts of the lines or bands of color are more susceptible to the action of the weather, because unevenly disintegrated, and finally present an unsightly surface. Bands or stripes of color, in all the marbles, indicate a different texture and composition from the other parts of the mass, and all examples of this character will weather unequally. Such stones, therefore, should be used with great caution in all structures intended to be permanent.

In some of the marbles there are numerous spots of soft talc-like substance, which weathers more easily than the surrounding stone. These will either weather to different color, or from softening readily on exposure, give opportunity for the growth of minute lichens, thus covering the stone with dark specks or blotches. Under other circumstances these spots may be of different color, but scarcely less unsightly, and in the end working the gradual dilapidation of the stone. The white marble of Lee in Massachusetts is everywhere marked by these talcy spots, and the monuments and gravestones in the cemeteries of the neighborhood are covered with black specks and blotches.

The marbles, however crystalline they may be, are not free from the same impurities that affect the unaltered limestones ; and iron pyrites occurs in these, both as segregated veins or lines of accumulation, interrupted strings or nodules, and disseminated in minute particles throughout the mass. A good example of the latter may be seen in some marble at Sheffield in Massachusetts, where the stone contains minute particles of iron pyrites, which, becoming decomposed on exposure, gives to the entire surface a slight rusty hue. The same change supervenes in the dressed marble ; and some of the blocks in the New City Hall of New York show the rusty hue immediately after having been laid in the wall. This may be a case in which the change will cease after a time, for want of access of moisture to the interior portions, or by the filling of the pores with sulphate of lime produced by the decomposition of the pyrites, and thus protecting the deeper portions of the stone.

Besides the ordinary seams or lines of color in the direction of the bedding, many of the marbles are marked by the presence of irregular veins or lines of segregation, which are different in composition and texture from the surrounding rock, and though sometimes not very different in color, and, therefore, showing little in the outset, will nevertheless usually decompose more readily than the adjacent stone. Veins of this kind are of common occurrence in some of the marbles used for building, and may be observed in their full effect in the State Hall and City Hall of Albany. These veins usually consist of some soft talc-like mineral with magnesian limestone and iron. The pure white marble, free from seams or veins of any kind, constitutes the smallest part of any or all marble quarries. The columns in front of the "old United States Bank," in Philadelphia, offer one of the best examples of the destruction of marble from the several causes mentioned. Although erected scarcely fifty years since, the bedding seams are weathered and opened to such a degree as to present an aspect of extreme dilapidation, and less than half a century more will effect their entire destruction.

The simple presence of magnesia alone does not necessarily impair the enduring quality of a limestone. Some of the hardest and most

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enduring limestones we have are magnesian in character, having such proportions of lime and magnesia as constitute a dolomite. This is the character of the Niagara limestone and of some of the older limestones of the Silurian series, both in their normal and metamorphic condition. As a general rule, however, the magnesian limestones, in their normal condition, are more friable, more porous and less firm in their character than the pure carbonates of lime. The presence of iron in magnesian limestones, either as an oxide or a carbonate of iron, may often aid in hastening their decomposition. They usually weather to a brownish hue, which is sometimes yellowish or drab-colored, but more often, in the unaltered condition, to an ashen gray. The yellowish color is due to iron in some form, either as an oxide or a carbonate.

In the selection of limestones for structures of any kind above ground, care should be taken to avoid the shaly seams which are the principal cause of decay; and though the stone containing them may endure for many years, they yet present an unsightly appearance. We have, in the city of Albany, a good example of this in the walls of the Reservoir on Eagle street in Albany; and numerous other cases of similar character might be cited. In all these examples, it may be observed that the dilapidation comes from the cause specified, and no other; for in most of the structures exhibiting this defect, the tool-marks are not yet obliterated from the surface of the solid limestone.

Limestones of this character, however, are perfectly safe and fit for any foundation or other work placed beyond the reach of freezing and thawing; and they possess a strength and power of resistance to pressure, which fits them for the heaviest structures.

Although limestones, in their normal condition, as well as the marbles, are liable to decay from the action of rain-water charged with carbonic acid, yet this cause usually operates so slowly on the walls of a building that the tool-marks are rarely obliterated in a quarter of a century.* The more porous limestones, and some of the marbles which notoriously lack cohesive power, may be more affected by this action. The liability to be decomposed and disintegrated by this process is always sufficiently shown in the natural surfaces of quarries; and in some cases we find the exposed beds crumbled to a mass of sand, while the layers beneath the reach of water and frost are comparatively solid.†

GRANITE AND GRANITIC ROCKS.

In the extensive class of rocks coming under the head of GRANITES, the conditions of durability and causes of decay are somewhat modified by the chemical changes which have supervened among the original mechanical aggregations, and the crystalline character which they have assumed. In these rocks we have *quartz*, *felspar*, *mica* and

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* The dark compact limestone at the base of the Lower Helderberg group, in some specimens in exposed situations, has retained the tool marks for nearly a century; and lettering cut on blocks of this stone, more than a century since, are still fresh and well defined. These examples may be seen in an old church in Schoharie, known as the Old Fort, from having been thus occupied during the revolutionary war; and in the Lutheran Church near the Court-house, where some lettered stones, from the first church erected in that town, have been laid in its foundations.

† In this process, the water dissolves a small portion of the stone as far as it reaches, and thus separates the particles still more; and the further access of water, which freezes in the stone, produces a rapid disintegration of the mass.

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hornblende to deal with as simple minerals of definite constitution. The quartz or silica is in a crystalline condition. The felspar, a crystalline mineral, is composed of a large proportion of silica with alumina and a small proportion of potash, and often a small amount of soda and lime, with a trace of iron sometimes amounting to more than one per cent. The mica, also crystalline, is composed of silica with a larger proportion of alumina than in felspar, and a lesser percentage of potash or other alkali, with from three to six per cent of iron. The hornblende is likewise crystalline, and composed of a large proportion of silica with magnesia and lime and sometimes alumina, containing also a variable amount of iron, which sometimes reaches to fifteen or even twenty per cent.

We have therefore no new mineral substance introduced into the compound. The alumina, which was in mechanical mixture with the silica in the original stone, has combined chemically with a portion of that mineral, including also some potash, soda or lime, and thus produced the felspar and mica. Other portions of the silica, and sometimes of alumina, have combined with the magnesia, lime and iron, to produce hornblende. All these materials have existed in their normal condition in the mechanical or sedimentary deposits, and have taken their present form through chemical action during subsequent metamorphism. These crystalline aggregates may be coarse or fine, and the different minerals be present in very variable proportions, or even one or two of them absent from the compound. The prevailing compounds are of quartz, felspar and mica; or quartz, felspar and hornblende.

The aggregates may likewise be of very different colors, the quartz being usually translucent, the felspar varying from white to reddish brown; the hornblende, of a dark green or black color, while the mica may be of any shade from silvery white to a dark brown or black. The predominance of these, or of any one or two of them, usually gives their hue to the mass. The granites or sienites, in which hornblende predominates, are generally of a dark color; and those where quartz and felspar predominate constitute the lighter-colored granites.

As a general rule, the granites are more reliable as a durable building material than any other class of stone, and yet some varieties of them are rapidly decomposed by the action of the atmosphere. In these granites where felspar greatly predominates, or where this mineral occurs in large crystalline masses, there is danger of decomposition. The action of the weather upon the alkaline constituents of the mineral is the primary cause of the destruction; but this change goes on slowly, and, in the walls of a building, would scarcely affect the appearance of the surface in half a century. The presence of finely disseminated iron pyrites is often a cause of destruction in the gneissoid and granitic rocks.

Some of the fine-grained felspathic granites with mica are subject to a slow decomposition or disintegration of the surface, by which thin films are exfoliated. Such examples can be seen in some of the older granite buildings of the country. Fewer causes of decay are inherent in the ordinary granites than in any other stone used in our buildings; and with proper care in selection, a granite structure is comparatively indestructible from the usual action of the elements.

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But it should not be forgotten that *all* the granite of a quarry may not be of the high quality desired; and in this rock, as well as in any other, though not usually to the same degree, there will be waste and refuse material. Though generally more free from iron pyrites than the other rocks, yet this mineral does occur in all the granites, and there is rarely a building erected that does not show its presence; but in all the quarries examined, from which building-material is obtained, this mineral occurs only in scattered and inconsiderable amounts.

In those granites, where the crystalline mixture consists of fine or moderately coarse grains of the different substances intimately mingled throughout the mass, we may count upon a durable building material, and one subject to a less degree of change from atmospheric agencies than any other stone in our country.

VII.

MODES OF DETERMINING THE CHARACTER AND STRENGTH OF BUILDING STONES.

In the erection of all public structures, or those of any considerable magnitude, the strength and durability of the material is of the first importance, and that which should receive the most careful attention. In large and heavy structures the strength of the material is of more importance than in ordinary ones, which never approach a test of the strength or power of resistance of the material composing them. Even with all the experience we have had, and the experiments that have been made, there seems to be no settled opinion of or knowledge among engineers regarding the real strength of the various kinds of stones, either in regard to their direct resistance of pressure or their lateral strength. According to the report of Prof. Henry, the commissioners appointed to test the stone preparatory to the erection of the extension of the United States Capitol, found that the practice heretofore adopted for testing the strength or resistance to pressure was very defective, and the results unsatisfactory. If the result thus obtained be admitted, and of which there can be no doubt, the statements heretofore recorded on these points, and the tables compiled from the experiments made, are to be regarded with many grains of allowance in favor of the stone tested. While the instruments employed by Rennie and others were defective, the plan of placing the block of stone to be tested between steel plates with a sheet of lead intervening, in order to equalize the pressure from irregularity of the surface of the stone, or want of parallelism in the opposite faces, gave very imperfect results.

In experiments reported by Prof. Henry, we have the example of a cube of marble placed between steel plates, with lead intervening, giving way at a pressure of 30,000 pounds; while another block of precisely similar character placed directly in contact with the steel plates, sustained a pressure of 60,000 pounds. "This interesting fact was verified in a series of experiments embracing samples of nearly all the marbles under trial, and in no case did a single exception occur to vary the result. The explanation of this remarkable phenomenon, now that the fact is known, is not difficult. The stone tends to give way by bulging out in the center of the four perpendicular faces, and

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to form two pyramidal figures with their apices opposed to each other at the center of the cube, and their bases against the steel plates."

"In the case where rigid equable pressure is employed, as in that of the thick steel plate, all parts must give way together; but in that of a yielding equable pressure, as in the case of interposed lead, the stone first gives way along the outer lines, or those of least resistance, and the remaining pressure must be sustained by the central portions around the vertical axis of the cube." This fact, so clearly demonstrated, shows very conclusively that all experiments made upon blocks of stone with the intervening yielding material are fallacious, and really give us but one-half the actual power of resistance possessed by the stone tested. When we add to this fact also the practice of engineers as usually stated, that owing to imperfections of the material and other causes, it is not considered safe to load a stone with more than one-eighth of its crushing weight,* it will be seen that we are very far within the safe limits to which any stone may be loaded and retain its integrity.

By this process, Prof. Henry has shown that the marble of Lee, Massachusetts, will sustain a pressure of 23,917 pounds to the square inch. This marble was adopted for, and has been used in the capitol extension or new Capitol at Washington. In strength it is not superior to many other marbles, nor equal to some of the ordinary compact limestones, and is much inferior to the granites. In composition it consists of the carbonates of lime and magnesia, and is a true dolomite, as shown by the analysis of Dr. Genth and Dr. Torrey, containing minute proportions of iron and manganese. The experiment of using a dolomite on so large a scale will ultimately demonstrate whether a stone of this composition can be relied upon as a durable building material. As before stated, however, the simple presence of magnesia is not of itself evidence of the rapid decay of the stone; a small proportion of iron in some form, or combined with some other mineral, may effect the destruction of a magnesian limestone that otherwise appears sound and durable.

Less attention seems to have been given to the lateral strength of stone, than its importance would warrant. When we see, even in buildings of recent erection, the window sills and caps cracked through, and these parts giving way and becoming dilapidated and unsightly, it is evidently a matter of no small importance to be able to decide what amount of weight can be borne by stones of certain dimensions. This knowledge also becomes of the highest importance in view of the manner in which the foundations of heavy buildings are laid; the gradual retraction of the width above relieving the lower and outer layers of stone from the direct crushing force of the superincumbent walls, but testing its lateral strength.†

In estimating the strength of a stone to resist pressure, it is not safe to predicate an opinion upon examples of cracking or breaking in the walls of a building, whether before or after its completion; for a little inequality in the bedding may produce such a result, when, if evenly bedded, the stone would have borne many times the load it has

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* According to some engineers with but one-twentieth of its crushing weight.

† The results of experiments, showing the power of resistance to pressure of several of our limestones, marbles, granites, etc., will be found in an appendix to this report.

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sustained. In a large and heavy building it is all important that the foundations be firm and unyielding, for on this depends the integrity of the entire structure. Beyond this it is important that the stone be evenly cut, so that the bed of each succeeding block should rest evenly upon those below it. From an inequality in dressing two adjacent blocks of stone to the same thickness, leaving at their junction one of them projecting slightly beyond the other, I have seen the superincumbent block of granite cracked quite through. This breaking was not due to pressure alone, nor to want of strength in the material, as was evident from the perfection of the wall below, but entirely to the pressure bearing upon the center of a block resting on an uneven bed, or supported at the two ends and not in the center.

VIII.

Causes affecting the Durability of a Building Stone, which are Inherent in the Stone Itself.

The causes of disintegration and destruction in the ordinary building stones have already been mentioned under each one. They may be recapitulated, however, in this place.

1. *Want of proper cohesion among the particles producing inherent weakness.* This condition may arise from the loose aggregation of the crystalline grains of carbonate of lime, or of the compound of carbonates of lime and magnesia, sand, etc., without intervening cement, or from want of the pressure necessary to consolidate the mass. We have examples of this in the friable marbles and some sandstones. In some cases this condition occurs where the rocks have been much disturbed since their deposition and partial or entire consolidation. But this condition as frequently occurs in rocks which, so far as we know, have not been subjected to change, and lie in their original horizontal position. One of the most remarkable examples occurs in the western extension of the Potsdam sandstone, much of which, in some parts of Wisconsin and Minnesota, may be easily quarried with pick and shovel, and readily crumbles into an incoherent sand. Above the Potsdam the St. Peter's sandstone has still less coherence, and is shovelled out in the same manner as the ordinary sand of the drift of the sea beach. From this incoherent condition of the mass, we have all gradations to the most strongly coherent rock. This condition of the particles, be it in greater or less degree, affects the strength and durability of the stone.

Blocks of stone, wanting proper cohesion, may crack or be partially crushed by superincumbent weight; but ordinary judgment will guard against using such improper material. The cohesion of the particles or grains composing a stone does not depend upon their hardness or density; for the grains or crystals composing a mass of marble, and having half the density of grains of sand, often produce a stronger stone than one made up of the better material.

2. *Porosity.* The porosity of a stone is, in most instances, directly dependent on the degree of cohesion among the particles. Crystalline masses are usually less porous than mechanical aggregations; and where the interstices between the crystals are filled with a finer material, it has been shown that the latter is porous and absorbent,

while the former resists the penetration of fluids. In some of the crystalline limestones, the cohesion is so slight that the water admitted, and freezing, has gradually broken up the mass, and we have a bed of calcareous sand, of several feet in thickness, lying above the rock which yet retains its ordinary consistence. Some of the fine-grained and compact mechanical aggregations of rocks resist the absorption of water in a remarkable degree.

3. *Argillaceous matter in distribution or in seams.* I have already shown that the presence of a considerable proportion of argillaceous matter distributed throughout the mass, be it calcareous or siliceous, has a tendency to weaken and destroy the stone. Its presence in seams or thin laminæ produces the same result, as we have numerous examples to show.

4. *Iron pyrites (sulphuret of iron) and other foreign substances.* Iron pyrites (sulphuret of iron), whether intimately permeating the stone or occurring in masses, layers or irregular nodules, is more or less injurious and destructive. When not immediately destructive, its decomposition renders the surfaces unsightly by staining the stone, and finally breaking or disintegrating it wherever this mineral occurs. When disseminated through the mass, as it frequently is, it produces slow but entire disintegration.

It is not an uncommon thing to find masses of rock, in their native position, completely disintegrated or softened to the depth of several feet by decomposing iron pyrites. This feature is especially observable in the gold region of Virginia, North Carolina and other Southern States. In numerous instances, and sometimes over wide areas of country, the rocks containing iron pyrites are decomposed by percolating rain water, to the general water-level of the surrounding country.

In limestones or dolomites, the presence of iron pyrites operates disastrously; for if magnesia be present, the sulphuric acid from the decomposing iron pyrites produces a soluble efflorescent salt, which exudes to the surface and forms white patches, which are alternately washed off and replaced, but leaving a whitened surface probably from the presence of sulphate of lime. If the limestone be entirely calcareous, the salt formed (a sulphate of lime), is insoluble, and therefore produces less obvious results.

In some cases, however, the lime of which the mortar or cement is made may contain magnesia, and the decomposition of the iron pyrites in the adjacent stone produces an efflorescent salt which exudes from the joints. This condition is not unfrequently observed in buildings constructed of the blue stone of the Hudson river group. As an example, we may notice the efflorescent patches proceeding from some of the joints between the stones of St. Peter's Church on State street in Albany.

The presence of iron in a low degree of oxidation tends to the destruction of the stone containing it. This is observed in the greenish shales and sandstones and in some other rocks; and this condition of iron, as well as in the form of a sulphuret, may do much injury where it exists.

5. *Size of constituent grains or particles.* This feature has already been alluded to under the head of granites, sandstones, etc. When the separate minerals of a granite are in large crystalline masses, it is an objectionable feature and a cause of decay. Coarse sandstone, or a

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mixture of fine grains of sand with pebbles of various sizes, does not usually endure well. Similar sandstones or conglomerates, when partially metamorphosed, and cemented by silica, or some siliceous compound, are less affected by the weather and are more durable. In the crystalline marbles, some of the coarser varieties are weak from the want of cohesion or cementing matter between the crystals. The same is equally true occasionally of those which are more finely crystalline; and we sometimes find a coarsely crystalline marble stronger than a finer one, in similar beds but a few miles asunder, or even beds in the same quarry may differ in this respect. The coarsely crystalline marble of Tuckahoe is stronger than the finer-grained marble of Sing Sing and other places in the neighborhood. So far as the marbles are concerned, all the crystalline forms, be they coarse or fine, may be strong or weak. The fine-grained marbles, which show scarcely a crystalline structure, or such only as the calcareous muds might take on in their metamorphism, are the most durable stones of this kind.

6. *Cementing materials.* I have already alluded to this feature under the preceding head. When the cementing material is clay, or where argillaceous matter predominates, it is rapidly disintegrated by the absorption of water, and freezing and thawing while thus saturated. Where the cementing matter is calcareous, it will dissolve more slowly, and only through the agency of rain water carrying carbonic acid. Where the cement is siliceous, it is essentially indestructible from the effects of the atmosphere and water.

The cementing material of the Tertiary sandstones of which the Old Capitol, Treasury and other buildings in Washington were constructed, is clay and carbonate of lime, and its rapid disintegration from rain and frosts is always observable. As before noticed, some friable sandstones become harder on exposure, and this change has been presumed to be due to the formation of a siliceous cement on and near the surface. Sometimes probably a silicate of lime, or a small quantity of calcareous matter held in solution in the interstices of the stone, may become precipitated as solid carbonate of lime, in accordance to a well-know law, on exposure to the atmosphere.

Every geologist knows that not only sandstones, but all other rocks are more easily shaped and trimmed when freshly broken from the ledge or quarry, than after they have remained for some time exposed to the atmosphere or even carefully packed. The hardening or toughening process, however, extends but a little way beneath the surface, and the interior of a block remains essentially as when first quarried.

IX.

CAUSES AFFECTING THE DURABILITY OF A STONE, WHICH ARE ACCIDENTAL OR DUE TO ARTIFICIAL OR EXTRANEOUS CONDITIONS.

Many stones, which with proper treatment or under favorable circumstances might prove a durable building-material, are brought to a rapid decay by conditions to which they are subjected in the structure.

1. *The action of freezing and thawing.* This alternating process of freezing and thawing is the most trying to the durability of a stone, of any or all the conditions to which it is subjected. Of course this depends upon the climate or latitude in which the stone is exposed. The

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Caen stone of Normandy, and some of the less coherent limestones of modern geological formations are strong enough and quite durable for buildings in Southern Europe or where the frosts are not extreme; but in a climate like our own, they are rapidly destroyed by the alternate action of freezing and thawing.

Some of the finer sandstones, which have a considerable amount of argillaceous matter, are perfectly capable of withstanding moderate freezing; but the extreme changes from a moist condition, or one saturated with moisture, to the extreme of freezing, are fatal to their durability.

As before repeated, any stone in which clay enters largely, or a porous stone of any kind, is liable to decay under the extremes of wet and frost. The penetration of moisture among the particles of the stone, and its expansion on freezing, destroy the cohesion of the parts, and the succeeding rains wash away the loosened particles. In this way, during a long succession of years, the surface is disintegrated and the structure gradually crumbles. Although some stones are more susceptible to these atmospheric influences than others, yet none are entirely free from its effects.

Even the changes of temperature, without frost or moisture, operate upon the masses of stone and cause a motion of the particles. The observations of Prof. Horsford upon the pendulum suspended within the Bunker-hill Monument show that this massive structure "is scarcely for a moment in a state of rest, but is constantly working and heaving under the influence of the every varying temperature of its different sides." When to this is added the extreme action of freezing and thawing, it cannot be surprising that the poorer materials will fall into dilapidation, or that the best selected building-stone will ultimately give way. This cause operating everywhere, at all times and through all seasons, is a far more active agent in the destruction of buildings than all the others operating together; and though it may sometimes require years for an appreciable change to be accomplished upon a sound material, it is nevertheless constantly going on, however slow the change may be.

2. *The improper laying of stone* by presenting the faces of laminæ to the weather, often hastens the disintegration of the mass. I have already alluded to this especially in regard to the brown freestone which is now so extensively used, and which presents such uneven weathering, from being in part laid according to the bedding, and in part with the bed facing the exterior.

3. *The vegetation of microscopic lichens* takes place upon the surface of the stone, when, from any cause, that surface becomes roughened so as to afford a lodgment for the seeds or spores of these plants. These growing, still further hasten the disintegration of the stone, and accumulating about them the fine dust floated by the atmosphere, become points for the absorption of more water, which on freezing still further roughens the surface, and the patch of lichen gradually extends. These lichens often gain attachment upon the surface of a finely dressed stone, from some little inequality of texture, or from softer material that more readily becomes decomposed, or more readily accommodates the growth of the plant. Such stones in time become partially or entirely covered by lichens, and present an unsightly aspect. The

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amount and degree of this growth varies with position in reference to the sun, and with a more or less elevated situation.

It should not be forgotten, however, that any stone giving root to lichens is not one of those which most easily disintegrate; for in these the destruction goes on so rapidly, that the surface does not allow the growth of such plants. The lichen-covered rocks in nature are usually those of great strength and durability. None of the softer or rapidly decaying rocks produce this vegetation.

4. *The solvent action of water* is never so great upon artificial structures, as upon the rock in its natural position; for in the latter case, it is usually aided by a covering of soil, through which the water is filtered; and if not thus covered, the rock is exposed in broad surfaces to much greater action than in the walls of a building.

5. *The oxidizing influence of the sun's rays* is only considerable when aided by moisture, and in this condition scarcely operates except upon iron pyrites and iron in a low state of oxidation.

6. *The effect of electricity.* Prof. Henry, after citing the effects produced by water charged with carbonic acid, says: "Again, every flash of lightning not only generates nitric acid — which, in solution in the rain, acts upon the marble — but also by its inductive effects at a distance, produces chemical changes along the moist wall, which at the present time are beyond our means of estimating."

7. *Effects from sulphurous gases produced by burning coals.* In the unexpected gradual dilapidation of the New Houses of Parliament in London, the causes have been sought and apparently found in an agent heretofore little regarded as one producing serious deterioration of buildings. The stone is a magnesian limestone from Bolsover moor, and was selected as having been found to retain its integrity and to have preserved in a very perfect degree some of the carvings in Southwell church through a long period of time.

The same material, and from the same locality as stated, has been used in London with a very different result. An examination made a few years since led to the belief that this disintegration of the stone was caused by the action of sulphurous vapors arising from burning coals; which lodging with the soot against the sides of the building, and especially in sheltered positions under the projecting eaves and moulding, and thus remaining saturated with moisture under the most favorable conditions for acting upon the stone. To this cause, in London, we may attribute some portions of the effects observed in this and other examples. Now it should be recollected that in this densely populated city, with its proverbial "London fogs," and the burning of bituminous coal, the rising of the soot and its condensation on the side of buildings during the heavy damp weather and fogs, would, as a matter of course, produce some effect upon the stone.

Such conditions, however, can scarcely exist in any Atlantic city (even if in any American city), with our drier atmosphere and the sulphurous gases mainly from anthracite coal, which gives no soot. In the Ohio and Mississippi valleys, where bituminous coal is burned and the soot lodges against the buildings, we might possibly look for some effect; but the comparative dryness of the atmosphere would probably counteract the otherwise evil effects from this cause. In considering this cause of deterioration, we shall find it only applicable to special locali-

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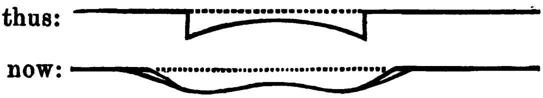
ties; and even in these it may be well to inquire whether other causes have not combined with this one, to produce the results recorded.[*]

I have received from Prof. J. P. Lesley, of Philadelphia, the following observations regarding the influence of climate in different localities, upon stone of identical or similar character. In speaking of the durability of stone in ancient structures it becomes necessary to know the conditions of climate before a just comparison can be made.

"One of the two obelisks erected by Thothmes III, at Heliopolis fifteen or sixteen centuries before Christ, was transferred to Alexandria and is now known as Cleopatra's Needle. It is of sienite, so streaked with hornblende, obliquely, as to suggest original stratification. Along these streaks, which are of irregular width, atmospheric erosion has taken place, by the ejection of one group of crystals after another, upon the melting away of the felspathic element. The whole face of the stone has suffered from the same action, but generally to a less degree, than at these exceptional places. Especially all the sharp cut edges have been rounded off. Wherever the solar disc, for instance, occurs, there is now nothing but an unsightly hollow, where originally had been cut a sharp clear circle, with a vertical wall around a central convex tympanum.



"All the hieroglyphs from pyramidion to base have suffered in this way. Some are almost indistinguishable, except in the very best slanting light of the sun. One or two of the four faces also have suffered more than the others, showing that the prevailing winds have determined the degree of erosion. The climates of Cairo and Alexandria are so different from one another, the former so constantly dry and the other so uninterruptedly wet, that we have a right to ascribe the most of this destruction to the sea air since the removal of the obelisk from its original to its present site. But all the monuments of Egypt, at least up to the first cataract, show marks of atmospheric erosion, in spite of the loose assertion often repeated by travelers, that they are as fresh and their lines as sharp as when the chisel cut them. This is not true of any monument in the open air; but is approximately true of the intaglios in the tombs. Many of the monuments of the middle and classic empires are built of such inferior kind of stone, the only wonder is that they have not tumbled into ruin themselves, through the slow wear and tear of the surface, by the atmosphere. And yet Egypt is one of the driest parts of the world. It must be remembered, however, that the stratum of air, which lies at night upon the broad bottom of the valley, is charged with the exhalations of the river, canals and irrigated fields, and in this stratum the monuments stand. When the sun rises this moist air-mass is broken up and carried over the mountain walls into the desert."

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[*] It may perhaps be worth while to inquire whether the effects ascribed to sulphurous gases are really due to such influences alone. A writer in the "Builder," for Oct. 30, 1858, says that the river front, "to the height of the area windows, was built of the Bolsover moor stone, but that the remaining upper part, to my wonderment, was built of stone obtained from Anston, in Yorkshire, a stone not even alluded to in the report," *i. e.*, the Report of the Commissioners. If this be true, the theory adopted in explanation of the cause of decay may require some modification.

X.

RESULTS OF THE TRIALS OF THE STRENGTH OF SOME OF THE SPECIMENS SUBMITTED TO THE CAPITOL COMMISSIONERS, MADE AT WASHINGTON IN NOVEMBER, 1868.

Specimens of the gray gneiss of Saratoga county of one inch cubes placed between steel plates, sustained a pressure of from 16,800 to 25,600 pounds; the lowest number doubtless from imperfection. The average of these specimens gave 22,666 pounds as the crushing weight per square inch.

Of the dark colored sienite, the range was from 18,000 to 25,700 pounds as the crushing weight; the lowest number in this case resulting from the want of entire parallelism in the two fases of the cube. The average of four specimens gives 22,575 pounds as the crushing weight per square inch.

A single cube of one and a half inches, from one of the beds of Tribes Hill limestone, sustained a pressure of 66,300 pounds, or 25,022 pounds to the square inch, before breaking. A similar specimen from another layer of the same limestone, sustained a pressure of 54,400 pounds, or 24,622 pounds to the square inch.

Three specimens of limestone from the Cobleskill quarries, in blocks of one and a half inch cubes, gave a range of from 51,000 to 72,700 pounds of pressure before breaking, being an average of 27,407 pounds to the square inch. A single cube of one and a half inches from another bed of the same limestone, gave 21,066 pounds as the crushing weight, to the square inch.

Three specimens of compact white marble from Alford, Mass., in one and a half inch cubes, sustained respectively 26,300, 26,900 and 27,000 pounds before breaking, giving very nearly 12,000 pounds as the crushing weight, per square inch.

These experiments sustain the opinion previously expressed in my report, that these compact limestones are stronger than the marbles, and equal to many of the granites.

In regard to the lateral strength of these stones, we have a right to infer from the close grain and compact texture, as well as tenacity shown in the process of crushing, that they are also superior in that character.

I may remark in this place, that the stone used in the New Capitol foundation at Washington, is gneissoid rock or mica slate, and has not the strength of the gneiss and limestones here recorded.

The remaining collection of specimens submitted for trial have been left with Prof. JOSEPH HENRY, and the results of the experiments will be reported at a future time.

Very respectfully,
Your obedient servant,
JAMES HALL.

NOTE.— The remarks upon the red or brown sandstone (freestone), are mainly based upon an experience of the Connecticut river stone and in a smaller degree upon that from New Jersey. The sandstone of the same age on the Potomac river, in Maryland, known as the Seneca

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creek sandstone, has in many examples proved extremely durable; and I have been shown a specimen of this rock, taken from one of the old locks on the river where it has been exposed to the elements for eighty years, and the stone is still sound. This specimen, however, is very compact, highly siliceous, and with no visible seams of argillaceous matter.

The observations made upon buildings already erected of different material, have been, with few exceptions, omitted from the present report, but may be published at a future time. Probably no better service could be rendered to the future architecture of the country than an unsparing exposition of the condition of various buildings and public edifices erected of stone. When it is considered that very few of these have existed for fifty years we shall be prepared to appreciate the extreme dilapidation and ruin which must ensue within the next century.

The map presented with the report is colored to show the sources of the several kinds of building stones, as *granite, marble, sandstone, etc.*, in New York and New England, but it will not be published at the present time.*

[The author begs the indulgence of his friends and the public, in offering so incomplete a report upon a subject of so much importance as that of building stones of the State and country. The investigation requires much more time to make the result at all worthy of being presented in printed form. This time it has not been possible to give during the past year, and the publication at this moment is beyond his control. The matter has all been put in type and the first thirty-two pages printed off during the absence of the writer, in consequence of which several typographical errors have occurred. The memoranda in the margin of some of the pages were made for the writer's use in giving an abstract of the report, and were not intended for printing.]

XI.

CATALOGUE OF THE PRINCIPAL BUILDING STONES IN THE COLLECTION WHICH HAVE BEEN SUBMITTED TO THE COMMISSIONERS FOR THEIR INSPECTION, OR WHICH HAVE BEEN COLLECTED DURING THE EXAMINATION OF QUARRIES.

A. *Granites and Granitic Rocks.*

1. Quincy Granite. Dressed block of one cubic foot. Old Quincy quarries, from the Quincy Railway Granite Company.

2. A smaller dressed block of the same, brought from the quarry at time of examination.

3. Quincy Granite. Light colored, a small block partially dressed, brought from the quarries of Rogers & Co.

4. Gray Granite. A rough block, brought from the quarries at Rockport, Cape Ann, Mass.

5. Porphyritic Granite. A block six by twelve inches, partially dressed, Fall River, Mass., from Geo. Wrighton, Esq , of New York.

6. Gray Granite. Dix island, Maine, from Messrs. Learned & Dickson.

7. Gray Granite. Concord, New Hampshire, a dressed block of one cubic foot, from the Quincy Railway Granite Company.

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* This map still remains as at the date of this report.

8. Gray Granite. A cubic block of six inches square from the same.

9. Gray Granite. Fitzwilliam, New Hampshire, a dressed block of one cubic foot, from Runels, Clough & Co.

10. Gray Granite. Berlin, Vermont, a dressed block of ten inches square, from M. E. Howard.

11. Gray Granite. Barre, Vermont, a dressed block of one cubic foot, from Mr. I. P. Harrington.

12. Gray Granite. Barre, Vermont, a dressed block of one cubic foot.

13. Gray Gneissoid Granite. Greenfield, N. Y., a dressed block of one cubic foot, and two dressed blocks of six-inch cubes with several larger rough blocks of the same, from John H. White, Esq., and Dr. R. L. Allen of Saratoga Springs, N. Y.

14. Dark Colored Sienite. Greenfield, N. Y., a dressed block of one cubic foot and two other blocks of six inch cubes, one of the latter polished on two sides.

15. Gray Gneissoid Granite. Luzerne, Saratoga county., N. Y., a dressed block of one foot by two feet, from Col. B. C. Butler of Luzerne.

16. Gray Gneissoid Granite. Several rough blocks from Moreau, N. Y., from Mr. W. B. Conant.

17. Gneissoid Granite. Luzerne, N. Y., a block of two feet long, twenty inches wide and one foot thick, from Dr. R. L. Allen.

18. Gneissoid Granite. Butter hill, Highlands, N. Y., a rough block, from Hon. A. M. Sherman of Newburgh, N. Y.

19. Light Gray (nearly white), Granite. Specimen of 12x8x2 inches, cut and partially polished. Said to be from St. Albans, Vt., but believed to be from Berlin, Vt. From Mr. Charles E. Young of Oswego, N. Y.

20. Sienite. Two rough specimens from Warren county, from Mr. John Higgins of Troy N. Y.

B. *Marbles of White or Variegated Colors, Metamorphic and Crystalline in Character.*

21. Variegated and Monumental Marble. Sutherland Falls, Vt.; one dressed and partly polished block of one cubic foot; three blocks of one foot face by six inches thick, polished on one face ; one block of one foot face by six inches thick, one face sand-rubbed and moulded; one block of 12x12x10 inches, one face polished; two blocks of six-inch cubes polished and variously dressed. These specimens were all presented by the Otter Creek Marble Co.

22. Berkshire Marble, Silver Blue Marble. Alford, Mass. ; one block of a cubic foot, variously dressed and polished on one side.

23. White, or Slightly Clouded Marble. Lakeville, Connecticut; a block of one cubic foot, dressed with one side polished; from H. Tudor Brownell, Esq.

24. Marble, Bluish or Dove-colored. Lakeville, Connecticut; a cubic block of one foot, two faces polished ; from H. Tudor Brownell, Esq.

25. White Marble. Sheffield Mass.; a block of 10x10x8 inches, one side polished ; from one of Mr. Chester Goodale's quarries.

26. Clouded Marble. Sheffield Mass.; a block of one cubic foot,

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one side polished; same as the marble used in the Girard College. Quarry of Mr. Chester Goodale.

27. Striped Marble. Sheffield Mass.; a block of one cubic foot, one side polished. Quarry of Mr. Chester Goodale.

28. White Statuary Marble. West Rutland, Vt.; dressed block of one cubic foot, one side polished.

29. Striped Marble. West Rutland, Vt.

30. Brocatella Marble. West Rutland, Vt.

31. Marble, Muddy Layer. West Rutland, Vt.

32. Striped Marble. West Rutland, Vt. The preceding five specimens are blocks of one cubic foot each, three of the lateral faces dressed in various modes with one face polished, the upper side showing the fracture of the stone. These blocks are from the new quarry of Sheldon & Slason, presented by the owners through W. C. Rowell, Esq., of Rutland.

33. White Crystalline Marble. Tuckahoe, N. Y.; a dressed block of one cubic foot, one face polished, the upper side showing fresh fracture; from Masterton & Hall.

34. White Crystalline Marble. Tuckahoe, N. Y., a cubic block of six inches square, one face polished; from Masterton & Hall.

35. Clouded Marble. A block of 10x7x5 inches, dressed, with one face polished.

36. Clouded Marble. A dressed block of 8x5x4 inches (blocks 54 and 36 have been received as coming from Dutchess county, particular source unknown).

37. Clouded Marble. A dressed cubic block of six inches square, one side polished; from the Berkshire Marble Company, Alford, Mass.

38. White Crystalline Marble. A dressed block of 12x8x6 inches, with one face polished; locality unknown, probably Tuckahoe or Hastings, N. Y.

39. White Marble. A dressed block of 9x9x6 inches, locality unknown.

40. Clouded Marble. A dressed block of 6x6x9 inches; locality unknown.*

41. White Crystalline Marble. A dressed block of 16x12x8 inches, with one face polished; from the State quarries at Sing Sing.

42. Gray Crystalline Marble. A dressed block of one cubic foot, one face polished; Hastings, N. Y.

43. White Marble, coarsely crystalline. A dressed block of ten inches cube, one side polished; Hastings, N. Y.

44. Gray Marble. A block of 12x12x18 inches, two sides dressed; from Stockbridge, Mass.

45. Serpentine Marble, Verd Antique. A dressed block of eleven inches cube, with one face polished; from the quarry of Mr. Walton, Port Henry, N. Y.

46. Serpentine Marble, Verd Antique. Port Henry, N. Y. A specimen dressed as a pillar with sqare base of 9x9 inches and 15 inches high, moulded above, with cylindrical shaft of two feet high; from ——— Sherman, Esq., of Port Henry, Essex county, N. Y.

47. Serpentine Marble, Verd Antique. A rough slab of 12x18x4; Port Henry, Essex county, N. Y.

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* Several specimens have been sent to the collection without the localities having been communicated to the writer.

C. *Limestones not Metamorphic.*

48. Gray Limestone. Lockport, N. Y.; finely dressed block of one cubic foot; from B. & J. Carpenter.

49. Dark Blue Limestone. A dressed block of one cubic foot, with one side polished; from James Shanahan, Tribes Hill, N. Y.

50. Dark Blue Limestone. A rough dressed block of one cubic foot; from James Shanahan, Tribes Hill, N. Y.

51. Blue and Variegated Limestone. A finely dressed block of one cubic foot; from James Shanahan, Tribes Hill, N. Y.

52. Gray Limestone. A dressed block of 14x10½x6; from J. Critzer, Jacksonburgh, N. Y.

The four preceding specimens are from the Trenton limestone group.

53. Dark Blue Limestone, Black Marble. A dressed and polished block of 12x7x6 inches, from the Howe's Cave Lime and Cement Company, Cobleskill, N. Y.

54. Gray Variegated Limestone (Coral marble). A polished slab of 8x32 inches; from the Hudson Coral Marble Company, Hudson, N. Y.

55. Gray Limestone, Gray Marble (Onondaga limestone). A dressed block of 9x9x9, with one face polished; from Mr. J. Hughes of Syracuse, N. Y.

56. White Marble. Lakeville, Connecticut. A rough block of 24x20x12 inches; from Wm. R. Smith of Athens, N. Y.

57. Blue Micaceous Limestone. Barrington, Mass. A rough block of about two and a half feet cube; from Dr. Clarkson T. Collins.

D. *Sandstones or Freestones and Varieties of these Rocks.*

58. Brown Sandstone, Medina Sandstone. A dressed block of 12x12x9 inches; from H. J. Sickles, Albion, N. Y.

59. Brown Sandstone. A finely dressed block of one cubic foot: from Geo. Wrightson of New York.

60. Gray Sandstone. A dressed block of one cubic foot; from B. Clough, Plato, Ohio.

61. Gray Sandstone. A dressed block of 12x17x17; from B. Clough, Plato, Ohio.

62. Gray Sandstone. A dressed block or shaft of one foot square at base, and two feet nine inches high; from B. Clough, Plato, Ohio.

63. Fine Gray Sandstone. Columbia, Ohio; a finely dressed block of one cubic foot; from B. Clough, Esq.

64. Gray Sandstone. Specimen consisting of a dressed base of 12x12 inches and six inches high, surmounted by a cylindrical shaft of fifteen inches high and terminated by a carved rosette: Amherst, Ohio; from R. P. Wilson, New York.

65. Malden Blue Stone. A finely dressed block of 12x8x5 inches; from the Bigelow Blue Stone Company, Malden, N. Y.

66. Hudson River Blue Stone. A dressed block of 20x8x7 inches; from Benedict & Gill, Schenectady, N. Y.

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