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The Building Stones of Boston and Vicinity.

By G. F. Loughlin.

Introduction.

The condition of the stones used in Boston's buildings is certainly a matter of some importance; but heretofore no systematic inquiry along this line has been attempted. About fifteen years ago Prof. Julien of Columbia University investigated the decay of the building stones of New York City; and I have attempted to make a somewhat similar study of the building stones of Boston.

Historical Review.

Since Boston is one of the oldest cities in America, and was one of the first to use stones for building purposes, a brief historical sketch of the introduction and use of the different kinds of stone will not be out of place.

The first instance on record of the use of building stone in Boston was, according to Shurtleff's History of Boston, in 1650, when the house of Deacon John Phillips was erected. It was built of granite boulders found in the vicinity, and stood until 1864. The oldest stone building now standing in Boston is King's Chapel, erected in 1749-54. This building was, at the time, the greatest stone construction ever undertaken in Boston, if not in America. It is built of Quincy granite obtained by splitting boulders.
In 1792 gneissoid granite was shipped from Connecticut to Boston for curbing and paving; but it was not until the early part of the 19th century that granite was used at all extensively beginning with the micaceous granite of Chelmsford, Mass. This was shipped to Boston by the Middlesex Canal. It was of this stone that was constructed in 1810 the old Boston Courthouse; and in 1814, the New South Church and the old Congregational House at the corner of Beacon and Somerset Streets.

In 1824 granite quarrying was begun in Gloucester, and in 1825 in Quincy; and most of the older stone buildings of Boston are built of Quincy granite.

The granite from Concord, N. H., was used in the construction of the City Hall, in 1862-65, and about the same time found its way into several of the business buildings. Hallowell, Maine, granite is of more recent introduction. The Soldiers' Monument on Boston Common (1880) is a fine example of it; and the latest important instance of its use is, probably, the Masonic Building at the corner of Boylston and Tremont Streets.

At the present time the public taste appears to favor the red and pink granites; and the gray granites of Cape Ann, Quincy, Concord, Hallowell, Fitchburg and other places are being less generally used in architectural as distinguished from engineering works. A glance at the new large granite buildings along State Street and the vicinity will show them to be con-
structured mostly of Milford and Stony Creek granites. All the
colored granites used in the city have only been introduced re-
cently.

The use of Roxbury puddingstone in buildings of any
size dates back to the 60's and 70's. The Cathedral of the Holy
Cross, erected about 30 years ago, and several other churches
of about the same age, are of Roxbury puddingstone. This stone
is characteristic of churches and stone-walls.

The first sandstone used in Boston was probably from
Portland, Connecticut. This stone was quarried as early as
1665, and became very widely used. I have no dates of its use
in Boston, but it is to be seen in the Old Hancock House, 28(?)
Beacon Street, and in many old buildings in Back Bay, and as
window sills and trimmings in brick blocks of the South End.
Portland brownstone is by far the commonest stone in Back Bay
buildings. Gray sandstone from Acquia Creek, Va., was used for
the columns of St. Paul's Church on Tremont Street in 1820.

The brownstones from New Jersey and Longmeadow, Mass.,
are of more recent introduction,—as are the freestones from
Nova Scotia, New Brunswick and Ohio. A few churches, the
Arlington Street, and Second Unitarian on Boylston Street, are
built of New Jersey stone. Many buildings in the business
part of the city, which were built after the great fire
of 1872, are of New Brunswick freestone. The Longmeadow
stone occurs only in buildings of twenty-five years or less
in age. It is the characteristic stone of Huntington Avenue.

The only sandstone used today for Boston buildings is the Ohio gray and buff freestone. The fashion about 13 years ago, changed from brown to light colored stones; so many of our brownstone residences on Beacon Street have gone out of fashion.

Slate: Merrill says:

"The quarrying of slate for roofing is a comparatively recent undertaking -- thirty or forty years; but it is stated that, as early as 1721, a cargo of 20 tons of split slate was brought to Boston from Hangman's Island, which may have been used for roofing purposes; but the greater part of the material for this purpose was imported directly from Wales. Slates were quarried at Lancaster, Mass., as early as 1750 or 1753, and were used extensively for gravestones soon after the close of the Revolution." The black slates used for roofing purposes today come from the slate belts of Maine and Pennsylvania. The greenish, and purple slates come from the Vermont belt, and the red slate, often used as tiles, comes from the extension of the same belt in eastern New York.
Marble has been used for exterior building stone to some extent. The Parker House, of Rutland, Vermont, marble, built in 1854, is the oldest marble building of which I have record. The strong tendency for marbles to turn black with dirt has probably prevented their extensive use in late years.

The use of limestone in Boston for exterior purposes dates back to 1890 when the Algonquin Club house was erected on Beacon Street. The limestone, white in color, has become a very popular stone, and is used very extensively today. All the white limestone comes from Indiana.
The Durability of Building Stones in Boston.

Stone structures should always be intended to be long-lived; that is, to keep not only their strength, but color and appearance, for a long time. Many stones meet these requirements, but many more do not; and the sad condition in which some of the stone buildings of Boston are, should be an incentive to have every stone thoroughly tested before being used in a prominent building. A stone may be very tough, and have an enormous crushing strength, and last but a relatively short while in the climate of a city; or a stone like the Portland brownstone may consist of the most insoluble of elements, and still crumble away after being used but a few years. Some stones may have a very low absorptive power, but still suffer from changes in temperature; other stones may be from the points of view of chemical stability and crushing strength, very poor, but may last indefinitely if put to the proper use. My intention is to discuss the different conditions which stones used in Boston have to meet, and the qualities of the various stones for meeting such conditions.

The various divisions in which I shall treat the subject are as follows:

1. Destructive Agencies.
2. Ability of stones to face these Agencies. -- Destructibility. Elements of Durability.
Destructive Agencies.

Chemical Destructive Agencies.

The air in a city like Boston is necessarily full of various chemicals besides those necessary to form pure air. Carbon dioxide, besides forming three-hundredths of one percent of pure air, is also derived from animals, from the combustion of fuels, and the decomposition of organic matter; and is probably the most important chemical agent to be considered. The principal rock components that suffer from the action of $CO_2$ are the lime, ferro-magnesium and alkalies and rock minerals; but while the action of $CO_2$ water in ground has been considerable, its chance to act on stones in buildings is comparatively very slight.

Sulphurous and sulphuric acids are always in the city air, where the smoke from chimneys carries $SO_2$ and steam, which unite with oxygen and form these acids. They may also be derived from sewer gas, and the decomposition of street refuse to a slight extent. These acids, besides dissolving the lime and alkalies, also act on the aluminum silicates, as slate for instance; but their destructive power is not so prominent as in that of $CO_2$, as the source of the acids is much more limited (mostly to soft coal.)

Nitric and hydrochloric acids may exist near some factories, but they are not in sufficient amounts to do any particular harm. The same may be said of the various organic acids that are derived from smoke, street dust, etc.
(Organic acids in ground may act but probably do no great harm in air.) Experiment has shown that citric acid will act on many rock forming minerals if given time enough. (See Julien).

Oxygen is important in the decomposition of rocks. Water with oxygen in solution is a powerful oxidizing agent, (oxidizing ferrous compounds) and is especially detrimental where it oxidizes pyrite \((\text{FeS}_2)\) and sets free sulphuric acid, which in turn decomposed the slate. (S. S. Oxidization of pyrite beneficial to Amherst. See page 40, note-book).

Ammonia, arising from various sources, can do no harm, and serves to neutralize acids. Sea salt dissolved in rain water, thus forming an alkaline solvent, may, theoretically, act on the silica in rocks, but its effect on building stones is practically nothing. (Mention dropping out of quartz grains in granite rocks on coast.)

The most important chemicals, then, are \(\text{CO}_2\) dissolved in water and the sulphuric acids; but chemical agencies alone would probably have little effect on stones in buildings. They need the help of other agencies, especially mechanical.

**Mechanical Destructive Agencies.**

Frost.—The most destructive mechanical agency is frost. No stone, save possibly some quartzites, is absolutely non-porous, and must contain more or less water, which must
freeze on cold nights. The disrupting force of freezing water when enclosed is too well known to be discussed; and it is evident that, all other things being equal, the more water a stone contains, the shorter will be its life in Boston's climate.) The amount of water in a stone depends, of course, on its amount of pore space. Pores, however, are not all of equal size in the same rock. Pore spaces are classified according to size into capillary and sub-capillary. (Metamorphism of rocks, by C. R. Van Hise, Bul. G. S. A. Vol. 9, page 272. Quoted from Buckley, Geol. Surv. Wis. Vol. IV. p. 21). The capillary pores are the larger, and the water which they hold is known as the water of saturation. Openings included in this class are over .0002 centimeters in diameter. If a rock containing capillary pores is allowed to drain off naturally, a portion of the water will escape, but another portion will remain, which is known as the water of imbibition. The sub-capillary pores are conceived to be of such a size, smaller than .00002 centimeters in diameter, as to contain only the water of imbibition. Thus, the more numerous the sub-capillary pores in a rock, the greater the danger from freezing.

If, however, none of the pores are more than 9/10 filled with water, there will be no danger from freezing, as it has been shown that water passing from liquid to solid state expands in the proportion of 100 to 109.

Thus, if some pores are large enough to lose their water spontaneously, it is evident that not only absorbing capacity, but also the size of the pores must be considered in the danger from freezing.

Water may also get into incipient cracks, freeze and split the stone. Such is likely to be the case with coarse feldspar crystals in coarse granite, and with slates laid on edge that have well developed cleavage planes, as, for example, the old gravestones of Lancaster slate in the old grave yards of Boston.

Variations in temperature, while not of such primary importance as frost action, are, nevertheless, continually occurring. They cause the expansion and contraction of the rock grains, and weaken their cohesion. While a rock of homogeneous composition, such as sandstone or limestone, will expand and contract uniformly, a granite, consisting of various sized crystals of different minerals, each with a different coefficient of expansion may have several minute cracks developed, into which water can find its way, and increase subsequent frost action. The crumbling of granite in fires is attributed to the sudden cooling of the highly heated rock by the application of cold water.

Wind and Rain.—Wind and rain are most efficient on the north and east sides of buildings, the sides facing the direction of the
worst storms. Rain, falling on the stones and working into their pores and cracks, supplies water for frost action, and, by moistening the stone surfaces, aids in the collection on rough surfaces of dust blown by the wind. The dust collects more water. The damp stone surface is also favorable to the growth of algae and, possibly, other organisms, which will be discussed under organic agencies.

**Alterations in Temperature.**

It is evident that considerable variations of temperature must cause by the resulting expansion and contraction in stones great variations of tension, not only between their superficial and interior portions, but also still more variant between its component mineral grains. The latter are due to the difference in amount of cubical expansion by heat of the various kinds of minerals. (F. W. Clarke "The Constants of Nature." Smithsonian Misc. Coll. XIV.

The coefficient of cubical expansion for quartz (0.000036) is over twice that for orthoclase feldspar (0.000017); also the difference in degree of linear expansion within each mineral in the direction of its crystallographic axes, e.g. varying in the axes of a common form of feldspar, adularia, as 659; 2914 : 15687, or as about 1 to 494 to 28.8. In other words, the grains of one of the most common constituents of rocks expand over 4 times as much in one direction as in another, and nearly 24 times as much as in a third direction. (A. A. Julien, Jour. Franklin Inst. May 1899, p. 394.)
"In experiments of U. S. Engineers at Watertown Arsenal, it was found that bars of stone 20" long, after being heated 180° and again cooled to the starting point, 32°F. still retained a slight expansion, 'permanent swelling', which amounted in several granites to .004"; in marble to .009"; in limestones .007", and sandstones .0047 inch. --- Even at ordinary temperature variations in the atmosphere, expansions and contractions occur sufficient to embarrass, or defeat the builder in constructing water tight joints."

It is not surprising after realizing the power of expansive force exerted, that stones of high crushing strength may become weakened and yield, in time, to the pressure of superincumbent masonry.

A good example of the effect of the heat of the sun is seen in Bunker Hill monument which has been found to describe daily an ellipse whose major axis is 3/4" long. This action, continuing for nearly 20 yrs., must be gradually weakening the granite in the monument. The granite today, seen the chipping out of hundred, & melting of Superincumbent Pressure. Some incrusting, appears to be in good condition, & promise to endure for a long time.

The pressure of superincumbent masonry is a factor that may be serious if stones are not properly laid. Relatively light and weak stones as sandstone, should not be laid for the base of a building with heavy and strong stones or granite above them. Again pressure that was insufficient at first to do damage, may become sufficient later, owing to the weakening of the stones by other mechanical, and chemical agencies. Pressure, according to Prof. Julien, may after
long duration, cause rocks to flow, although not sufficient to fracture the stone.

Prof. L. M. Hoskins has shown ("On Flow and Fracture of Rocks as Related to Structure") that, under a predominant pressure in one direction, a rock which is rapidly deformed may pass beyond its elastic limit and become ruptured; but, when under less rapid deformation, it may simply tend to flow. (Note split stones in blldgs.)仰在hydrick, Boston later sch, especially. The flexure of marble mantels, supported only on the ends, is a not uncommon example of the effect of superincumbent pressure. But if the proper stones are properly laid, a very long time and a very tall building would be necessary to cause such a flow. Tall buildings of today are supported by steel frames, so that the pressure of superincumbent masonry ceases to become a very serious factor.

Abandoning action may cause stones to split. Superincumbent pressure also may, as result of poor foundation.

Abrasion.

Abrasion from wheels, horses' hoofs, and human feet is an agent of considerable importance. The rounded, polished and slippery surfaces of granite pavements in streets and sidewalks is well known to everybody. The unevenness of the tiled floors of the Boston Post Office, the City Hall, and, somewhat, in the Rogers Building, (M.I.T.), as well as sandstone doorsteps, the marble stairs in the New Boston Court House, the mica schist sidewalk on Pemberton Square, and even hornblende granite at the entrance to Boston Common from the corner of Park and Beacon Streets, and in the steps of the
Rogers Building show what people's feet can do. While no stone can resist abrasion forever, proper selection of stone would produce better results than exist in Boston today. G. P. Merrill states that resistance to abrasion may be ascertained by observing the manner in which stone works under the chisel. (Md. Geol. Surv. Vol. II, p. 101.)

The damage done by fire, as mentioned above, is simply an extreme result of expansion and contraction. Most of the minerals in building-stones are too insubstantial to be fused by fire alone. Where fire-proof buildings are wanted, stones of uniform composition and texture, as siliceous sandstone, should be used.

Organic Destructive Agencies.

Vegetation.

A general rule as regards vegetation cannot be made. Vegetation may be advantageous in some ways, and detrimental in others. Each case should be considered separately. Vines on buildings aid in catching dust and moisture. A soil may thus be made in which moss and other lower plants may grow. The decay of these plants gives rise to organic acids which aid in chemical disintegration. Vegetation, on the other hand, protects stones from the atmosphere, heating and freezing. Vegetation on limestone, by collecting water holding $\mathrm{CO}_2$, would hasten the solution of the stone. Again, theoretically, organic matter, being a reducing agent, may cause decomposition.
of brownstone by the deoxidization of Fe₂O₃ cement, but nothing of this sort has been noticed in Boston.

Green algae, besides hiding the true color of stones, are not known to do any harm. Brownstone in Back Bay that is covered with algae is not scaled. Algae may be most expected to grow on porous rocks that face north, northeast, or east; but, in an open place like Boston Common, they have succeeded in growing on Hallowell granite. In damp places they grow on stones which face in any direction (Howard Church).

Lichens, although abundant on outcrops near Boston, have not been noticed on building stones. Lichens on ledges of rock have a protective as well as destructive influence, acting as protection against atmosphere, but generating organic acids by decomposition and driving rootlets into rock. Lichens in cemeteries, especially Mt. Auburn, are found associated with fine scaling on Muscovite granite (probably from Hallowell). The lichens in some cases surrounded the scaled surface, sometimes occupied it, proving subsequent origin. Their rootlets penetrating into the crevices of the rock may have a disrupting effect.

It is evident from the properties of destructive agencies that the various agencies, chemical, mechanical, and organic, work together, helping each other, in a very slow, but steady and certain work of destruction; and that a stone that can resist practically destructive agencies of one kind may fall an easy victim to agencies of another kind. The best
building stone then must be the one that is proof against the most agencies of destruction; but proper selection of stones for various positions will do away with the greatest defects seen in buildings today.

Withstand

Ability of Stones to Face the Destructive Agencies.

Internal Elements of Durability.

Thru divers chnr, phy, artifical.

Chemical. Mod. Comp.

The internal elements of durability depend upon chemical composition of constituent minerals and of their cement. Their relative solubility in atmospheric water is important. Calcium carbonate is soluble in water, containing \( \text{CO}_2 \), as all rain water does. (Calcareous cement, by its solution, will cause the once cemented grains to crumble away.) Sulphides, marcasite, and pyrite, which often occur in slates and marbles, are oxidized by rain water, giving the slate a rusty color and giving off free sulphuric acid, which will decompose the alumina silicates in the slate. Black mica, a ferro magnesian silicate, is easily acted upon, suffering oxidation and hydration. The oxidized iron tends to give the stone a rusty color; the solution and weathering out of mica leaves little pits in the surface of the stone, and gives the weather a chance to attack the adjacent minerals on two or three sides at once. When mica hydrates
it swells and thus fractures the stone internally, and
the resulting fractures give access to percolating water, which
will help to disintegrate the stone. Such an action is
supposed to have caused the deep disintegration of the
granite on Pike's Peak. Biotite in building stone that
is only twelve years old has been found so soft that it can
be picked out and scratched to a powder with one's finger-
nail. Muscovite, the common white mica, is very stable
chemically, but tends to swell by taking in water. This
swelling loosens the lamellae, and the mica crystals are
in consequence liable to weather out, leaving the stone in
a pitted condition.

Other ferro magnesian silicates, as hornblende
and the pyroxenes, are subject, in some degree to oxidation
and decomposition; but many years of atmospheric action
does not appear to do much damage. The hornblende in granite
almost always appears fresh and black, and is considered
a good mineral constituent. It appears to have weathered out
in some of the old buildings of Quincy granite, but there
are no present indications of oxidation of the mineral.
Chlorite, in some instances has replaced the hornblende;
but this change which is a deep-seated alteration, resulting
from loss of CaO and union with quarry sap took place
before the rock was quarried. The chlorite in building-stones
has remained unharmed by the weather for over 80 years.

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Pyroxene is more susceptible to the weather than is hornblende. It most commonly occurs in augite in the more basic rocks. Atmospheric agencies alone do not appear to affect it very rapidly, although the outcrops of basic rocks are very much weathered. A most striking example of this fact is shown in the Somerville diabase, whose outcrops are weathered to a brown soil, but which, in buildings, has lasted over sixty years with no apparent disintegration, as may be seen in the old Catholic Church on Fourth Street, E. Cambridge, and in the front of the Lyceum Building, at Harvard Square, Cambridge.

The feldspars are of great importance, as they occur in all igneous and in many metamorphic rocks. Feldspar is generally the most abundant constituent of granite, and the durability of the granite is practically dependent upon it. There are, chemically, two principal divisions of feldspars -- the potash, and the soda-lime. The potash feldspars consist principally of potash, alumina, and silica, with, generally, more or less iron. They are not as easily decomposed as some of the soda-lime feldspars, as the calcium and sodium oxides are more readily attacked by carbonic acid than is potassium oxide, which forms a strong union with silica; but ferrous oxide is the first constituent of all to oxidize, becoming ferric oxide, and makes the potash feldspars that are high in iron, the first to show signs of decomposition. Micropscopic study shows this fact very clearly. Wherever specks of red iron oxide occur, the feldspar is more or less decomposed. The
red feldspars, as those in the red granites from St. George, N. B. or from West Roxbury, Mass. are very much decomposed, and their structure is almost wholly destroyed. After the iron has oxidized, the next step is kaolinization, i. e. the changing of the lime and alkali oxides to soluble carbonates, which are removed by solution, leaving only silicate of alumina and free quartz. Kaolinization is the limit of feldspar decomposition. A curious fact is that kaolinization begins from the centre of the crystal. It is often seen, by microscopic study, to have begun in several granites, and, once begun, it is sure to continue. But the partial kaolinization of these feldspars was brought about by the ceaseless action of carbonic waters for thousands of years, and may not be as serious a defect as it might at first seem to be. Still it is obvious that the less decomposed the feldspar is, the stronger and longer lived will be the stone.

Silica, as quartz, occurs in most acid igneous rocks, either as an essential constituent, as in granite, or as accessory, as in porphyry, diabase, etc. It is also the principal constituent of sandstones, and occurs in slates as quartz flour. Silica, in the amorphous state, often occurs in limestones, where it was deposited, along with lime and magnesian carbonates, from the shells of radiolana and skeletons of diatomae. Silica, from a chemical point of view, is practically indestructible, as it requires an alkaline solvent, and the only alkalie in the atmosphere is sea-salt, which has not been
found to have acted upon silica. The hardness of quartz is 7, but in spite of this fact, quartz is very brittle, and in great quantity, would give a stone a comparatively low crushing strength. This fact explains the greater toughness of diabase over that of granite.

Cements.

Silica, as cement, in sandstones is practically indestructible. It is deposited as quartz from saturated solutions that percolate through the rock, and binds the loose fragments firmly together. It diminishes the porosity of the rock, and, as the fragmental grains in the sandstone are principally quartz, makes a stone of homogeneous composition, which is least affected by alteration of temperature. It is the most powerful of all cements. Quartzites, sandstones whose pores have been completely filled with silica, are the most indestructible of rocks. The objection to them is that their extreme hardness makes their working too difficult and expensive.

Iron oxide, as cement, is usually in the hydrated form of limonite or turgite, and is not subject to oxidation. It may suffer reduction from organic acids that may arise from decomposition of vegetation growing on the walls of buildings. Prof. Alexis A. Julien says of iron oxides, clay and silt cements: "But these are among the feeblest, except when uniformly diffused in minute films among closely abutting grains." It is considered the weakest of cements.
Clays are also a weak cement, and are objectionable on account of their absorptive qualities, which give frost a chance to break up the stone. Their cementing power is sometimes increased by their marly or calcareous character. Clay in little lenticular masses weather out, leaving pits. (Portland S.S. on bed.) Journal of the Franklin Institute Vol. CXLVII, No. 4, p. 272.)

Calcite, a lime carbonate, forms the cement of fragmental limestones, as well as of some sandstones. It, like iron oxide, is a strong cement only when found in crystalline veinlets. (A. A. Julien, Building Stones p. 273) Its ready solubility is liable to make the stone weak, more porous and easily disintegrated by frost.

Cement occurs to some extent in crystalline rocks, and affects their strength. The strength of a stone is increased by seasoning, or exposure to the air, because the water, or sap, in the rock is drawn out by capillary attraction and evaporated on the surface, leaving their solutes deposited in the pores of the stone. The stone now becomes more cohesive and impervious.

The cohesive power of cement is greatest in stones whose constituent grains are of the same chemical composition as is the cement. Thus quartzite and non-porous limestones have greatest cohesive power. When the grains are of different chemical composition than the cement, their adhesion is less. In such cases sandstones with lime carbonate cement are found to disintegrate less readily than those with iron oxide cement.
(E. R. Buckley, Ph. D. Bull. Surv. Wis. No. IV. p. 32.)

Physical Elements of Durability.

Texture and Mineral Composition.

The texture and mineral composition of a stone are of vast importance in the consideration of its durability; size, form and position of constituent minerals are important. A stone consisting principally of one mineral in fine, uniform grains, as a sandstone, is not likely to suffer from changes in temperature. It will expand, but not suffer disruption. A stone composed of several different minerals, as a granite, may have a fine, uniform texture, and so, suffer little from changes in temperature, although the coefficient of expansion is different for each mineral, the size of the minerals is too small to make the difference felt. A coarse-grained or porphyritic granite, however, must suffer considerably from the differential expansion of its constituent minerals. Its cohesive power is weakened, and small cracks are developed between adjacent crystals, giving easy access to water, and so, promoting chemical and mechanical disintegration. Large feldspar crystals are liable to have cleavage cracks well developed. An abundance of mica, as already observed, is detrimental, especially if it lies in parallel position, when it serves as an element of weakness.

A porous rock absorbs a great deal of water and is very liable to suffer from frost action. Every rock absorbs more
or less water. According to Prof. Ansted, granites ordinarily contain 0.8% water, and are capable of absorbing some 0.2% more. That is, a cubic yard in its ordinary state would contain 3.5 gallons of water (Merrill's stones for Bldg. etc.) If such is the case a cubic yard of porous sandstone must be capable of containing a great many gallons of water. When a stone containing so much water is subjected to a freezing temperature, the internal disrupting force of the crystallizing ice must be enormous. Porosity and absorptive power are thus of great importance.

Hardness and Toughness.

The hardness and toughness of a rock depends upon its constituent minerals and their degree and manner of cohesion. A rock may consist almost entirely of hard mineral quartz, as do many sandstones, and yet possess so little cohesion as to be a soft, or pliable, rock, unfit for the resistance of abrasion or the supporting of great weight. as the mica granite, Crystallized rocks consisting mostly of quartz, are very easily powdered under hammer.

Again, stones composed of minerals softer than quartz may have their crystals of so tough a nature and so firmly interlocking that their resistance to abrasion is very great.

The worn appearance of mica schist compared to the even surface of diabase in a sidewalk at 16 Thornley St. Dorchester, both taken from Pemberton Square, is an excellent
illustration of the toughness and cohesion of a rock as properties resistant to abrasion. The rather coarsely crystallized marbles often have a surprisingly high crushing strength, a strength that is due to the close interlocking of the crystals, that formed under pressure. Resistance to abrasion is an important factor in stones for paving, curbing, sidewalks, steps, and tiling, and stones used for such purposes should be known to have high resisting power. Where two or more kinds of stone are used together as in tiling, care should be taken to select stones whose resisting powers are equal or nearly so. Failure to do so often results in the unequal wearing of the tiles, and, in consequence, uneven floors, such as may be seen in the Boston City Hall, Boston Post Office, and the Rogers Building, M. I. T. In all of these cases, white and black marble tiles were used, and, in every case, the white has worn more rapidly than the black. Another noteworthy example of unequal resistance to abrasion is in the entrance of the Rialto Building, 131 Devonshire St. Here the steps from the sidewalk to the entrance are of Quincy granite, practically unworn, while the entrance is tiled with various marbles, which, close to the granite, are so worn as to endanger the tripping of persons who leave the building.

Some sandstones, for example, the Hudson River Bluestone, used so extensively for street flagging, are so composed of small grains of sand pressed into the interstices between larger grains, and the whole firmly cemented, as to present a maximum
power of resistance. It is this property, together with its non-absorbing qualities that makes the Hudson River Bluestone so well adapted for street flagging and sidewalks.

Color.

Not the least important property of a stone, from a building point of view is its color. Several stones, otherwise ideal stones for buildings, are barred out on account of their poor, or sombre colors. The Hudson River bluestone has such an objection; the Quincy granite, though more durable than the red and pink granites, presents so gloomy an appearance when comprising the whole building, that the lighter colored granites are much more desirable for attractive building fronts. The more impure marbles are often more desirable than the pure, as their great variety of color, due to impurities, is far more pleasing than the monotonous white of pure marble. (Discuss fading of marble.)

Artificial Elements of Durability.

Finish of the Stone.

The durability of a stone is considerably influenced by the character of its surface, whether it be polished, smoothly dressed, or rough hewn; for upon this character depends the rate at which water and dust will collect, or wash away. Both rough and smooth surfaces have arguments in their favor, each is preferable for certain stones, or for stones in certain
positions. A rough stone face presents more surface to the weather, and easily collects dust and water in its many little cracks and crevices. The dust aids in the collecting of more water, and holds it for the stone to absorb at its leisure. The dust, composed of various organic and inorganic substances, gives rise to various decomposing agents, such as organic acids, and so there is a variety of destructive agents all acting on the stone together.

But, equally objectionable, or may be worse, is a smoothly dressed stone, which has suffered from repeated hammering, and may be full of incipient cracks, which draw in water by capillary attraction, and subjects the stone to frost action, which results in blistering, or a fine exfoliation of its surface. Such is the explanation, as given by the owner of the quarry, of the exfoliation of the Chelmsford granite, so evident in the Merchants' National Bank Building at the corner of Devonshire and State Streets. This building was erected some time ago, when stone dressing was not so perfected as it is today. The more modern methods of stone dressing are prophesied to yield better results. The scaling of granite will be discussed more fully later on.

Smooth dressing also spoils much of the color of the stone, as the repeated hammering powders the surface of the minerals, and gives a whitened effect. Stones with smooth
finish, no matter what their natural color may be, are always light colored. Dust collects enough to discolor the stone.

Polished surfaces, while suffering from the incipient cracking, still possess so smooth a surface that rain water readily flows off, and takes with it any dust that may have collected in dry weather; so polished surfaces are always fairly clean, and display the color of the rock. Polished surfaces, of course, could not be used everywhere; both because of the additional cost of polishing, and the monotony that would occur from too general a use; but the following paragraphs may serve to bring out the advantages of the polished and other different kinds of surface, as observed in the buildings of Boston.

The Ames Building, at the corner of Court and Washington Sts. is built of the light pink granite from Milford, Mass., but its roughly finished surface has enabled dust and smoke to collect for the past ten years, so that the stone now appears nearly black. The South Station has a rough surface that has become dirtied. The Dewey Monument, in front of the South Terminal Station, is built of the polished red Granite from Stony Creek, Conn., and, although exposed to dust and smoke for six years, presents a clean surface. The ages of these two structures are too unequal to afford a just comparison, but Prof. Julien has stated that polished
granites have lasted in New York for twenty-five years without any noticeable weathering. The New Hampshire granite has, although the wine-red granite has, although those from New Hampshire, although

The buildings of the finer grained granites from Concord, N. H. and Hallowell, Me. have smoothly finished surfaces, which are in many cases very free from dirt and dust; but many of these buildings, as the City Hall, show exfoliation, presenting a spot of clean surface in the midst of a somewhat dirtied one, which spoils the general appearance.

It would seem from these observations, that coarse granites, like that from Stony Creek, that have numerous little cleavage cracks, and are easily subjected to the weather, cannot suffer from the tool work, and are safer the smoother their surface, as then they are most readily washed clear of dust, and most easily shed water. The fine granites, like those from Concord and Hallowell, are well adapted for rough hewn faces, as their fine grains suffer relatively little from temperature variation, and exfoliation is not hastened by tool work. The Soldiers' Monument on Boston Common shows with what good results a smooth surface can be made. This monument of Hallowell granite, although exposed to all sorts of weather, shows no signs of exfoliation. The hornblende granites show satisfactory results in all conditions, whether with rough hewn, smooth, or polished surfaces.
METHODS OF TESTING BUILDING STONE

Prof. Julien divides the methods for testing building stones into two classes; natural methods and artificial methods. The natural methods are (1) Examination of quarry outcrops; (2) Examination of old masonry; (3) The studying of stones erected in the older cemeteries.

1: Examination of Quarry Outcrops:

Where an outcrop of the rock has been exposed to the weather a long time, some indication of its resistance to decomposition may be obtained. A rock that can stand the ravages of the weather for thousands of years ought to last well in a building. Such an inference, however, should not be too hastily drawn. An outcrop may have, until recently, been covered by a few feet of hard pan, or bowlder clay, which has preserved a fresh surface on the rock.

The protecting power of hard pan till is further illustrated by the lack of sheetjointing in granite that has had a covering of till ten feet or so in thickness. Sheet jointing is caused by the diurnal variations in temperature due to the heat of the sun. Where granite is seen in quarries with no covering, or a covering of only three or four feet of hard pan, sheet jointing is developed to an extreme degree. Parallel layers only four or five inches
thick occur close to the top and the layers, often to a
distance of twenty or thirty feet, are too thin to be
worked. These thin sheets between open cracks are easily
attacked by percolating water and suffer a rather rapid
disintegration, so that a good stone might be unjustly
condemned if judged by its thin sheets at the top of a
quarry. On the other hand, where the overlying layer of
hard pan is as much as ten feet thick, the sheet jointing
is very moderately developed and the uppermost layers are
thick enough to be worked, while large blocks can be ob-
tained at a comparatively slight depth.

This difference in sheet jointing is very inter-
resting from a geological point of view and may well be
discussed at this point. The protection of the granite by
the hard pan, which was laid down by the great ice-sheet
in the Quaternary Period of geologic time, proves that
the sheet jointing has been developed since glacial times.
The depth of sheet jointing where outcrops are exposed, may
serve to give some idea of depth to which glacial erosion
took place. If sheet jointing has been so extensively de-
veloped since glacial times, reaching, as it does, depths
of sixty feet and more, as in the Quincy quarries, it must
certainly have gone much deeper than that in the long eras
and ages that preceded the great glacier. As all the sheet
jointing of to-day is evidently of post-glacial origin, all
the pre-glacial sheeting must have been eroded by the ice-
sheet and the surface of the land planed off for a thickness of at least one hundred feet.

Examination of the quarry openings is an important test. The amount of sap-rock, or brown-stained rock, along the seams or joints. The amount of sap rock serves as an indication of the amount of iron protoxide in the rock, on the amount of which depends largely the tendency of the rock to discolor.

The fine grained granite of Westerly is a striking example of discoloration from iron staining. Not only were the seams bordered by a considerable thickness of sap-rock, as much as four inches, but the small loose fragments of rock nearly all have a very thin coating of brown iron stain after lying exposed to the weather for a comparatively short time.

Poor rifting, harmful inclusions, veining and all such objectionable features are best seen and considered by an examination of the quarry openings.

2: Examination of Old Masonry:

Examination of old masonry is a very desirable test, as it shows just how the stone wears in buildings; but, here too, some considerations should be borne in mind. The more crude methods that may have been used in the working of the stone, the rock from which the stone was cut, and the particular position in which the stone was used, should greatly influence the decision made on any old stone. Thus the scaling so commonly seen on the Chelmsford granite
in Boston would certainly not have been so bad, if more modern methods had been used in working the stone.

Any one who sees King's Chapel without knowing that the granite was cut from bowlders on Quincy Common one hundred and fifty years ago might easily form a bad opinion of Quincy granite because of its profuse scaling; but, when they realize that those bowlders had been in contact with the ground and exposed to the weather for upwards of ten thousand years, their surprise may justly be that the stone holds together at all when supporting the walls of a building. A glance at Bunker Hill Monument shows that Quincy granite, taken from quarries has lasted eighty years to satisfaction and bids fair to last a much longer time.

The serpentine in the trimmings of the Harvard Church on Harvard Street, Brookline, certainly condemns that stone for exterior use but it does not show that the stone is useless. The beautiful effect produced by the verde antique or serpentine marbles when used for interior decorative work, wins for them a good position among ornamental stones.

3: The study of Stones Erected in Old Cemeteries:

The study of the stones erected in the old cemeteries is a very thorough as well as rigorous test. The stones are here subjected on all sides to all sorts of weathering in contact with the moist ground and are subject to the invasion of lichens and algae. The effects of me-
chanical as well as chemical agencies of disintegration are shown by the cracking all through of marble monuments their corroded surfaces, scaling of sandstones, and of lichen covering and incipient scaling on some granite steps. The monuments of polished granite have always appeared in good condition; but none of them are very old. The old grave yard at Copp's Hill showed the Lancaster slate grave stones dating back to 1700 and farther in excellent condition. The lettering was clear cut and distinct in every case. Ribboned slates showed a little weathering along the ribbons. Several stones that were laid on edge have begun to split down along the bedding planes, but other than this, very little scaling was observed. The few brown stones seen were scaled until they were about all gone, leaving no kind of inscription. The marble stones were all dissolved so that nearly all the inscriptions were gone. One date 1805 (?) was barely discernable. Greenstone retained its inscriptions but had suffered from the weathering out of its more decomposable minerals. Hornblende granite dated 1846 was in good condition.

The conclusions to draw from cemetery observation are 1. Hornblende granites have lasted well for sixty-five years. They are liable to be partially covered with lichens but these to a great extent may be avoided if the stone is polished. Marbles are to be avoided for cemetery work as they are liable to crack before thirty years and, by a
hundred years are so corroded as to leave the inscription illegible. Coarse brown stones will not last; and those that do not scale become green with algae. What few instances of blue-stone have been seen, are new; but they will probably last indefinitely. Well selected slate is certain to last for two hundred years and to keep fairly free from organic growth.

ARTIFICIAL TESTS:

Artificial tests are many, various and often more or less indefinite as applied at the present day. Some tests may be valueless on some stones, while other tests may be carried on in such a way as not to give the most practical results. Too much weight is thrown on one or two particular tests.

Artificial tests may be grouped under three general heads, a) chemical; b) microscopical; c) physical, as follows:

a) Chemical Tests:
   1. Chemical analysis.
   2. Preservation of color, (also due to physical);
   3. Resistance to corrosion from \( \text{CO}_2 \) and \( \text{H}_2\text{SO}_4 \), and \( \text{H}_2\text{SO}_3 \) and organic acids.

b) Microscopical Tests:
   4. Study of thin sections of the stone.

c) Physical Tests:
   5. Resistance to abrasion;
6. Absorptive powers
7. Resistance to freezing.
8. Ratio of expansion and contraction (Inch$^3$/ft$^2$) of change each degree and average color (here too).
10. Crushing tests
11. Elasticity tests
12. Resistance to shearing.
13. Specific gravity, (weight per cubic foot.)

Solution tests, for instance, mean little with some sandstones, which are composed almost wholly of insoluble minerals. Although the sandstone is insoluble, its porosity or lack of cohesion may condemn it for the same uses for which insolubility would recommend it.

Absorption tests might be applied in a different manner with more practical results. A stone in the wall of a building cannot absorb moisture equally on all sides. If it is properly cemented only the exposed surface can absorb; if the cement has given way and the water has worked its way into the joints of the wall, then absorption can take place on four more faces of the stone to better advantage than on the exposed face as there is no evaporation there to diminish the quantity of water. The joints, however, should be properly cemented and kept in good condition. Consider expansion and contraction: if a stone is on the corner of a wall it has twice the area exposed
that the other stones in the wall have. It is obvious that absorption calculated by the percentage in weight of the water absorbed when the stone is immersed, will give an indefinite result. Tests that give the amount of absorption per unit area would be far more practicable and applicable to any case.

Tests are often unreliable because of the small piece of stone tested. The crushing strength, for example, is determined by the force under which a small cube of stone is crushed. This cube is, naturally, likely to be a sample of the best quality of the stone, free from flaws, and inclusions, etc., and consequently to give very good results; or the cube may suffer from tool work; but a large block of stone is likely to possess more or less flaws, so that the crushing strength of the cube cannot be directly reliable. While a granite of uniform grain like that of Gloucester, Quincy, or Westerly, R.I., might be fairly represented by only a very few sample cubes, one of varying texture, like that of Stony Creek, Conn., would be fairly represented only by several cubes of different characters; while the sample of Stony Creek tested at Watertown Arsenal stood whole weight of machine, there might be several cubes taken from the stone in Boston that would not give such fine results. It seems that, for a thoroughly impartial and reliable test, sample cubes should be taken at definite intervals in the quarry, so as to get a fair representation
of the stone that is quarried. Such a test would, of course, be more expensive and would take a longer time, but such a method seems to be the only way to get a perfectly fair test. What is the use of a test that is not an average test? Records of crushing strength as they exist today should not be taken with too much faith as a proof that a stone is indestructible.

Crushing tests, moreover, are made on fresh specimens and record the strength of unweathered stone. Stone that is originally very strong may become weak and slightly disrupted through weathering, such as hydration, expansion and contraction of mica and kaolinization of feldspar, and its crushing strength is lessened. A porous stone must be weakened by frost or by solution. A stone that withstands a heavy load from a testing machine, may succumb to the slow but never-ceasing pressure of superincumbent masonry and be made to flow. The incessant expansion and contraction of the constituent grains of a stone are continually weakening the rock, so that a stone that has a high crushing strength, is liable, sooner or later to give way under the several weakening forces and to crack. Such cracks have been seen in many buildings, notably Quincy granite at #_____ State Street, the Gloucester granite in the Boston Post Office (fire?) the limestone in Westminster Chambers.

Other tests, such as freezing and fire tests and discoloration tests, are useful, but still have much
room for improvement. These tests, too, are likely to give very satisfactory results with samples of fresh stone; but these results might not be so encouraging if taken from tests on a sample of weathered stone.

From this review of the more common tests on building stone, it may be said that tests, while very important and valuable, should not serve alone as an indication that any stone is indestructible, but should be used as a basis upon which most accurate predictions may be made, and which would show the adaptability of various stones for their several uses. Almost no stone can resist all tests to utmost satisfaction; but some stones may be shown, by tests, to be better adapted for certain uses than others. Thus the Hudson River blue stone, through its non-absorption, tensile strength, resistance to chemicals, strong cohesion and refusal to polish under abrasion, is much better than granite or brownstone for flagging; while granite is far more desirable for buildings on account of its color and ability to take polish, besides its durability. No stone is perfect, but many stones by proper testing, may be put to uses in which they will be nearly so.

CHEMICAL ANALYSES:

Chemical analyses are important in that they show the relative amounts of chemical constituents in the rock, and afford data for considering the liability of the stones to suffer from chemical agencies; but, like
all other tests analyses must not be taken with too much confidence. A stone may be high in silica and low in iron, lime and alkalies, but still be an easy victim of disintegration on account of its mechanical properties. (Portland Brownstone, Stony Creek Granite, Chelmsford Granite.)
MEANS OF PROTECTION AND PRESERVATION

Prof. Julien separates the means of protection and preservation of building stone into four divisions: (1) Selection of Stone; (2) Seasoning; (3) Position; (4) Preservation by Organic Substances.

1: Selection of Stone:

The selection of a stone for building requires a thorough knowledge of lithology as well as other branches of geology. Past experience shows that too much care cannot be used in this selection. If the builders of 1820 had had a better knowledge of the dependence of durability upon the lithological character of the stone, they probably would not have used the porous sandstone from Acquia Creek, Virginia, for the columns at the entrance of St Paul's Church, on Tremont Street. The Quincy granite in the church is in splendid condition; but the sandstone, laid with its bedding planes at a slope of forty-five degrees, is badly scaled and discolored. Experience shows that it is dangerous to use porous and micaceous sandstones like those from Virginia, New Jersey and Portland, Conn., where they will be exposed to rain, changing temperature and frost.

Knowledge of lithology might easily prevent the use in conspicuous places of stones that are liable to discolor. Granites containing garnet (special kind of garnet),
pyrite or other easily oxidizable iron-bearing mineral are very likely to show rusty staining. Example: The granite from Deer Isle, Maine, used in the Subway entrances on the Boston Common, have in many cases turned to a dirty yellowish-brown color.

Knowledge of the ready solubility of carbonates in carbonic and other acids, might have prevented the use of the French Verde Antique and the Red Lepanto serpentine marbles as the pedestals of statues in the yard of Boston City Hall. I have not found out the exact date of their erection, but it cannot be much, if any, over thirty years. Much of the polish has gone from them, the white veinlets of magnesite and calcite have, especially in the red Lepanto been dissolved to a depth of 1/16 inch, and cracks have formed at several places, showing the utter unfitness of the serpentine marbles for out-of-door use. (Watch the Lepanto doorways in Back Bay.

A good selection of stone, in short, requires a knowledge of the stone as regards its fitness to meet the various demands made upon it, and to resist the attacks of the various agencies of destruction.

2: Seasoning:

Every stone, when quarried, is full of sap, or ground water, which holds more or less mineral matter in solution. This water, when the stone is exposed to the sun, is leached out by capillary attraction and deposits its
solutes in the pores or interstices of the stone close to the surface, thereby making it more impervious. This process is called the seasoning of the stone.

The importance of seasoning is well illustrated in the Portland brownstone, which is a very porous stone, and one very subject to exfoliation. It is not uncommon to see one part of a stone deeply scaled, sometimes to a depth of an inch or more, while the rest of the stone appears to be unharmed. (Such occurrences seen at the corner of Brookline and Tremont, Mt. Vernon St., etc.) The question arises: Why does not the whole stone scale uniformly? Because of the seasoned surface. The scaling began at a point where the stone was more porous than elsewhere—(where a porous layer was exposed). The atmosphere attacked the seasoned stone, finally succeeded in penetrating this weak spot and, by developing internal frost action, caused a small piece of the stone to exfoliate. This exfoliation left exposed an unseasoned surface, which the atmosphere found very easy to disintegrate. The next layers following were scaled with increasing rapidity as they were more distant from the seasoned surface; so that, while the seasoned surface of the rest of the stone is yet unattacked, several of the unseasoned layers have been destroyed.

The carvings on the new brownstone entrance of Trinity Church, Copley Square, were made with disregard to the seasoning quality of the stone. The seasoned stone
was laid in the entrance, and the figures were carved after
the stone was in place, thus breaking through the seasoned
surface. The structure is built of the durable Longmeadow
brownstone, and is not more than five years old so no
serious damage has yet happened; but, in spite of the
lasting qualities of the Longmeadow stone in other buildings,
it need not be surprising if the figures on the entrance
to Trinity Church begin to crumble away at an early date.

Seasoning in crystalline rocks, granites and
marbles, does not necessarily play so important a part
as in the fragmental rocks; for the crystalline structure
means a relatively impervious rock. The matter deposited
by evaporating water in the minute cleavage cracks and pores
of the various constituent minerals of granite, prolong
the life of those minerals.

Exfoliation in the granites of Boston, has occurred
only in the white mica granites in some of the older build-
ings and is probably due more to blistering or to the
weakening effect of the mica than to lack of seasoning.
It is reasonable, however, to expect the unseasoned surface
exposed by exfoliation to suffer more rapidly than the
seasoned surface of the stone.

3: Position: Bed and edge.

The position of a stone in a building has great
influence on the life of a stone. A stone, properly laid,
may last even for centuries, while the same stone, improperly
laid may begin to disintegrate in a few years. The most striking example of improperly laid stone is the Portland brownstone already referred to several times. This stone is very micaceous with a stratification very distinctly marked by alternating coarse and fine layers; but, in spite of this well marked lamination the stone has almost always been laid on edge. Water, in time, works through the pores of the seasoned surface and opened cement seams of stones, and follows the lines of easiest flow—the bedding planes. The mica, along these planes, hydrates and swells with a tendency to bulge the stone outward where least resistance is offered. The heat of the sun causes the outer layers to expand and bulge still more, and the enormous force of freezing of the included water on cold nights finishes the work, and breaks off the outer layer of the stone.

If the stone had been laid on bed conditions would have been different. The bedding planes would now be normal to the surface, and, while readily admitting water, would just as readily discharge it. There would be no stratum of rock to hold the water back. The mica would hydrate just as readily as before and would tend to bulge the stone; but the expansion outward of the edges of the layers is of no serious consequence, while the expansion upwards of the layers themselves is prevented by the downward pressure of the superincumbent wall. The heat of the sun cannot affect the layers of the stone laid on bed;
but it will draw the included water out from the bedding planes. Lastly, the expansion of freezing water, which is evidently the most active cause of the exfoliation of brownstones, will take place, as before, in the direction of least resistance; but this direction on a stone laid on bed, is outward along the bedding planes.

The scaling of Portland stone is almost too common to need the mention of special examples. A walk along Beacon Street from Charles Street to Dartmouth Street will afford many examples. Marlborough Street, Mt Vernon Street and Columbus Avenue also give numerous illustrations. The New Brunswick and Ohio freestones often show exfoliation to a considerable degree, when laid on edge; while the New Jersey brownstones, as in the Arlington Street Church, show almost as bad results as does the Portland stone.

Laminated crystalline rocks are also liable to scale if laid on edge. The white mica bearing granites that have exfoliated in Boston are all of more or less gneissic or laminated structure, and in every case where scaling has taken place, are laid nearly on edge, (said to be due to blistering, but why have not hornblende granites blistered?)

Position: b: Form of Projections:

The form of stone projections in buildings can easily be made so as to protect the stone without diminishing the beauty of the building. Projections should be so cut that rain and snow cannot lodge on them for any length of time. The bottom especially, on which the sun never shines,
should slope downward to the outer edge, so that the water would drip off most easily. The results due to wrongly cut projections is strongly shown on Beacon Street, opposite Boston Common and the Public Garden where house after house has projections that are scaled on the under side. The stone used is generally the Portland brownstone, but, in one or two instances, even the compact and long-lived Longmeadow brownstone has succumbed (87 Beacon Street.)

The tops of the doorways, windows and the eaves of these buildings often have more or less carving, such as scrolls, and these scrolls are generally partly gone. They never receive the sunlight, and are always in more or less damp places. Their shape facilitates the retention and absorption of water, and exfoliation is not surprising. Elaborate carving no doubt made the buildings very beautiful once, but the exfoliated scrolls give to them a dilapidated appearance now.

While no stone could be expected to endure forever if used as an improperly cut projection, some stones, notably the Portland brownstone ought never to be used as projections, even when properly laid, because of their structure. The projecting window-sills of West Brookline Street, between Shawmut Avenue and Tremont Street, although laid on bed, are all more or less cracked along their bedding. Water here is able to enter the stone on three sides, and, as there is no superincumbent pressure on the stone, the combined dis-
integrating forces easily split the stone. The same process, far more advanced, is shown on East Dedham Street and other streets in the neighborhood. Here the brownstone has disintegrated so far that all resemblance to a window-sill has gone.

EXPOSURE:

Porous stones should not be placed in positions near the ground (?) that are exposed to north, north-east and east winds if they are to remain free from dust and organic growth. Brownstone steps and curbing, along the south side of Beacon Street, that, otherwise, are in good condition, are green with algae or black with street dust. It is a noticeable fact that while the curbing and steps of porous stone along the older parts of Back Bay streets are greatly discolored those of relatively impervious granite are remarkably clean. Proper selection of stone for different purposes would produce much more satisfactory results than at present exist.

Some of the more recent dwellings in Back Bay have curbing of white oolitic limestone around their lawns. The white limestone soon becomes discolored by dust, and its position, which subjects it to the carbonic, humic and other acids that are in the ground and to the region of most frequent frost action, is prohibitive of anything but a short life of a very long duration.

It is a surprising fact that the porous curb-stones
around lawns almost never show any exfoliation when the same kind of stone in the wall of the house, not ten feet away, is often badly exfoliated. The curb stone, in contact with the ground, must be well saturated with water, and much exposed to frost; but brownstone curbs, mostly laid on edge, are generally whole. When stones are in contact with iron, due allowance should be made for the expansive force of the iron.

A brownstone post, split through the middle by an iron rail— is not a very rare sight in Back Bay, while in the gateway of the old cemetery on Washington Street, opposite Rutland Street, a post of hornblende granite is split at the point where the iron gate is attached to it.

4: Preservation by Organic Substances:

Oil, tar, parrafin, etc., have been used in this country for protection to stone, but not with success. I have no information of the use of any of these substances in Boston. Inorganic chemicals, (water, glass, oxalate of aluminum, etc.,) have in some cases met with success, but they have been little, if ever, used in Boston. Paint has sometimes been used on granite, especially on little stores, in the busy parts of the city. The paint, a dark green in color, probably serves to hide dirt more than any other purpose. The paint on the Chelmsford granite on the old part of the Quincy House, #1 Brattle Square, serves to hide the exfoliation of the granite.
The brownstone at the corner of Commonwealth Avenue and Clarendon Street which has weathered full of holes of various sizes, has had the larger holes filled with a brown cement, and the surface of the stone roughened. This work is more of an attempt to hide defects rather than to preserve the stone; but, like most other such attempts, has not been very successful.
PART II.

DESCRIPTIONS OF THE CHARACTER AND BEHAVIOUR OF THE VARIOUS BUILDING STONES USED IN BOSTON.

Now that the various destructive agents and the ability of stones to withstand these agents have been discussed, the descriptions of the different stones will show these strong and weak points. The different kinds of stone used in Boston are conglomerate, sandstone, slate, mica schist, limestone, marble and granite.

CONGLOMERATE

Roxbury Puddingstone:

The only kind of conglomerate used in Boston is the Roxbury Puddingstone. It consists of well rounded pebbles of quartzite, red granite, felsite, and occasionally of melaphyr, cemented by a very strong matrix of sandy and clayey material. The size of the pebbles varies, but the average size in the stones used for building is about the size of a hen's egg. The rock is split with great difficulty, and presents a rough fracture which would render its working too expensive, were it not for the well developed systems of joints or seams, which cross the rock in two great systems, nearly at right angles to each other, and are supplemented by other minor systems of joints. These joints afford seam-faced stone, that is smooth surfaces stained
brown with ferric oxide. This stone has been used to very good effect in several Boston Churches and in a few other buildings. It is a common occurrence in stone walls in the outlying parts of the city. Its peculiar structure bars it from any use in other buildings than that mentioned above and in rough foundations. It is also used considerably as road metal.

SANDSTONES

a: Brownstones:

Portland Brownstone: The Portland, Conn., brownstone is a medium to coarse grained rock of Triassic age. It consists of angular grains of quartz, feldspar, and white mica, cemented principally by Fe₂O₃. The quartz and feldspar grains are covered by coatings of limonite or turgite, the hydrous ferric oxides. These oxides probably surrounded the grains when they formed the residual soil that once covered the crystalline areas of central and western Massachusetts. When the grains were transported into the Connecticut Valley, they were carried too short a time and too short a distance to lose this coating, and were deposited as brown grains which gradually became cemented by the iron coating. (Also CaCO₃ in the cement; Fe₂O₃ is poor.)

The abundance of white mica is characteristic of the Portland stone, and, as has previously been noted, is a source of weakness. It occurs in flakes of considerable (?)
size and follows the bedding.

The texture of the stone is very variable and the difference between the coarse and fine layers is very marked. Sometimes the stone is so coarse as to be a typical conglomerate. It often contains clay concretions, varying in size from almost nothing to an inch or more in length. Its color is a chocolate brown, and is a very attractive stone when not used too continuously (?)

The Portland stone has been quarried for a long time extensively, and is one of the most common stones in Boston, but is not used in any of the newer buildings. The frequent reference to this stone in the earlier parts of this paper make a detailed account of its durability unnecessary. It cannot endure the weather when laid on edge, and, when laid on bed, the clay concretions soon weather out of it, leaving it full of unsightly holes. While in a milder and dryer climate it might last, it is, for all general exterior purposes, unfit to be used in Boston's.

New Jersey Brownstones: The New Jersey brownstones in Boston buildings were quarried at Newark, Belleville, and Little Falls. They resemble the Portland stone in general color and in geological age. Their color, however, is sometimes a lighter brown and their texture is more uniform than the Portland. They are also very micaceous, but not so much so as in the Portland stone.
The occurrence of New Jersey stone in Boston buildings is very limited—a fact that is not to be regretted, as the New Jersey stone, where used, has suffered about as badly as the Portland stone. It is sufficiently micaceous to scale readily and often is full of little pits where clay concretions have weathered out. It is unfit for exterior work in Boston’s climate.

East Longmeadow Brownstone:

The brownstone from East Longmeadow, Mass., is a fine grained, compact sandstone. It is also of Triassic age, and is part of the same formation that contains the Portland stone; but its character is very different. Its color is a reddish brown, its texture is very fine and compact, and it contains very little mica. The mica often seems to be wholly absent, and, when visible, occurs only in minute scattered grains, barely enough to show the bedding of the stone.

Clay concretions, while not common in Longmeadow stone, are occasionally met with, but are too small to detract from the general appearance of the stone.

The Longmeadow stone used in Boston has come principally from three (?) quarries, the Maynard, Kibby and Worcester. The reddest stone, common along Huntington Avenue, came from the Maynard quarry, while the browner stone used in Barristers’ Hall Pemberton Square, came from the Kibby.

The Longmeadow stone has been used very extensively.
in Boston, but it is not used there to-day. It is a very durable stone and has worn satisfactorily wherever used. Its use in Boston dates back to over twenty-five years ago. The only instance of its scaling was an improperly cut projecting stone on Beacon Street. The cause of its not being used to-day is merely a change in fashion, which at present calls for the light-colored stones. The only defect found in the Longmeadow stone, other than blackening by dust and smoke, is the insignificant pitting above mentioned.

b: Freestone:

Acquia Creek, Virginia: The stone from Acquia Creek is a moderately fine, almost white stone, of Jurassic age, consisting principally of grains of quartz and more or less decomposed feldspar, and a few scattering flakes of white and black mica. Streaks of ferric oxide follow the bedding planes. The stone has a strong odor of Kaolin, or clay, which probably increases its absorptive power. Its unfitness for exposed work was long ago demonstrated by its bad behaviour in the White House and other Government buildings in Washington. The badly scaled columns at the front of St. Paul's Church on Tremont Street, are of this stone. Owing to the unfitness of this stone for exposed use, quarrying has long since been discontinued.

Bay View, N.B.: Many of the buildings erected after the great fire of 1872 are built of the stone from Bay View, N.B. It belongs to the lower carbonic series of
rocks and varies in color from reddish to yellow and olive gray; the latter variety being almost exclusively used in Boston. It is fine and even grained, works readily, and is a very durable stone. Most of it is in good condition after thirty years of exposure, although incipient scaling is not an uncommon occurrence. It has in one or two instances, as at Peoples' Temple, on the corner of Berkeley Street and Columbus Avenue, disintegrated considerably, so as to present a rough, powdery surface. The other New Brunswick sandstones from Caledonia, Wood's Point, and Mary's Point, little used in Boston, are similar to that from Bay View, and, when used, have lasted well.

Amherst, Ohio: There are two varieties of stone from Amherst, Ohio, the gray and the buff. The buff is the same kind of stone as the gray save that, owing to its position above the ground-water line, the pyrite disseminated through it has been oxidized to ferric oxide. The stone belongs to the Waverly group of sub-carboniferous rocks, and is said to be 97% pure sand. The stone usually contains about 95% silica, with small amounts of lime, magnesia, iron oxides, alumina and alkalies, which suggest the presence of feldspar. Analysis has shown this stone to contain from 5.83 to 7.75% of water when first quarried, and from 3.39 to 4.28% when dry. There is very little cementing material, the grains being held together by the cohesion induced by the pressure to which they were subjected when the stone
consolidated. The presence of pyrite renders the grey stone liable to rapid change of color; but the pyrite is usually so evenly disseminated that the color changes evenly. The Hotel Alma, 782 Massachusetts Avenue, shows the uneven coloring of the Amherst stone, which is very objectionable. The buff stone, in which the pyrite is already oxidized, is a safer stone to use as the color is permanent and the cementing power is slightly increased by the ferric oxide. The Amherst stone has generally proved itself durable, but has scaled in a few instances where improperly laid. It is, owing to its light color and rough surface, easily discolored by street dust. The Berea, Ohio, freestone, is similar to the Amherst.

OTHER SANDSTONES USED IN BOSTON

Malone, New York:

The Malone sandstone belongs to the Potsdam formation. It is generally of a light yellow to reddish color. It is composed almost wholly of quartz grains cemented by silica, forming a quartzite, with just enough ferric oxide to give it color, and is a very durable stone. I know of only one instance of its use in Boston, and there, the block on Washington Street, between Worcester and Concord Streets, it has lasted for thirty years with no signs of injury.

Potsdam Red Sandstone:

This stone is of the same formation as the Malone,
and is quarried three miles south of Potsadam, New York. Its composition and texture are the same as that of the Malone stone, but its color is redder. It is unaffected by chemical agencies, is rendered practically non-absorptive by the interstitial deposition of silica, and, with its pleasing color, is practically a perfect stone. Its only use near Boston is in the building in Mt. Auburn Cemetery just to the left of the main entrance.

**Portage (Lake Superior) Sandstone:**

The Portage stone is reddish in color, and has a fine uniform texture. I know of only one instance of its use in Boston, where it was recently used for window trimmings in Back Bay. I have therefore not been able to study its weathering qualities. It is, I am told, liable to show white spots on its surface.

**McDermott Red Sandstone, Ohio:**

I am told that a red, friable sandstone from McDermott, Ohio, has been used for trimmings in a brick block on Clinton Road, Brookline, and has shown signs of weathering in three years; but I have not had an opportunity to study the stone.

**Gatelawbridge, Scotland:** The Gatelawbridge stone is a medium-grained, red sandstone very distinctly banded. It has only recently been used in Boston, and, where used, has been laid on bed, and bids fair to last, provided it does not have to sustain too great a weight.
Hudson River Bluestone (Graywacke.)

Graywacke or argillaceous sandstone, occurs in New York and Pennsylvania, in the Hamilton formation, and has a variety of colors—pink, purple, blue, green and gray. The most important variety is the dark blue quarried along the North River, and is used in many cities for flagging. This stone is harder, firmer and more durable than that from Pennsylvania. It is particularly adapted for flagging purposes. It is, though argillaceous, so compact that it is non-absorptive. The fine particles of clay are so arranged among the sand grains that the pores are practically closed. Thus, although it is commonly placed in the ground where water and frost can most readily act upon it, it is not known to suffer from frost action. The bluestone, furthermore, has a great resistance to abrasion. Flagstones in Boston streets show practically no wear except along the edges and at the corners; while, in the United States Treasury Building at Washington, the heavy trucks of bullion have gone back and forth for thirty years over bluestone flagging, without making any noticeable impression upon it. As bluestone wears it does not become glassy and slippery, as does granite, but it wears away grain by grain and maintains an unpolished surface. These qualities put bluestone in a class by itself, for flagging and similar uses.

Bluestone is good for dye-house floors as the dye cannot soak into it.

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Its sombre color bars bluestone from external use in buildings. It has, however, been used in late years for underpinning of buildings, such as Hotel Touraine, the Pierce, and the Converse Buildings. It has been used in one or two New York buildings and the tool marks are perfectly visible after fifteen years of service. Bluestone is one of the most satisfactory stones used in Boston.
SLATE IN BUILDINGS

Somerville, Mass.

The dark, bluish-black clay slate of the carbonic series has been used to a limited extent for churches and foundations of dwellings. It is a fine, even-grained rock, and is rather thinly bedded, but is unfit for roofing purposes. It gives to buildings a very sombre appearance, which is partly offset by light granite trimmings. It has lasted well for sixty years in the old St. John's Church in East Cambridge, and looks as fresh as if it had only recently been quarried. While it resists successfully the various agencies of weathering, the well developed jointed structure in the quarries and the rather thin beds prevent the use of any but small blocks of stone.

Roofing Slate.

Slates used for roofing must have the following properties: toughness and permanency of color, and the ability to shed water readily.

Monson, Me., Roofing Slate.

The Monson, Me., slate is a black, highly micaceous slate. It can be split into very thin sheets, and is very
tough. A piece 3 feet long has been turned in a lathe to \(\frac{1}{2}\) inch diameter. Hoops \(\frac{1}{2}\) inch wide and 3 feet in diameter for register borders have also been made out of Monson slate. Its composition is very uniform, and it contains no pyrite or other discoloring matter. It is said to have lasted over forty years on a roof and to be as strong and black at the end of that time as it was when first laid. Its highly micaceous character causes it to shed water very readily on roofs, and to make the best quality of blackboards, as chalk dust cannot lodge on the smooth surface. Prof. H. B. Cornwall, after testing a large number of slates, found the Monson slate best in the power to resist the action of acids. It is, therefore, especially adapted to use for laboratory desks, and its freedom from iron makes it most desirable for electrical purposes.

**Pennsylvania Slates.**

The principal quarries of Pennsylvania slate are at Bangor and Slatington. The Pennsylvania slates resemble the Monson slate very closely, but have not so shiny a surface. They are, furthermore, likely to have a ribboned structure, which is an element of weakness. They have not proved so durable as the Monson slate. Their life as roofing
slate is said to be 10 to 12 years, after which they fade, probably from the loss of carbon. Then, when removed, they are found to crumble. Pennsylvania slates are evidently not so highly metamorphosed as the Monson slate, and consequently are not so highly micaceous. As it is the mica that enables the Monson slate to shed water so readily, the Pennsylvania slate must suffer somewhat from absorption, which in time disintegrates it. Thus the presence of mica, so injurious to sandstones and granites, seems to be a desirable element in roofing slate.

The Pennsylvania slates are more widely used than any other slates for purposes other than roofing, and such as writing slates, laundry work, lavatories, blackboards, etc. As blackboards they become discolored by the lodging of chalk dust.

The Peachbottom slates from southern Pennsylvania have probably been used in Boston, but, if so, only to a very slight extent. These slates are said to be of good quality, but they are no better than the Monson slate, and the transportation from Pennsylvania to Boston makes them more expensive; so they are not used in Boston today.
Vermont and New York Colored Slates.

There are in western Vermont and eastern New York three belts of colored slate running north to south. The eastern belt is gray, the middle belt purple, and the western belt red slate. The variety of color is due to the amount of ferric oxide in the slate. The red slate is richest in ferric oxide, the purple is intermediate, while the gray is practically without it, and contains the protoxide. These slates have all behaved well in Boston buildings.

There is, however, a poor gray slate quarried at Granville, N. Y., that contains a large amount of pyrite. This slate was used on the Brookline Manual Training School, and changed color within 3 weeks of the time it was put there.

Lancaster, Mass.

The slate from Lancaster, Mass., was used extensively for tombstones in Revolutionary times, and has lasted until today with no signs of decay, save in a few cases, where stones set on edge have begun to split along their bedding planes as the result of frost action. The quarrying of these slates was stopped long ago because of the successful competition of marble for tombstones; but while the more recent marble stones have so far disintegrated that many of their
inscriptions are no longer legible, the slates are as readable today as they ever were.

Wales Slate.

Some of the old buildings of Boston are probably roofed with Wales slates; but those slates are no longer used. Slates today are exported from New England to Europe,—a fact that seems to prove the New England slates superior to those from Wales.

Marbleized Slate.

Slate is sometimes painted and glazed so as to imitate various kinds of marble. The cheaper qualities of slate are generally used for this work. This imitation is often found in bathrooms, bar-rooms, tables with supposed onyx tops, clocks and soda fountains. It is very little used in Boston, where imitations are not welcome; but it finds considerable use in the country.

Mica Schist.

A light colored mica schist was used for the sidewalks of Pemberton Square, but I have not been able to find out where it was quarried. It has been considerably worn by foot abrasion, and is not resistant enough for flagging. It is composed chiefly of white and black mica, and quartz.
LIMESTONES.

Indiana Limestone.

The Indiana limestone is an Eölitic limestone belonging to the Subcarboniferous Era, quarried at Bedford, Indiana, and is known to geologists as the Bedford eölite. It is a rock of fine, even texture, composed of little rounded concretionary grains of calcite, cemented by cement of the same material, which completely, or almost completely, fills the interstices. Thus the stone, although composed of soluble material, is nearly impervious, and can suffer solution only on the surface, where water quickly evaporates. The greater cohesion of grains and cements of the same material gives the stone a high crushing strength for a limestone, and makes it adaptable to use in the walls of buildings. It is often however, that some stones possess flaws or lines of weakness, where small fossil shells occur along the bedding, and crack sooner or later along these lines, from inability to withstand the superincumbent pressure. Two such cracked stones occur in Westminster Chambers, on Trinity Place.

This Indiana stone is white, or nearly so, in color, and with the Ohio limestone is now in the height of fashion.
Although it was first used for building in Boston only 13 years ago, when the Algonquin Club House was built on Beacon street, there are now upwards of sixteen buildings in Boston in which the Indiana limestone is the principal stone. The chief difficulty with these light stones is that whatever dust collects on them will quickly give them a dirty look. This is especially the case with buildings near railroads, as Trinity Court and South Station, where black smoke is always in the air to some extent. These buildings are very much blackened. The stone also, of course, has a discordant appearance, where some parts retain water longer than others.

The softness of the stone and the readiness with which it is worked especially adapts it for carving, and practically all the light stone used for carved work in Boston is the Indiana stone. The Indiana limestone, as far as observation goes, has proved fairly durable. It has only been in use for a short while (13 years), but has shown no very great evidence of disintegration. The Cunard building on State street showed a white efflorescence on the surface of the stone; the Westminster Chambers shows two poor and improperly laid blocks that have cracked; and several buildings show the stone discolored by dirt; but none of these defects are yet sufficient to cause any great alarm. It seems that a stone
consisting of so soluble a material must succumb relatively soon to the CO₂ and H₂SO₃ in the city's atmosphere; but as the impervious character and uniform composition of the stone protects it from mechanical weathering, the chemical agencies must work alone, and must act slowly. (The future long life of this limestone may be a proof that the amount of chemical weathering that stones in buildings endure is very little.) (foot-note)

Pennycook, N.H., Argillaceous Limestone.

There is in the Winter Hill and Somerville Highlands railroad stations in Somerville a dark gray to black stone that is said to come from Pennycook, N.H. It is a metamorphosed carbonaceous and argillaceous limestone, consisting of highly folded strata, with a few small beds of mica schist material occurring in it. It is used as rough-hewn stone, and, in many places, small pieces of it are ready to chip off from frost action. The lime carbonate has been leached to the surface, giving it a whitened appearance. It is an attractive stone, and is not commonly used about Boston; but it does not show any striking signs of durability.
MARBLES.

Marbles have been used both for exterior work, and interior work; but it has not generally proved successful in exterior use. The marbles thus used are mostly white Vermont marbles from Southerland Falls, Pittsford, Dorset, and Rutland. They are all metamorphosed dolomitie limestones of medium structure, containing more or less of impurity.

The Southerland Falls marble is a white variegated stone, full of streaks of micaceous and sandy material. Wherever it occurs near the ground, its surface appears somewhat roughened by corrosion, and is black with gathered dust. It often shows where little pieces have been split off by frost where a bedding plane emerges oblique to the surface. Its general appearance in buildings, that have been standing for 30 years is dirty and weathered.

The Pittsford stone was generally found in use only above the first story, so I could make no close examination. In the Penny Savings Bank it had weathered yellow. It appeared, except for the dirt and one or two flaws in stones, in fairly good condition.

The Rutland white marble showed a coiled sandy surface, where calcite had dissolved, leaving the dolomite grains in relief. In the Parker House, 60 School St., it has weathered yellow, and has often grown where solution has taken place more rapidly along bedding planes than elsewhere.
The Dorset marble does not occur in any Boston buildings that I know of, and has not yet been studied. The Sprague House in Brookline is built of the Dorset Marble.

Massachusetts White Marbles.

The marbles of western Massachusetts are practically true dolomites, and are very strong and resistant stones. That from Alford, occurs in the buildings on Pearl St., between High and Purchase Sts., and does not appear to be seriously affected by 30 years of service. It is somewhat discolored, especially beneath window sills, where water is able to remain longer than elsewhere, and with the help of a little dust, darkens the stone. The marble from Lee, Mass. is a white and very durable stone. The only objection to it is its liability to contain tremolite crystals, which soon weather out, and give dust a chance to collect, when the marble receives a dirty, pitted appearance, as may be seen in the newer part of the State House.

Georgia White Marble.

The coarse white marble from Tate, Georgia is composed of pure calcite. The fact that calcite is readily soluble has led to the supposition that, by the uniform solution of the calcite, the marble would preserve a clean surface; but such has not proved to be the case in Boston. The Ames office building, at the corner of Bedford and Kingston Sts. is built of this marble. Here, the grains, by contraction and expansion, have opened cracks between adjacent crystals, and have opened up cleavage cracks and gliding planes. All
these cracks are black where dust has collected. Solution, owing to the cracks, has given the stone a corroded surface, so that still more dust has collected, and the Georgia marble is the one of the dirtiest looking stones that I have noticed.

New York Marbles.—Tuckahoe.

The only New York marble used for exterior work in Boston is that from Tuckahoe. This stone is a coarse grain-ed dolomite, and is often full of scales of phlogopite, the magnesian mica, and tremolite. Tuckahoe marble is very durable. A piece removed from the Macullar Parker Building, after 30 years of service, showed no other defect than a film of dust on its surface. Its interior appeared perfectly fresh. The presence of the mica, however, is an element of weakness, and when on the surface, weathers and stains the rock a rusty color. The tremolite crystals, as in the Lee Mass. marble, are liable to weather out, giving the stone a pitted appearance, which spoils its looks. Although a white marble, it quickly gets a gray color from the dust of the city.
COLORED MARBLES IN EXTERIOR WORK.

Winooski Marble.

The Winooski marble from Colchester, Vt., is used in the Winter Hill station in Somerville. It is a brecciated marble consisting of red, brown, and white fragments, held by a brown matrix. Its color is very pretty, but at the Winter Hill station it is fading from weathering. The fading seems to be caused by a thin film of white substance, probably calcite, that has come to the surface and been deposited by evaporation.

Serpentine from Chester Co., Pa.

The Chester Serpentine is of a uniform grass-green color with numerous little veinlets of magnesite. It is used in the trimmings of the Harvard Church in Brookline, and fortunately has not been used elsewhere for exterior work, for here it was worse than any other building stone that I have seen. No matter whether it is laid on edge or on bed, it either scales, or weathers along the bedding planes, while the veinlets of calcite are all deeply weathered. This stone is a pretty stone and could be used to good effect in-doors; but it is utterly unfit for out-of-door use.

Verde Antique from France.

The French Verde Antique marble is a dark green brecciated serpentine, with its fragments held together by broad veinlets of magnesite and, perhaps, of calcite.
like that from Chester, Pa. is unfit for exterior work and use. It is used as the pedestal of the Franklin Statue at the City Hall, and lost much of its polish, cracked in many places, and became more or less grooved where the magnesite veins have been dissolved.

Red Lepanto.

The statue of Josiah Quincy, opposite that of Franklin at the City Hall, has a pedestal of Red Lepanto marble. This marble is a red and green brecciated serpentine, with the rounded fragments held together by veinlets of magnesite. The magnesite veinlets are interwoven all through the serpentine fragments, so that hardly a square inch of surface occurs, without more or less magnesite. This stone weathers more easily than does the Verde Antique above mentioned. The polish is largely gone, the serpentine shows fine cracks, and the magnesite veinlets have dissolved to a depth of $\frac{3}{16}$ of an inch, leaving the serpentine in marked relief. The stone, close to, is unsightly, and, even at a distance of thirty feet has an aged appearance.

Neither of these pedestals has been standing much over thirty years, if as long as that; and they are utterly unfit for the positions that they now occupy. Only the most durable and strongest stones should be used to support statues in the open air, as statues of prominent men are structures that are wanted to remain for centuries, not merely for a few years.
My observations on Serpentine marbles simply confirm the statement that they are unfit for exterior use or for positions where they have to support great weight.
MARBLES FOR INTERIOR USE.

The marbles used in the interior of buildings are generally in the form of polished slabs, or as stair treads, tiles, bannisters and pedestals for statues. If the slabs are not made to support any great weight, there is no reason why they should not last for centuries, as they are unaffected by all the agencies of destruction. Mantels may sag from lack of support or too great weight above them, and slabs may bulge when not given room to expand. As for the stair treads, and bannisters, they are subjected to foot abrasion, and have in many cases been considerably worn, as was shown in the discussion of abrasion. As all the injuries of interior marble have now been mentioned, practically nothing remains for me to do but to describe briefly the different varieties that have been used in Boston.

The white Vermont, the Winooski and Georgia marbles were previously described among the exterior marbles.

TENNESSEE MARBLE.

There are two varieties of colored marble quarried at Knoxville, Tennessee, that are known as the old or brown Knoxville and the new or pink Knoxville.
Brown Knoxville. The brown Knoxville marble is a "highly fossiliferous, chocolate, stone variegated with white" (Memill P 105). It is a very attractive stone.

Pink Knoxville. The pink Knoxville marble underlies the brown Knoxville, and is the older in geological age, though the newer in use for building. It is a gray to pink crystalline stone of moderately coarse texture, with frequent streaks or veinlets, of black oxide of manganese running through it. It is characterized by absence of fossils; but traces of fossils are occasionally seen in some slabs. Its light color makes this stone good for a variety of uses for which the brown marble is not suitable; and it at present is more extensively used.

The pink Knoxville marble has been used occasionally for exterior work in the walls of buildings, and as tomb stones. Both instances are too recent to show the weathering qualities of the stone. It is often used for stairs, and lasts well in that position where there is not too much passing, but the steps in the New Court House (before mentioned) are considerably worn. The stone is very commonly used for wash-basins.

Isle la Motte Marble. The Isle la Motte marble from Isle la Motte in Lake Champlain, is a black stone of the Chazy formation, full of white fossils of cephalopods and gastropods. It resists abrasion very well and is commonly used for black tiles. The black tiles in the Rogers Bldg. M. I. T. are of Isle la Motte marble, and many of them show the fossil gas-
teropodi, Maclurea magna. These black tiles are much more resistant to foot abrasion than are the white tiles with which they alternate, and stand in noticeable relief. Although the stone makes excellent tiles, its black color bars it from any other noteworthy use. This stone has not suffered the metamorphism and crystallization that the other marbles have; hence its preserved fossils. It is really a carbonaceous limestone, but takes a good polish, and is commercially speaking, a marble.

Vermont Blue Marble. The blue marble from West Rutland Vt. is a beautifully mottled stone with black zig-zag lines running through it. The corridors of the New Court House give the only noteworthy instances of its use in Boston.

Serpentine Marbles. The only native serpentine marbles used in Boston are those from Roxbury, Vt. and Westfield, Mass. They are known as verde antique marbles, but the name verde antique strictly applies only to those green serpentine marbles used by the ancient Romans, and which were obtained originally from Italy, Greece, or Egypt.

Roxbury, Vt. The verde antique marble in Westminster Chambers is probably from Roxbury, Vt. It is a dark green stone with patches of red and light green.

Westfield, Mass. There are three kinds of serpentine quarried in the western part of Westfield. They are known as the "black and green," the "spangled," and the "verde antique." They are all beautiful stones, but the "black and green" is
the only one that has so far been extensively used, and is
the only one used in Boston. It is when polished a black ser-
pentine, altered from hypersthene, full of small round patches
of the green serpentine. It is apparently very durable for a
serpentine. A drinking fountain in Westfield, built of this
stone, although somewhat weathered in appearance, is said not
to have suffered any weathering since it was erected eight
years ago. The green columns at the entrance of the Hotel
Lenox are the only example of this stone that I know of in
Boston; but the stone has found considerable use in New York.
FOREIGN MARBLES AND LIMESTONES.

The other marbles used to any extent in Boston are imported from foreign countries. They are mostly all colored.

FOREIGN MARBLES AND LIMESTONES. (INTERIOR).

Caen Stone, France. G. P. Merrill gives the following description of the Caen stone: "This is one of the most noted limestones of modern history. It is a soft, fine-grained stone, very light colored, and admirably adapted for outdoor work in such a climate as that of the United States. Eggleston (Treas. Am. Soc. of Civil Eng. xv 1886) states that in the climate of New York City the stones do not endure longer than ten years unless protected by paint." The stone is used only for interior work in Boston.

Hautville, France. The Hautville limestone is a very light yellow limestone, showing traces of fossil shells. Its color is very uniform and monotonous. It is used for the steps of the grand staircase in the Boston Public Library.

Eschallion, France. The Eschallion Stone is a very fossiliferous stone, often confused with the Hautville stone. It is, however, of a darker shade than is the Hautville, and is very fossiliferous. Its use in Boston is very limited.
French Griotte. The French Griotte marble, named owing to its brilliant red color, from griotte cherry, (Voilet, Les Marbes etc. Ropports sur L'Exposition Universelle 1878 xxvii, p, 15, quoted from Menett p 210) is composed of many (egg-shaped concretions in a red ground mass. The color is uniform.

Verte Campan. France. The verte campan marble is a greenish gray marble, composed, like the griotte, of large grayish concretions in a ground mass of the same color. Its appearance, however is very variable, and no two specimens are said to be alike. The wide difference between the verte campan in the Parker House, and that at the entrance of the Gordon Bldg. on Bedford St., will illustrate its variability.

Rouge Antique. Rouge Antique is the name given to the massive red marble, crossed by occasional narrow, white veinlets of calcite, which is used in the doorways of the delivery room in the Public Library.

Verde Antique. The verde antique from France was described among the exterior marbles. It has behaved well in doors.

Belgian Black. The Belgian black marble is a jet black stone, and takes a very deep polish. It is, owing to its black color, used for the borders of floors and the bases of short columns, as in Bates Hall of the Public Library.

Alps Green(1) Is the green and gray, rather coarsely crystalline marble, used as the pedestal to the statue of John L. Bates in Bates Hall of the Public Library.
Yellow Sienna marble is quarried near Voltaire, Italy. Its color is a deep to light yellow, interwoven by varying amounts of veinlets of black oxide of manganese. It is exceedingly fine grained, and takes a very beautiful polish and is a very effective stone for interior work, a walk up the grand staircase of the Public Library will show the qualities of this stone. It is there so arranged that the percentage of black color increases with the ascent, until, at the top of the staircase, it constitutes nearly half of the stone. The adjacent slabs in this staircase were taken from the same block of stone, and are so laid, that the veinlets and streaks of black continue from one slab to the other, and increases the regularity and beauty of the stone as a whole. "The Sienna marble, is next to the white Statuario marble of Cararra, probably the most sought and widely known of the Italian marbles." (Menitt p, 210).

Yellow Verona marble from Italy is of very different appearance than the yellow Sienna. It is a coarse breccia, of a dark yellow color, and takes a dull polish. It is probably of Jurassic age, as is shown by the frequent occurrence of fossil ammonites, or large cephalopods. These fossils are very large and distinct in the stone used in the Public Library, often showing the successive whorls and septa. The red Verona is like the yellow in all respects except color, which is probably due to a higher percentage of ferric oxide.
Pavanazza Marble is a white marble full of black veinlets. It takes a glossy polish.

Numidian Marble from Africa is quarried in Algiers and Tunis. It is a breccia, varying in color from yellow, through pink to red, traversed by brownish veinlets of varying width. It takes a glossy polish, and is considered the best of all marbles. Its pink variety is especially beautiful.

Mexican Onyx. The onyx marble from Mexico has a translucent, pale green color, with parallel reddish bands traversing it. It is obtained in unusually large blocks for an onyx marble, some blocks having the dimensions 8' x 6' x 4'. It is used only for ornamental work, and especially for soda fountains.

There is a coarse breccia marble used in various places in Boston, which, as near as I can ascertain, is called the "breccia violet". It is usually of white and black fragments, with sometimes a tinge of violet or red color. It is used in the floor of the Main Hallway of the Public Library, and the front of the A. E. Conservatory of Music.
GRANITES.

There are several varieties of granite, but those used in Boston may be divided into six classes, depending upon the chief accessory mineral: the hornblende granites, hornblende-biotite granites, the muscovite granites, the muscovite-biotite granites, which include most of the colored and the epidote granites. The colored, or reddish granites in Boston buildings are of comparatively recent date, as are granites used as ornamental stone; but their use is steadily increasing. Granites are used for a greater variety of purposes than is any stone, and are employed in buildings, exterior and interior, columns, monuments, fountains, sidewalks, curbing and paving. As G. P. Merrill says, (Building Stones P 232) "There are, indeed, few stones fitted by nature for so wide an application. Ranging in colors from nearly white to dark gray, from the most delicate pink to deep red, from fine and evenly granular to coarsely porphyritic, the stone more nearly meets the universal need than any other stone that can be mentioned. It has well been called the noblest of rocks."

HORNBLENDE GRANITES.

QUINCY GRANITE. The Quincy granite is a medium to coarse hornblende granite. It is generally dark bluish
gray in color, but has sometimes a pale pink or reddish shade. This pink variety is found only near the surface, and can often be seen to shade into the blue variety at a moderate depth. The rock is composed of glassy, smoky quartz, orthoclase, plagioclase, and hornblende. A brittle pyroxene is also said to be present but I have never noticed it. The larger crystals of hornblende are often partially altered to chlorite. Microscopical study of the rock shows it to be full of minute lath shaped prisms of blue hornblende. These little crystals are included in the feldspars, and occasionally in the quartz, and form a fringe around the large hornblende crystals. It is this multitude of minute blue hornblendes that give to the Quincy granite its characteristic bluish color. The durability of Quincy granite is well proved by its present almost unaltered condition in the old stone buildings of Boston. Only one instance, King's Chapel, has been found in Boston where Quincy granite has scaled; and, when it is remembered that King's Chapel was built of stone taken from boulders that had lain on Quincy Common, exposed to the sun, rain, frost, and contact with the moist ground for upwards of ten thousand years previous to their use, it is not surprising that some disintegration has occurred. The only other defect noticeable in Quincy granite, besides the blackening from dust and smoke, is the pitted appearance due to the partial weathering out of some of the larger bornblende crystals, a fact particularly noticeable in St. Paul's Church, and Bunker Hill Monument. While this pitting in itself is not serious, still it gives a chance for the weather to act
on two or more sides of the feldspars, and may thus be a source of subsequent scaling. The crushing strength of Quincy granite, as given by Merrill, is 17,750 lbs. per square inch. Its component minerals are little affected by the atmosphere, only the hornblends showing any marked change, and the colored feldspars darkening somewhat after 80 years of exposure.

Its uniform texture and nonabsorptive qualities render it safe from mechanical weathering agencies. Although the top of Bunker Hill Monument moves every sunny day because of expansion from the sun's heat, in an ellipse whose major axis is three quarters of an inch, the monument today looks perfectly firm.

Quincy granite, for durable buildings, cannot be surpassed, except in color. The dark color of the stone, increased by the dust and smoke of the city, gives to buildings a particularly gloomy appearance. The stone is almost black on polished surfaces, and can be used to very good effect. It is very commonly used for monuments in cemeteries. Upwards of 162 buildings in Boston are built, wholly or in part, of Quincy granite.

St. George N. B. Red Granite. The only other hornblende granite used in Boston is the red medium grained granite from St. George, New Brunswink. It is redder than the other granites, being almost the shade of bricks. The red color is due to the feldspar, which is crowded full of little grains of ferric oxide, and is considerably decomposed. The principal constituents of the rock are red orthoclase, glassy quartz, and hornblende. This stone has been described as being "Tough and
compact, taking a brillaint polish", and " being apparently
durable". This description, however, is not well borne out
by the stone as it appears in the Bedford Building, at the corer
of Bedford and Lincoln Sts. Here the polish on the granite col-
umns is marred by the dropping out of hornblende crystals. There
is also one slight instance of scaling, or blistering. The gen-
eral red color of the stone is not so pleasing as is that of any
of the colored granites of New England. These defects, togeth-
er with the highly decomposed character of the rock as revealed
by the microscope, do not recommend it for use in Boston.

HORNBLENDE-BIOTITE GRANITES.

Cape Ann Granite. Cape Ann granite is the most important
of the hornblende - biotite granites that have been used
in Boston. It is medium to rather coarse in texture, and varies
in color from light gray, through different shades of green,
to almost black. The gray granite is quarried at Rockport and
Pigeon Cove, and sometimes has a slightly purplish tinge due to
fluorspar. The feldspar is much more abundant
than the quartz and hornblende, hence the light color. The
green varieties are quarried at Bay View and Lanesville. The
green color is caused by the orthoclase, which appears to have
a pale green substance, like chlorite, along their cleavage
planes. This green granite is probably more basic than the
gray, and lies near to an outcrop of typical diorite, or black
granite.
The constituent minerals are orthoclase, microcline, (oligoclase) plagioclase, hornblende, and black mica, which professors Dana and Cooke have shown to be lepidomelane or annite, (Text book of mineralogy page 313, Merill page 248), but which is described by J. P. Iddings as biotite. (Ed. S of Rock speci-men es, Page 178. Diller). Titanite, zircon, and magnetite crystals of microscopic size are also sparingly present.

The rock is hard and tough, fairly free from basic segre-gations or "knots", and to all appearances, is a durable stone. The granite in the Boston Post Office, with the exception of a part that suffered from the effects of the great fire of 1872, has lasted for 30 years without no signs of weathering. The outcrops on Cape Ann are considerably disintegrated, and are discolored sometimes to a depth of nearly 3 feet, where the rock is well exposed; but the exposed position of Cape Ann renders the rock subject to a very great amount post action, so that the crumbling surface of the ledges should not be re-garded too seriously. That there is considerable iron in the stone, is shown by the amount of band of stained rock along the seam or joints. This stained band is sometimes as much as five inches wide.

The crushing strength of Cape Ann granite ranges from 12,423 to 25, ... lbs. per square inch on bed, and averages 19,750 lbs. per square inch on edge. Its resistance to chemical and mechanical weathering agents is practically the same as is that of Quincy granite, which it closely resembles in texture. Its color is not so gloomy as is that of Quincy.
granite, and, for that reason, it may be considered preferable to Quincy granite for use in buildings. It takes a very good polish. The Boston Post Office, the Boston Water-Works, the St. Vincent de Paul church, the Subway entrances, the inclines to the Elevated Road, the foundations of the new West Boston Bridge, and 40 or 50 buildings in Boston are built of Cape Ann granite. (Largest quarries next to Vinal Haven).

CHEMICAL ANALYSIS OF ROCKPORT GRANITE.

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si O₂</td>
<td>77.61 %</td>
</tr>
<tr>
<td>Ti O₂</td>
<td>0.25</td>
</tr>
<tr>
<td>Al₂ O₃</td>
<td>11.25</td>
</tr>
<tr>
<td>Fe₂ O₃</td>
<td>0.55</td>
</tr>
<tr>
<td>Fe O</td>
<td>0.85</td>
</tr>
<tr>
<td>Mn O</td>
<td>trace</td>
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<tr>
<td>Mg O</td>
<td>trace</td>
</tr>
<tr>
<td>Ca O</td>
<td>0.31</td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.80</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.48</td>
</tr>
<tr>
<td>H₂O (110⁰)</td>
<td>trace</td>
</tr>
<tr>
<td>H₂O (ignition)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

99.85
The Vinal Haven Granite. The only record of use in Boston of Vinal Haven granite was at the corner of Bedford and Kings-
ton Sts., and that building has, in late years, been replaced, so the best that I can do is to quote from the descriptions of G. P. Merrill and J. P. Iddings. "At Vinal Haven, or Fox Is-
land, in Penobscot Bay, are the most extensive quarries at pre-
sent (1897) in operation in this country. Their capabilities can best be illustrated by stating that during a visit of the writer to these quarries in the summer of 1883, he was shown the remains of a huge block of granite 300 feet long, 20 feet wide, and varying from 6 to 10 feet in thickness, that had been loosened from the quarry in a single piece. The largest block ever quarried and dressed was the Gen. Wood monument, now in Troy, New York, which measured, when finished, 60 feet in height by 5 1/2 feet square at the base, or only 6 feet 7 in-
ches shorter than the Egyptian obelisk now in Central Park.

"In texture the Vinal Haven rock is rather coarse and the general color gray, although the prevailing feldspar is som-
times of a light flesh color. It takes a good and lasting pol-
ish, and is well adapted for all manner of ornamental work and general building purposes. The stone has been used so extensive-
ly, all over the country, that to cite special cases seems su-
perfluous". (Bldg. Stones, pp. 240-241). It would seem, from this last statement, that there must be a few instances of its use in Boston, but I have been unable to find any.

J. P. Iddings says of the Vinalhaven granite (Ed. Series of Rock Specimens, p 178): "It is medium grained and light col-

-88-
ored, and consists of pinkish gray feldspars and about an equal amount of brownish quartz, besides a smaller quantity of black ferromagnesian minerals, mostly biotite, but partly hornblende. These dark colored constituents are in much smaller crystals than the feldspars". He further states that the large feldspars are mostly microcline, intergrown with a lime-soda feldspar, probably oligoclase. The feldspars have in part altered to muscovite and kaolin. The quartz exhibits the characters commonly found in the quartz in granite. Biotite occurs in irregularly shaped plates. It incloses numerous crystals of colorless apatite and fewer of zircon and magnetite. Hornblende is in smaller amount than biotite and occurs in irregular anhedrons. Biotite and hornblende are sometimes grown together. They are both quite fresh and unaltered. Sphene, or titanite, occurs associated with the hornblende. This granite, from descriptions, seems to be a very durable and well appearing stone.

Hurricane Island Granite. The Hurricane Island granite is said to resemble that from Vinalhaven, and so needs no detailed description here. Hurricane Island is only three miles distant from Vinalhaven, and probably belongs to the same formation. The Hurricane Island granite also resembles that from Milford, Mass. at a short distance; but it is found on close inspection, to have glassy quartz and evenly distributed hornblende crystals, neither of which the Milford granite has. Hurricane Island granite, furthermore, shows no gneissoid structure, while in the Milford granite the gneissoid structur-
ure is very prominent. The Hurricane Island granite occurs at 
#60 State Street, and in the upper part of the new Court House 
in Pemberton Square.

MUSCOVITE GRANITES.

Westford, Mass. Granite. There is a belt of muscovite 
granite that extends from the vicinity of Chelmsford west to 
Boylston in northern Massachusetts. Granite in this belt was 
quarried at West Chelmsford at a very early date, and was ship-
ped by canal to Boston, in the early '80's. The old Congre-
gessional House at the corner of Beacon and Somerset Sts., was 
built of this granite in 1814. It is a fine to medium grained 
gneissoid granite, light gray, and sometimes pinkish in color. 
It is, as are all muscovite granites, a very acid rock, con-
sisting principally of feldspar, (probably microcline, orthoclase, 
and albite), quartz, muscovite, and occasionally a little biotite. 
Granites of considerable size are sometimes present. The mus-
covite is often in pretty large prismatic crystals, which does 
not appear to be a desirable quality. Micas absorb water very 
readily, swell, expand by their hydration, and work out of the 
rock on the surface, leaving it full of little pits, into which 
the rain can get and react upon the feldspar. This granite, 
although very durable chemically, being used for a tank to con-
tain muriatic acid, is badly scaled in several places, notably 
the Merchants' National Bank at the corner of State and Devon-
shire Sts. This scaling, as was previously stated, is explained by quarry owners as blistering due to rough tool work; but it is very evident that the older hornblende granite blocks, which must also have suffered the former rough methods of working, are not scaled at all. It is also noteworthy that all the granites containing white mica crystals, The Chelmsford and Westford stones are really durable stones, and should if properly laid on bed, not scale; but time will best prove whether or not this is the case by the behavior of the Westford granite in the more recent buildings in the vicinity, namely, the Registry of Deeds Building in East Cambridge, The Massachusetts General Hospital, and Hotel Lenox.

MUSCOVITE - BIOTITE GRANITES.

The Fitchburg Granite is a rather coarse coarse muscovite-biotite granite, any definite information about which I have not yet been able to obtain. It was used in the Fitchburg Depot on Causeway street in 1846. There the rough hewn stone is now considerably scaled, which scaling cannot possibly be attributed to blistering.

Monson Granite. The Monson Granite is a rather fine, gressoid granite, consisting principally of quartz and biotite and very deficient in feldspar as is shown by the abundance of garnets. Muscovite is present in variable amounts,
sometimes predominating, sometimes almost wholly lacking. There are three varieties of stone, the mottled, light gray, and bluish. Very large blocks are quarried, one block being 534 ft. long, 11 ft. wide, and 4 ft. deep. It has been shipped all over the country, as far west as Iowa. Owing to its lack of feldspar it does not possess very great cohesion, and should not be expected to stand much abrasion or to support very heavy weight in walks. Its abundance of mica renders it very liable to scale, especially if laid on edge, but if laid on bed, with not too great a superincumbent mass above it, it should last for a very long time. Chemically it is very durable. A chemical analysis of Monson granite is as follows:

Copy of analysis made at Watertown Arsenal in 1896.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>52.59</td>
</tr>
<tr>
<td>Ferric Oxide</td>
<td>14.55</td>
</tr>
<tr>
<td>Alumina</td>
<td>23.42</td>
</tr>
<tr>
<td>Lime</td>
<td>9.05</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.28</td>
</tr>
<tr>
<td>Manganous oxide</td>
<td>0.09</td>
</tr>
</tbody>
</table>

99.98
Concord, N. H. Granite. The Concord granite is well known both as a building and a monumental stone. It is a biotite-muscovite granite of medium to fine texture, and of light gray color. It is composed principally of feldspars, (orthoclase and oligoclase), glassy quartz, muscovite and biotite. The micas are usually evenly distributed in fine scales, and do not mar the polishing qualities of the stone. The rift and grain of this rock are very well developed, and the stone, if properly laid, should prove to be durable; but, where laid on edge, or with rift vertical, it is very liable to scale, as is shown by the badly scaled stone in Boston City Hall.

Hallowell, Maine Granite. The granite from Hallowell, Me. is very similar to that from Concord, N. H. only finer grained. It is composed of orthoclase, microcline, plagioclase, quartz, biotite and muscovite. There are also minute needle-shaped crystals of apatite, scattering grains of iron ore, occasional garnets, and inclusions, probably of rutite in the quartz. The microcline occurs in rather large, sometimes rusted, crystals that inclose small, rounded grains of quartz. With this exception the texture is fine and uniform. The iron ore, as is usual with muscovite granites, seldom occurs. The Hallowell granite has so far proved a very desirable stone. The Soldier's Monument, built of Hallowell granite, has stood the sun, wind, and rain on Boston Common with no visible injury, except the coating of algae on its northern side. It shows, however, in some buildings an incipient scaling, which is not noticed unless looked for especially.
Troy, N. H. Granite. The Troy, N. H. granite is similar to the two preceding stones, but is very fine in texture. I know of but one instance of its use in Boston, so that its durability cannot be properly judged. It is used in the Devonshire building at the corner of State and Devonshire Streets. Where it has a smoothly finished surface, it is in good condition; but, on the rough hewn blocks, there is a tendency to scale. This scaling, however, may have been aided by cracks developed in the quarrying of the rock. The rock is so fine grained that an accurate determination of the principal minerals is practically impossible with the naked eye, and I have had no chance to study them with the microscope. The following analysis will give a fair idea of the constituents of the rock.

Chemical analysis made at the Worcester Polytechnic Institute.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>73.15%</td>
</tr>
<tr>
<td>Alumina &amp; Iron Oxide</td>
<td>17.04%</td>
</tr>
<tr>
<td>Lime</td>
<td>0.81%</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.30%</td>
</tr>
<tr>
<td>Potassium oxide</td>
<td>5.74%</td>
</tr>
<tr>
<td>Sodium oxide</td>
<td>2.05%</td>
</tr>
<tr>
<td>Loss and undetermined</td>
<td>0.91%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
BIOTITE GRANITE.

Frankfort, Me. There are two varieties of biotite granite quarried at Frankfort, Maine. One is fine and uniform grained, the other is coarse and porphyritic with large orthoclase crystals. It is the second variety that is used mostly in Boston. "The mica occurs in large flakes, which the microscope shows to be frequently pierced with small crystals of apatite. A part of the mica is greenish in color and contains a few small grains of epidote. An occasional flake of white mica was noticed in this rock, and there is present the usual sprinkling of magnetite granules, together with an occasional cube of pyrite." (Merrill, p. 240). I know of only one building built of this stone, namely, Gerrish Block at the corner of North and Blackstone Streets. Here the stone has generally lasted well for nearly 60 years, but some of the blocks have blistered slightly.

Somesville, Me. "At Somesville, on Somes Sound, near Southwest Harbor, Mt. Desert, is quarried a granite of rather coarse texture and of a slightly pinkish tinge, the color being due to the orthoclase which is often present in crystals of such size as to give the rock a slight porphyritic structure. This stone was used in the arches and foundations of the new bridges in Back Bay Park in Boston." (Merrill, pp. 238-239)
Jonesboro and Jonesport, Me. The Jonesboro and the "Moos- 
abec" from Jonesport are red biotite granites generally of a 
coarse texture. They consist principally of red or pink and 
creamy white feldspars, smoky quartz, and a few small shreds 
of mica. The mica is of a greenish color, and is evenly dis- 
seminated through the rock, bearing numerous inclusions of 
magnetite. A few small apatite crystals are present, occa- 
sionally visible to the naked eye, but usually microscopic in 
size. The lack of mica in large crystals enables the rock to 
take a high, lasting polish. The combination of colors 
brought about by the red and white feldspars and the smoky 
quartz is very pleasing, and makes this granite one of the 
prettiest, if not the prettiest in use. There is no need of 
importing granites from Scotland when such granites as these 
can be had in New England.

The Jonesboro granite is used for many of the bases of 
statues in Boston and vicinity, and in a few buildings where 
it shows up to good effect.

The "Moosabec" granite, which is coarser than the Jonesboro 
contains many rather fine-grained segregations of diorite and 
small quantities of diorite can often be seen all through the 
stone. The very coarse texture of this stone does not recom- 
mend it for out-of-door use. Some rough blocks of it that had 
lain in the sun for a time at a stone yard at Cape Ann, were 
seen to be scaling on their tops and sides, a fact that should 
argue strongly against their use for exterior work in a moist 
and changeable climate like that of Boston.
Deer Isle Me. Granite. The granite from Deer Isle, Me., is a coarse, porphyritic granite, generally of a very pale pinkish color. The porphyritic crystals are of orthoclase, and sometimes reach a length of two to three inches. All the feldspars in the rock are large and possess prominent cleavage cracks into which water may find its way. The biotite crystals are of considerable size, and often occur in bunches. The structure of the rock is slightly gneissoid, with a few small pegmatitic veins. None of these properties of the stone are indicative of a very long life. In fact, many of the blocks, though only five years in use, show a dirty yellowish brown staining due to some alteration. Just what the alteration is, is uncertain.

Stonington, Me. The Stonington granite is also a coarse porphyritic granite, with large feldspar crystals attaining a length of two to three inches. The feldspars are mostly red or brownish red in color and are said to fade after considerable exposure. This fading, as near as I can ascertain, is really a turning of the red feldspar to a brown color, and is caused by the hydration of the ferric oxide by the water that works into the cleavage cracks and gliding planes of the crystal. The coarse texture, and variable size of the crystals of the different minerals, means that the stone must undergo considerable strain and consequent weakening, near the surface, from variations in temperature. The Stonington granite is shown to good effect in the Armory of the First Corps of Cadets on Columbus Avenue.
Wolfboro, N. H. Granite. The Wolfboro granite is not a prominent stone, and is not mentioned by G. P. Merrill in his book on Building Stones. It is a medium grained pink rock, of a not very striking appearance. It is used for the trimmings on the First Church of Christ on Falmouth St.

North Conway, N. H. The North Conway granite is a coarse to medium biotite granite of a green color, and, when polished, resembles very closely some of the Bay View granite from Cape Ann. The feldspars are rather large, and, close to, are light blue in color. The quartz is smoky and in glassy blebs. The biotite is in fair sized crystals, and is uniformly distributed. The stone is used to good effect in the monolith columns at the entrance to the Board of Trade Building on Broad Street, and to the Wakefield Building, #90 Canal Street.

Mount Ascutney, Vt. The granite from Mt. Ascutney, Vt. is dark green in color when polished. It is a basic granite, and might well be called a quartz diorite. It consists mainly of biotite, hornblende, with a few grains of labradorite feldspar, and an altered feldspar-magnesian silicate, quartz. In texture it is strikingly like the Bay View and Quincy granites, of which I have not yet ascertained, as I have seen only the polished surface of the stone. The green color is probably due to chlorite, a product of the alteration of the ferro-magnesian mineral. Only a few grains of quartz occur. The only instance of the use of Mt. Ascutney granite in Boston is on the exterior of Boston Journal Building.

Barre, Vt. Granite from Barre, Vt. is used to some extent in the cemeteries in and about Boston. It is a fine
grained biotite granite. It is almost always polished and is in good condition.

Milford, Mass. There is quarried at Milford, Mass. a coarse gneissoid granite, often known as Worcester Granite. It is light pink in color, but appears to be gray from a short distance. It is composed of the following minerals: microcline, showing signs of decomposition; oligoclase; quartz in finely granular form; biotite often in distorted crystals of considerable size; and chlorite, in small irregular pieces, which has resulted from the alteration of the biotite. The abundance of microcline, the granular quartz, the drawn out appearance of much of the biotite, and the partial alteration of the biotite to chlorite, are all indicative of metamorphism by pressure. This fact suggests that the stone will suffer from weathering more quickly than if not subjected to pressure. The rather large size of the different minerals will cause considerable strain to be felt from alternations in temperature. The decomposed condition of the feldspar may promote further decomposition. The granular form of the quartz may give access to water. The large amounts of biotite in their drawn out and altered condition are very subject to hydration. It would seem, therefore, that the granite was not destined to as long a life as might be desired; but the stone has a very good appearance in buildings, and, with the exception of the alteration of biotite, has lasted well for twenty years. The rock when tested had a crushing strength of 20,883 lbs. per sq. in. A chemical analysis of the granite made at the School of Mines, Columbia College, is as follows:
Silica  76.07 per cent.
Alumina  12.67 "
Iron peroxide  2.00 "
Manganese oxide  0.03 "
Lime  0.85 "
Magnesia  0.10 "
Potash  4.71 "
Soda  3.37 "

99.80 "

Westerly, R. I. There are two varieties of biotite granite quarried at Westerly. One is a medium grained red granite, with numerous pegmatite veins; the other is a very fine pink granite that is a neodike in the medium grained granite. Both are colored only near the surface, that is above ground water. At a moderate depth they are both gray. The fine granite becomes colored very quickly when exposed. Fragments of stone in the quarry were colored on the surface. It would seem advisable, on account of this fact, to use only the colored granite; but the coloring proceeds uniformly, so that the appearance of the stone will not be marred by irregular blotches. The coloring is probably due to the oxidation of finely disseminated pyrite. The medium grained stone is used for buildings and somewhat for monuments. It occurs in the lower part of Trinity Church. The fine grained granite is used almost wholly for monumental work, as its high price prevents it from be-
ing used for buildings.

**Stony Creek.** A granite that is being used in Boston considerably at the present time, is the coarse red granite quarried at Stony Creek, in Branford, Connecticut. It is very irregular in texture, varying from a medium grained to a very coarse grained pegmatitic rock, with feldspars sometimes four inches long. The rock seems to be a whole series of small pegmatite veins running through a network of finer grained rock of the same composition. The rock is composed of large red microcline crystals, a little orthoclase, plagioclase, and biotite, which is sometimes scarce, and sometimes in segregations of considerable size. Magnetite and pyrite are also present in variable amounts. Small rust spots sometimes appear as a result of oxidation of the pyrite. The granite has only been used in Boston for a few years and is all in good conditions; but this stone, like all the coarse granites, may be subject to the darkening of the red feldspars by hydration, the opening of cleavage cracks, by alternation of temperatures, and the hydration of the mica, and cannot reasonably be expected to endure for a very great number of years for exterior work. The stone is very pretty, takes a good polish, and is very well suited for ornamental and monumental work, especially in the interior of buildings. The South Terminal Station shows the Stony Creek granite to very good advantage in its various uses. The stone when quarried is not decomposed, and has a very high crushing strength, 22,447 lbs. per sq.in. In spite of this high crushing strength two blocks have been ruptured by superincumbent pressure or shear-
ing, in the entrance of the Exchange Building, 53 State Street.

Chemical analysis is as follows:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
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</tr>
<tr>
<td>Alumina &amp; iron oxide</td>
<td>16.95</td>
</tr>
<tr>
<td>Lime</td>
<td>1.05</td>
</tr>
<tr>
<td>Magnesia</td>
<td>trace</td>
</tr>
<tr>
<td>Potassium oxide</td>
<td>8.15</td>
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<tr>
<td>Sodium oxide</td>
<td>0.90</td>
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<td>Loss &amp; undetermined</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.00</td>
</tr>
</tbody>
</table>
EPIDOTE GRANITE.

Dedham, Mass. The Dedham granite is a medium grained granite, consisting of microcline, orthoclase, oligoclase, quartz, hornblende, chlorite, epidote, and magnetite. Both the feldspars, which are pink in color, and the quartz are traversed by little stringers of epidote. The hornblende is rotted and full of magnetite. The chlorite is an alteration product of hornblende, and the epidote from the lime feldspars. The rock has, evidently undergone metamorphism and alteration. The twisted appearance of the feldspars indicate that pressure has acted upon the rock.

The pink feldspars and the green specks of epidote give the rock a pleasing color both in polished and rough-faced work, but a stone that has undergone so much alteration cannot be expected to endure for a very long time. It is used in Trinity Church and in the Brookline Town Hall.
SEAM-FACED GRANITE.

Weymouth, Mass. The granite quarried at Weymouth, is traversed by two systems of parallel joints. The rock surface along these joints, or seams, is very prettily colored in a variety of shades, and for this reason, the stone is used wholly as seam-faced granite. The seam-faced granite is not subject to the weathering of ordinary granites, as its surface, produced by the chemical action and alteration of thousands of years, cannot be altered any more. This altered surface, consisting as it does of kaolin, ferric oxide, and silica in a thick coating, acts as a protection to the rest of the stone. The color, furthermore, which is a more or less dark and rusty hue, cannot easily be spoiled by dust. This rock, as was the case with the Roxbury puddingstone, cannot well be improved upon for its especial use.

DIABASE.

Somerville, Mass. There is in Somerville, and also in Medford, an occurrence of coarse diabase, which has been used to some extent in buildings. The outcrops of this stone are very highly weathered, to a considerable depth, and have crumbled to a brown soil on the surface; but the stone has lasted almost perfectly in buildings for 60 years. The
diabase in St. John's Church in E. Cambridge, erected in 1842, is very fresh in appearance, save for the bleaching of some biotite grains. This evidence seems to indicate that chemical agents alone do not cut much figure in the weathering of building stone. In the outcrops, the water charged with CO$_2$ and organic acids can percolate through the rock unmolested for ages; but rain that falls on a building is soon evaporated, and can do no great amount of harm.

The Somerville diabase consists principally of plagioclase, feldspar, augite, biotite, and a few grains of olivine. The absence of quartz and the dense form of the rock make it more difficult to work than granite. Its color is more sombre than that of most granite, and probably for these reasons, it has not been extensively used. The Somerville quarry is no longer worked.

Other Rocks.

There are other rocks that have been used locally for rough work in the suburbs of Boston, such as diorites, mafic phyr, and felsites. The felsites, especially, are of very attractive colors, but these stones are all usually so thoroughly jointed that it is difficult to cut blocks of any size.
CONCLUSIONS.

The discussion of the various stones after the considerations of the various destructive agencies and the durability of stones in general, dependant upon their chemical and physical properties leads to the following conclusions.

1. **Chemical agents** alone have, with the exception of marbles, only very slightly effect upon building stone in general. Marbles show the effects of chemical action in 30 yrs.

2. **Mechanical agents** are the principal agents of destruction, varying in intensity with the character of the stone. Absorption and alternation of temperature are important, but frost has been most instrumental in the work of disintegration of building-stone.

3. **Superincumbent Pressure** should not cause the disruption of stones, if stones were properly selected and placed.

4. **Organic agents** have not produced any noticeable effects in Boston buildingstone save the discoloration from algae; they must help in the chemical action upon stones, but such action is found to be insignificant. Lichens on granites in cemeteries may have aided in the scaling of the stone.

5. Internal Elements of the stone. Minerals, such as pyrites, that are easily affected by weather are detrimental and should be avoided.

6. Abundance of mice has a weakening effect.

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7. Of the various cements, silica is best, calcium carbonate next, and ferric oxide the poorest. Clay is a weak cement, and when in concretion, easily weathers out, giving the stone a pitted appearance.

8. The finer and more homogeneous the texture, the less affected will the stone be by weathering agencies.

9. The more porous stones are most easily disintegrated, and should not be placed where they must receive much rain, and endure great variations of temperature. If properly placed they will avoid disintegration and discoloration from organic growth.

10. Hardness and toughness are important factors, especially with stones that endure great weight or much abrasion.

11. The thorough testing of buildingstone is a very complicated piece of work and is far from being perfect; so too much reliance should not be thrown upon any single test.

12. Selection of stone cannot be too carefully made. The seasoning of a stone and its position in a building are all important items and greatly influence the life of the stone. The scaling of brownstone is due mostly to improper placing of the stone, which has given frost a chance to do damage.

13. Roxbury puddingstone, though limited in use, is a very durable stone.

14. The coarse micaceous brownstones are not fit to be used in Boston.

15. Longmeadow brownstone has proved a durable stone.

16. The freestone has generally lasted well, but should
be laid with care; otherwise they may exfoliate.
17. Hudson River Bluestone has given entire satisfaction whenever it has been used.
18. Slate as building stone weathers well, but is of too gloomy a color.
19. Roofing slates in Boston as a whole have behaved well; some have discolored from the oxidation of pyrite and loss of carbon.
20. Indiana limestone has generally lasted well for 13 years.
21. Marbles, in general, have proved unsatisfactory for exterior work; for interior work they will last indefinitely, except where used as tiles and steps in much frequented buildings.
22. Of the granites, the gray hornblende granites have proved very durable. The granites containing muscovite are durable stones, but are liable to scale if not laid on bed. They are also liable to become pitted by the weathering out of large mica crystals. The biotite granites are generally inferior to the hornblende granites. The colored granites are mostly coarse, and although at present in good condition, do not promise to be so long
lived as the hornblende granites that have lasted satisfactorily for nearly one hundred years.