Credit Valley Brown Sandstone. Buildings of the Legislative Assembly, Toronto.

CANADA
DEPARTMENT OF MINES
MINES BRANCH
HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

REPORT

ON THE

Building and Ornamental Stones

OF

CANADA

VOL. I.

BY

WM. A. PARKS, B.A., PH.D.

OTTAWA
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ERRATA.

Page 61, line 13—For *divided by* read *divided into.*
" 63, " 8—For *0·002* read *·00002.*
" 63, " 11—For *0·0002* read *·00002.*
" 64, " 7 from bottom—Insert *in* before *a table.*
" 69, " 15—For *water* read *power.*
" 70, " 14—For *effected* read *affected.*
" 78, " 2 from bottom—For *2·75* read *4·95* and amend sentence accordingly.
" 104, " 8 from bottom—For *water* read *motor.*
" 128, " 6—For *calcerous* read *calcareous.*
" 180, " 23—For *punctuate* read *punctate.*
" 283, lines 21 and 25—For *Solway* read *Solvay.*
" 318, line 27—For *Haliburton* read *Hastings.*
" 337, " 18—For *ferrico* read *ferric.*

NOTE.—In addition to the above corrections there is one to be made on Fig. 20, page 293. In this instance the symbolic legend was omitted from the map. To remedy this, a special slip accompanies this sheet, gummed at one end, so that the reader can fix it on the map.

Building Stones of Canada—Vol. I.

LETTER OF TRANSMITTAL

Eugene Haanel, Ph.D.,
Director Mines Branch,
Department of Mines,
Canada.

Sir,—I have the honour to submit, herewith, Parts I and II of a Report on the Building and Ornamental Stones of Canada. Part I consists of a general introduction to the subject, and deals with the chemical, physical, and geological features of building stone, and the methods of quarrying, testing, and preparing stone for the market. Part II consists of a systematic description of the Building and Ornamental Stones occurring in that part of Ontario lying south of the Ottawa and the French rivers.

I have the honour to be, Sir,

Your obedient servant,

(Signed) **W. A. Parks.**

University of Toronto,
May 10, 1911.

AUTHOR'S PREFACE

The intention of the Director of the Mines Branch (Dr. Eugene Haanel), as expressed in his verbal instructions to the writer is, to issue a series of reports on the Building and Ornamental Stones of Canada. Each report is to deal with a certain section of the country, and they are to appear yearly, until, practically, all the commercial stones now being quarried in the Dominion have been described. The investigation orders were, that the report should be of a strictly economic character; geological and scientific information being introduced only when necessary for a clear understanding of the practical problems presented; hence it is to be distinctly understood that the work is not intended for the professional geologist, but rather as a summary of Canada's resources in building stone, and as a guide for the builder and quarry operator.

The systematic description of the geographical areas will be preceded by an introduction containing general information with regard to the quarrying, testing, and handling of stone. This information, as presented in Part I, may be obtained generally from text-books, and from different Government reports; it is not the intention, therefore, to make this part exhaustive, but only of sufficient length to render intelligible the subsequent reports on definite areas. The present volume comprises Part I, as defined above; and Part II, which contains a systematic description of the different building and ornamental stones occurring in that part of the Province of Ontario which lies south of the Ottawa and French rivers. While no attempt has been made to describe all the quarries in the Province, all the types of stone which have actually reached economic importance are included in this report.

The writer desires to express his sense of obligation to many gentlemen without whose assistance the preparation of the report would have been much more difficult; to the Director of Mines for clear instructions and kindly advice; and to all the quarry owners and operators—without a single exception—for hearty co-operation and assistance in the field; to the following members of the staff of the University of Toronto: Professor McGowan, Mr. J. B. Marshall, and other members of the staff of the Department of Mechanical Engineering in the University of Toronto, for the very careful determinations of crushing and transverse strength; Professors Ellis, Walker, McLennan, and Bain, for the loan of apparatus and for other assistance; Professor A. P. Coleman, for the excellent reproductions, in colour, of 45 typical Ontario stones, as well as for many valuable suggestions during the preparation of this report; and to Mr. Alex. McLean, of the Department of Geology, for valuable assistance in determining many of the physical properties of the stones examined. Owing to academic duties, this work of Mr. McLean had to be done at night, his willingness, therefore, to assist the writer, even to late hours, was very much appreciated.

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REPORT

ON THE

BUILDING AND ORNAMENTAL STONES

OF

CANADA

VOL. I.

Part I.

REPORT

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BUILDING AND ORNAMENTAL STONES

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Wm. A. Parks, B.A., Ph.D.

VOL. I.

PART I.

INTRODUCTORY.

STONES USED FOR BUILDING AND ORNAMENTAL PURPOSES: THEIR PROPERTIES, OCCURRENCE, USES, METHODS OF QUARRYING, AND TESTING.

CHAPTER I.

GENERAL DESCRIPTION OF THE CHIEF KINDS OF STONE USED FOR BUILDING AND DECORATION. THEIR ORIGIN AND MINERAL COMPOSITION, MANNER OF OCCURRENCE, VARIATIONS, AND CLASSIFICATION.

There is scarcely any variety of stone which may not be used for building purposes; cheapness and accessibility often outweigh all other considerations, and, in works of expediency, are the chief controlling factors. It is, therefore, manifest that any attempt to describe building stones in full, or to classify the various types, would lead to a treatise on rocks rather than to a general description of the materials usually employed. In a restricted and economic sense, however, the building stones fall into four groups which may be designated as:—

(1) Granite and its allies, the igneous rocks.
(2) Sandstones and related rocks.
(3) Limestone and related rocks.
(4) Slates.

By exceptional beauty, rarity, and adaptability many members of the above groups may pass over the indistinct line which divides building from ornamental stone. On the other hand, the so-called ornamental stones pass by a similar insensible gradation into gem stones. Ornamental stones therefore constitute a group, ill defined either scientifically or economically.

Of the more common decorative materials the following may be mentioned:—

Handsome varieties of granite and other igneous rocks.
The iridescent feldspars.
Sodalite and sodalite-bearing rock.
Serpentine and verde antique.
Handsome varieties of conglomerate and breccia.
Fossil limestone, marble, and "Mexican" onyx.
Vein stuff and varieties of silica as agate and amethyst.
Varieties of gypsum.

As these materials, whether used for building or ornamentation, are the product of natural processes it is advisable to consider them according to their origin. Not only is this advisable for scientific reasons, but also from a purely economic standpoint; for the structure, grain and composition of these materials as well as their method of quarrying stand in direct relation to the mode of origin.

The first group of substances consists of those which have resulted from the consolidation of molten matter from the interior of the earth. Here belong granite and its allies the igneous rocks.

The second class of materials comprises those laid down in water, those derived from the decay of older rocks and deposited on the floor of the sea, *e.g.*, sandstone, limestone, conglomerate, and gypsum.

The third class consists of rocks of either of the above methods of origin which have been subjected to such severe alteration since their formation that the chemical and physical character is much changed. Here may be included gneiss, marble, slate, and serpentine.

A fourth class of materials consists of those which fill cavities in rocks, and which have been formed at a later date than the rock itself. Such deposits are of limited extent and comprise vein-filling material, agate, amethyst, and cave onyx together with a long list of rarer substances.

To these four rather distinct classes may be added a fifth for the reception of a few rare miscellaneous materials.

MINERALS AND ROCKS WHICH HAVE ORIGINATED FROM MOLTEN MATTER.

A molten mass of material from the interior of the earth solidifies on cooling and this solidification takes place in one of two ways. In the first case, the matter may cool like molten glass into a homogeneous mass; in the second case, it may *crystalize* giving rise to distinct *minerals.* The resulting rock may consist wholly of minerals, or of minerals imbedded in glass or entirely of glass. The character of a rock in this respect is, in a general way, related to the conditions under which it is cooled. If the consolidation took place deep in the earth, the rock is composed wholly of minerals; if the cooling was effected on the surface of the earth, as in a lava stream, there would be a strong tendency to consolidate as glass. Those rocks showing both minerals and glass represent modes of cooling intermediate between the slow, deep-seated type and the free, quick consolidation of volcanic lavas. It is apparent that there can be no sharp distinction between these classes of rocks but that they gradate insensibly into one another.

The durability, hardness, weight and other important properties of the igneous rocks result from two sets of causes—first, the *minerals* of which they are composed, and second, the *structure* of the rock, *i.e.*, the manner in which the various constituents are set together.

Although a very large number of minerals are known, the great bulk of the igneous rocks is made up of not more than seven, to which must be added a few more of less importance. For a detailed description of these minerals the reader is referred to any standard text-book on mineralogy. The following account is designed to convey to the general reader a conception of these substances as they appear on freshly broken rock surfaces and is, as far as possible, divested of technicalities.

Every mineral, whether a constituent of the igneous rocks or not, is made up of certain definite chemical elements which vary only within narrow bounds. As the determination of this composition requires a chemical analysis, it cannot ordinarily be taken advantage of to identify a mineral. Nevertheless, a knowledge of this fixed composition is of great importance, as it enables one to judge of the probable rate of decay of a rock containing the mineral in question. Each mineral is also possessed of a definite shape—the crystal—which, in the hands of an expert, alone suffices for its determination. On broken rock surfaces, however, the various crystals are usually so crowded together that their crystal form is to be observed only in their angularity of outline. As an outcome of their crystallization, minerals may, or may not, be possessed of the property of breaking in certain definite directions and thus giving rise to flat surfaces on the fragments. This property is known as *cleavage* and is of great value in differentiating the minerals of the igneous rocks. The thin sheets of mica, for instance, are the result of the crystal of mica exhibiting the phenomenon of cleavage to a marked degree.

The *hardness* of a mineral also is taken advantage of for its determination. Some minerals may be abraded by the thumb-nail; others may be cut with varying degrees of facility by a knife; others have about the hardness of good steel or flint glass; while the rest are able to cut glass with more or less ease.

In order to determine minerals, many other physical properties are taken advantage of, such as colour, lustre, and specific gravity. In a rock, the latter means cannot conveniently be employed, and the two former are not of great advantage to the amateur, as the colour is often variable in the same mineral, and the lustre, *i.e.*, the manner of reflecting light, is only occasionally of advantage.

The minerals occurring in the common igneous rocks may be described under two heads:—

First—The *essential* minerals, forming the bulk of the rock.

Second—The *accessory* minerals, not essential to the rock and occurring in small and varying proportion.

The more important essential minerals of the igneous rocks are briefly described below:

Quartz.

Quartz is a crystallized form of dioxide of silicon, and is one of the commonest substances known. Besides being a constituent of many igneous rocks, it forms the bulk of common beach sand, as well as the solid sandstone rock.

Quartz is the hardest of the common minerals and will cut all of those referred to below. While quartz is normally colourless, like clear glass, it may be milky-white or tinged with various colours, as pink, grey, and blue, but it is seldom of a very dark hue. In the rock it usually appears as clear or lightly coloured crystals which are likely to be confused only with feldspar. From this mineral it is readily distinguished by the fact that the broken surface is irregular, while that of feldspar presents flat facets.

The superior hardness of quartz, as well as its resistance to decay, renders it a very permanent substance and it persists in almost unaltered form after the other minerals have disintegrated.

Quartz is an essential constituent of many igneous rocks, particularly of granite and porphyry. Its presence, in a proper amount, renders such a stone hard and permanent, but an excess causes difficulty in chiselling and consequently an increase in the cost of working.

Feldspar.

The feldspars constitute a group of minerals of similar, but not identical, composition. They are all complicated compounds of silicic acid with lime, soda and potash, and may be grouped into two divisions, based on the substance combined with the silicic acid. In one case this substance is potash, and in the other, soda or lime, or both soda and lime. The first type is called potash feldspar, or *orthoclase*, and the second, soda-lime feldspar, or *plagioclase*. This latter term is a comprehensive one and includes different varieties of feldspar in which the relative amounts of soda and lime vary.

Feldspar is hard enough to cut glass distinctly, but it is inferior to quartz in this respect. The colour is more commonly milk-white, but pink, grey, red, and other varieties are known. In the rock, feldspar appears as light coloured spots, usually of angular outline. It is more likely to be confused with quartz than with any of the other common constituents of igneous rocks. From this mineral it may be distinguished by its inferior hardness and by the fact that the broken crystals present flat surfaces, while quartz has an irregular fracture. On examining a number of the flat surfaces presented by broken feldspar crystals, they will be found to be quite smooth or to be marked by fine parallel lines; the smooth type is potash feldspar, or orthoclase, and the striated type is soda-lime feldspar, or plagioclase. Rocks containing quartz are more likely to present the former kind, while the darker coloured rocks, without quartz, usually contain the latter.

Owing to the ease with which feldspar cleaves, it is often filled with incipient cracks which allow the penetration of water, whereby decomposition is the more readily effected. In selecting a building stone it is very important to ascertain to what extent this decomposition has proceeded.

It sometimes happens that the feldspar crystals of a rock are so large or constitute so great a proportion of the whole mass, that the quarrying of the rock becomes an economic possibility purely on account of the feldspar which it contains. Most of the feldspar so quarried is used as a flux or in the porcelain industry, but the more beautiful varieties (the iridescent feldspars) are employed as decorative material; indeed, the finer examples may be classed as semi-precious stones. Pearly, opalescent, iridescent, and varicoloured varieties are known, among which might be mentioned sunstone, moonstone, labradorite, and perthite. A more extended account of those varieties which occur in Canada will be found in the chapters dealing with the localities of occurrence.

Nepheline.

This mineral approaches the feldspars in its chemical composition, but it forms a crystal of a very different shape. Although possessed of a cleavage, it does not show this property in the same perfection as the feldspars. While normally colourless, it may present many different hues. The hardness and the specific gravity of nepheline are likewise so close to those of feldspar that these properties cannot be employed for its identification. The best ready means for the determination of this mineral lies in the fact that the freshly broken surface has a resinous aspect, while quartz is glassy and feldspar stony, or sometimes pearly. A better method, if the means are available, is to boil a little of the powdered mineral in strong hydrochloric acid. Under this treatment nepheline turns to a jelly-like mass, while either quartz or feldspar remains in a granular condition.

Most treatises on building stones pay little or no attention to nepheline. In Canada, however, the mineral is of considerable importance, as it occurs in the rocks of more than one area.

Mica.

Chemically, mica is a complicated compound of silicic acid with several other substances, particularly potash, magnesia, and iron. According to the preponderance of these three elements we have three types of mica: potash mica, known as *muscovite*, magnesia mica or *phlogopite*, and iron mica or *biotite*. The micas are also designated as white mica, amber mica, and black mica respectively.

All the varieties are soft and may be easily cut by a knife. Mica crystals are six-sided and possess a remarkably strong tendency to cleave crosswise, thus giving rise to the familiar sheets. Even when the crystals are of small size, as is usually the case in the building stones, this property may be taken advantage of to determine the mineral. On abrasion with the point of a knife, the tendency to cleave exerts itself and the crystal may be easily picked out in small shining flakes. In the common rocks the white and the black varieties are more often encountered; they may be distinguished by the colour and by the pearly aspect of the flakes of the former.

Mica is a common constituent of rocks, particularly of granite, the colour of which is more or less controlled by the amount and character of the mica present.

The micas are not readily decomposed and flakes of mica are common in many sandstones, despite the severe treatment they have undergone in being torn from their original position, washed by water, and deposited in the sea. Biotite is more subject to decay than muscovite and, on long weathering, gives rise to a soft greenish mineral (chlorite). On account of its softness, its tendency to cleave, and its unsuitability to polishing, mica, if in large crystals, is not desirable in a stone intended for fine purposes. Rocks are known in which the mica crystals reach an extraordinary size, sometimes several feet in length; the rock is then quarried for its mica alone, which is split into sheets and used for many purposes. Among these purposes, that of decoration finds a minor place. For a full account of Canadian mica, the reader is referred to the Report on Mica (2nd edition), by Hugh S. de Schmidt, M.E., published by the Mines Branch of the Department of Mines.

Hornblende and Augite.

Hornblende is but one of a group of similar minerals known as *amphiboles*, but as it is by far the most common as a rock constituent, it will be first considered. Owing to the similarity of hornblende to another mineral (augite), the detailed description of both minerals is given together. As in the case of hornblende, augite is but the representative of a large group of minerals known as the *pyroxenes*.

Hornblende and augite are of practically the same composition, being complicated silicates of lime, magnesia, iron, and alumina. The colour is dark green, brown, or black. The hardness is somewhat variable; in certain examples it is about equal to glass in this respect, but it is usually a little, sometimes considerably greater. Both minerals form crystals which are often much longer than wide and they both have a tendency to cleave in two directions parallel to the long axis of the crystal. In hornblende these two directions are disposed at an angle of 125° to each other, but in augite, they meet at an angle of 90°. This difference in cleavage is the only simple way to distinguish between the two minerals. When broken, hornblende presents fragments with an acute angle (55°) and an obtuse angle (125°) while the cleavage fragments of augite are practically rectangular. On broken rock-surfaces, augite and hornblende appear as dark, angular, frequently elongated spots. On examining these spots, evidence of the distinctive cleavage may be observed, but, in fine grained rocks it is almost impossible to make the determination without the use of thin sections and a microscope. Augite and hornblende are likely to be confused only with biotite, but the latter mineral is easily differentiated by its inferior hardness and the ease with which it breaks into thin shining flakes.

Either or both of these minerals are common constituents of the darker and heavier varieties of igneous rocks (greenstone, trap) but they also occur, though more rarely, along with, or in place of mica, in the granite type of rock. Many rocks owe their individual peculiarity to the presence of other varieties of pyroxene or amphibole. The chief of these is a variety of pyroxene known as *hypersthene*, which may sometimes be identified by means of its bronze-like lustre.

Certain varieties of amphibole which possess a much lighter colour than hornblende are of importance in connexion with some of our decorative stones. Of these may be mentioned *tremolite*, which is almost white in colour and which occurs in long needle-like crystals in many of our crystalline limestones. *Actinolite* is a light green variety which also forms acicular crystals and which occurs in the crystalline limestone in the same manner as tremolite; it may also form blade-like crystals which sometimes arrange themselves in a radiating or star-like manner.

Olivine.

Olivine is analogous to the above minerals in its composition, but the crystal and the various other physical properties are different. It may best be distinguished by its olive green colour and its glassy aspect. Olivine may occur sparingly in the common greenstones but it is an essential constituent of several of the darkest and heaviest kinds of igneous rocks.

While the previously described minerals are to be regarded as essential in that they form a large part of the rocks in which they occur, the following substances are of less frequent occurrence and are to be regarded as *accessory* only.

Garnet.

Pink, red, brown, green, and other varieties of garnet are known; but it is usually the red or brown that occurs as an accessory mineral in many rocks. As garnet is a very hard and tough substance, with a not very pronounced cleavage, the broken crystals show an uneven and splintery surface; this feature, together with the colour and the resinous to glassy aspect, suffices for its determination. Many gneisses and other rocks in Canada contain a large amount of garnet, which adds to the beauty of the polished surface.

Pyrite.

Pyrite or iron pyrites is a compound of iron and sulphur which usually crystallizes in cubes of a bright yellow, metallic colour, whence its popular name of "fool's gold." The hardness is about the same as that of feldspar and it breaks with an irregular fracture without cleavage planes. The bright yellow, metallic colour is sufficient for the recognition of this mineral on rock surfaces.

Pyrite is the *bête noir* of building stone, as it decomposes easily, resulting in unsightly stains if the work is exposed to the weather. Its presence, in small quantity, is not prohibitive for inside construction; but for exteriors any appreciable amount is to be regarded with the gravest distrust.

Pyrite is a fairly common accessory constituent of rocks, not only of the igneous types, but of the other kinds as well.

Magnetite.

Magnetite is an oxide of iron and occurs in the igneous rocks as small, black, metallic-looking grains which are too hard to be cut by a knife. It may be distinguished from augite, hornblende, and biotite by its shining metallic lustre and by the fact that a small fragment, removed from the rock, is attracted by a magnet, to which it clings in the same way as a piece of iron.

Magnetite is a common accessory in rocks and is not desirable, as it slowly alters to a yellowish-brown substance which discolours the surrounding rock.

Hematite.

Hematite is another oxide of iron, of different percentage composition to magnetite, which mineral it resembles in its black and lustrous colour. Hematite may easily be distinguished from magnetite by the fact that, when abraded, it produces a red powder (streak), while the powder of magnetite is black like the mineral itself. On exposure hematite turns red and eventually brown. The decomposition which produces this appearance may eventually affect the whole crystal; but there is less tendency for the colour to run than in the case of magnetite.

Sodalite.

Sodalite is a rare constituent of the igneous rocks and would require no mention here, except for the fact that it occurs in one of the most beautiful decorative stones found in Canada.

The mineral presents grey, red, green, yellow, and blue tints; but it is the blue variety only that need be considered. Deeply coloured varieties, which are much prized, present an intense lavender blue, but lighter coloured examples occur in which the colour fades away to almost white. In composition, sodalite is a silicate of soda and aluminium in which some chlorine is present. The beautiful colour, together with the superior hardness, which is greater than that of glass or steel, renders it a valuable decorative material, whether occurring in small grains scattered through the rock or in sufficiently large masses to be employed by itself.

Chondrodite.

This mineral is of rare occurrence and requires mention only on account of its presence in some of our crystallized limestones. In this connexion it cannot be regarded as a constituent of igneous rocks, but it seems better to include it here. Chondrodite is a complicated silicate and appears in small yellowish dots in the rock in question. As the mineral is durable and not liable to cause stains, its presence is not to be regarded too seriously.

The incompleteness of this list of minerals, and its restriction to the very commonest only may be judged by the fact that G. P. Merrill mentions 34 minerals as common constituents of granite alone.[1]

As already indicated, an igneous rock is formed from molten matter which has consolidated either into minerals or into glass or both. Many classifications of a more or less satisfactory nature have been devised; but as all sorts of gradations are known to exist between the various types, it is proposed to describe the more common varieties employed as building stone without any attempt at classification.

Granite.

The term "granite" has been used in various senses and has been made to include many different stones; it has even been considered as synonymous with "igneous rock." A common usage with quarrymen is to make granite include all the lighter coloured types and to use the word "greenstone" for the rest. This loose use of the term is very ill-advised, as granite is a rock possessed of distinct characteristics which may easily be defined.

As already pointed out, the physical character of a rock, as well as its economic possibilities, depends on two things—its mineral constituents and its structure. It is natural therefore that these same two criteria should form the basis of the nomenclature, especially as they are almost in accord with the mode of origin of the rock.

In a typical granite the constituent minerals are quartz, orthoclase and mica; the first two are always present, while the mica, which may be either biotite or muscovite, is frequently replaced by augite or hornblende, more commonly the latter. In this way different varieties of granite arise which are known as biotite-granite, muscovite-granite, augite-granite, and hornblende-granite according to the mineral associated with the quartz and orthoclase. With regard to its structure, granite is composed entirely of minerals; there is no glass or uncrystallized material between the constituent grains. Further, the various minerals are of approximately the same size; a glance at the polished surface gives one the familiar "pepper and salt" impression so that the eye does not select any individual spot as particularly conspicuous. So characteristic is this even-grained structure that it has been designated "granitic structure," and is applied to other rocks than granite which present a similar appearance. The foregoing description of the mineral composition and structure of granite takes no account of the relative size or number of the component crystals. Variations in the size of the grains produce granites varying from extremely coarse examples with crystals of an inch or more in length down to those in which the constituent grains are of microscopic size. While the orthoclase is always present in considerable amount, both the quartz and the dark minerals may vary down to almost

[1] Report on the Building Stones of the United States, 10th Census of the United States, p. 16.

nothing. By the total failure of any of the constituents we pass into rocks which have received other designations than "granite."

"Three grades of texture of this sort may be distinguished:

Coarse, in which the feldspars generally measure over 1 cm.; *medium*, in which they measure under 1 cm. (two-fifth inch) and over 0·5 cm. (one-fifth inch); *fine*, in which they measure under 0·5 cm. In some coarse granites the feldspars measure one or several inches, and in some fine grained ones, all the particles range from 0·25 mm. to 1 mm. (one twenty-fifth inch) in diameter, and some average as low as 0·5 mm. (one-fiftieth inch). Extremely fine ones average 0·175 mm., or about seven one-thousandths inch."[1]

As the different minerals possess different colours, it is apparent that the relative amounts of these minerals is an important factor in determining the colour of the rock as a whole. More important still is the actual colour of the minerals themselves, which we have seen to be extremely variable. The quartz is usually colourless or white; but it often presents light tints of blue or red. While many different colours may be presented by the orthoclase, the most common are white and red. Granites are usually classified as grey or red, but a whole series might be selected ranging from almost white to a deep bright red. The lightest of the grey granites have a preponderance of white feldspar associated with muscovite; by a diminution of the amount of orthoclase and the substitution of increasing amounts of biotite, hornblende or augite for the muscovite the rock gradates into a dark grey granite. The bright red stones have a preponderance of red orthoclase in fair sized grains. With small feldspar individuals and an increase in the amount of biotite, etc., granites of a dull red colour result.

In addition to the essential minerals, granites are prone to contain accessory constituents such as garnet, pyrite, magnetite, hematite, and many others not herein mentioned.

Syenite.

Like granite, this rock is composed of even-sized mineral crystals of which orthoclase is the most important. With the orthoclase is mica, hornblende, or augite, or any two of them, or, more rarely, all three. Quartz is never present, and this fact constitutes the only difference from granite proper, with which the present rock is often confused. Indeed the line of separation is difficult to draw, for although no quartz is present in a typical syenite, the occurrence of a little of that mineral would not cause the rock to be classified as a granite. This is but one instance of the manner in which igneous rocks fade into one another.

The syenites are usually distinguished by the name of the mineral which accompanies the orthoclase; thus we have mica-syenite, hornblende-syenite (syenite proper) and augite-syenite, just as we have the same three varieties of granite. Other kinds of syenites are known which receive their distinctive

[1] T. Nelson Dale, The Granites of Maine, U.G.S. Bull. 313, p. 20.

name from some unusual constituent which is present; the only one of these worthy of mention in this connexion is nepheline-syenite, so called from the presence of considerable of that mineral in its composition. Very handsome examples of this rock are known to occur in the Province of Ontario.

As a rule the syenites are somewhat darker rocks than the granites, and they present great variations in colour according to the tint of the feldspar and its proportion with respect to the other constituents. Red and grey varieties are common, but blue, green, and varicoloured examples are not unknown. Some of the finer varieties of syenite present, on the polished surface, beautiful iridescent effects, which render them particularly desirable for ornamental purposes.

Detroite.

The variety of syenite in which part of the feldspar is replaced by nepheline has already been referred to as nepheline-syenite. In certain examples of this rock, the beautiful blue mineral sodalite is mingled with the other constituents; the variety thus produced is known as *detroïte.* The masses of sodalite are sometimes of sufficient size to be extracted for cutting into ornaments of different kinds. Even when the sodalite is in smaller patches, the polished surface of the rock, with its mottled blue and white effects, is very attractive and unique.

The township of Dungannon, in Ontario, has produced a considerable amount of this beautiful material; it is also known to occur on the Ice river in British Columbia, and at Montreal mountain, as well as in other places in Quebec.

The Porphyries.

The term "porphyry" was at first employed to designate all those igneous rocks in which certain of the crystals are conspicuously larger than the rest. Modern usage has, however, restricted the use of the word in a substantive sense; but the adjective "porphyritic" is still applied to all rocks in which some of the minerals are conspicuously larger than the rest.

Porphyry, in the narrow sense, is a rock of the same mineral composition as syenite, but differing in its structure. In syenite, the constituent minerals are approximately equal in size (granitic structure) but in porphyry some of the orthoclase crystals are relatively large and are imbedded in a mass of small crystals of orthoclase and mica, hornblende or augite (porphyritic structure). Besides the simple term "porphyry" the expressions "syenite-porphyry" and "quartzless-porphyry" are used to designate the same rock.

Syenite and porphyry are of identical mineral and chemical composition and differ only in structure; in fact the same molten mass which gives rise to a syenite when cooled slowly at great depths in the earth, will result in a porphyry if the consolidation has been effected in fissures through which the molten mass has endeavoured to escape to the exterior. Should the consolidation be delayed until the material has actually poured out on the surface, it will then take place very quickly, resulting in imperfect crystallization and the production of rocks characterized by the presence of more or less glassy matter (Trachyte).

Just as syenite, by the relative increase in size of some of its constituents gradates into porphyry, so granite on assuming a similar structure becomes quartz-porphyry or *granite-porphyry*. This rock presents relatively large quartz crystals or both quartz and orthoclase crystals imbedded in a fine grained groundmass of orthoclase and quartz with mica, hornblende or augite. The term "porphyritic granite" is applied to rocks intermediate between granite and quartz porphyry, *i.e.*, to rocks in which the difference in size between the large crystals and the small ones is not so conspicuous as in a true quartz porphyry. The origin of quartz porphyry is similar to that of porphyry proper. A magma of the proper chemical composition, cooled at great depths forms a granite; the same magma solidified in fissures in the earth's crust gives a quartz porphyry, and if allowed to escape to the exterior, results in rocks of a more or less glassy composition varying from *rhyolite* to *obsidian*.

Many of the porphyries, particularly those with large, bright-coloured porphyritic individuals imbedded in a darker ground mass, are of unusual beauty when polished and are much in demand for decorative purposes.

Greenstone.

The term "greenstone" has been applied to rocks of very different composition and structure and has no real significance. It will continue to be used, however, because it aptly describes a series of rocks presenting a dark green to black colour, the differentiation of which is often attended with considerable difficulty. With regard to the series as a whole, it is not easy to make any general remarks beyond the statement that they are darker, heavier, and tougher than those previously described. In composition they are all characterized by the practical absence of both quartz and orthoclase, although both of these minerals may occur sparingly in certain examples.

The dark and dull colour of the greenstones does not appeal to the architect, but they are nevertheless employed for architectural purposes where more desirable stone is not obtainable. The minerals which compose the greenstones are more prone to decay than those of the granite and syenitic series, which is an additional reason for their rejection. For certain purposes, as in the construction of macadam pavements, the greater toughness of greenstones renders it a desirable material. A brief description of the commoner greenstones follows:—

Diabase is an exceedingly common variety of greenstone and is composed of crystals of plagioclase and augite. The plagioclase crystals are much elongated and penetrate the crystals of augite. When the rock is coarse, this structure can be distinctly seen and even in the finer varieties it gives to the freshly broken surface the appearance of shining needles embedded in a groundmass. As fine grained examples are by far the more common, and as the plagioclase as well as the augite is often of a dark colour, these needle-like reflections from the broken surface are really the only ready means of determining the rock.

Gabbro is a rock of the same mineral composition as diabase but it lacks the peculiar structure described above. The constituent minerals are even-sized as in a granite or syenite, *i.e.*, its structure is granitic. The rock is habitually coarser than diabase and is more likely to present a distinctly granular appearance with a general tendency to a lighter colour.

Both diabase and gabbro are of deep-seated origin and occur in great irregular masses or in dykes and sills.

Diorite is a greenstone, very similar to gabbro in its structure but differing in its mineral composition, as it contains hornblende instead of augite.

Basalt is a rock of more variable structure, containing plagioclase, mica, hornblende or augite, as well as accessory minerals with a greater or less amount of glass. This rock is the volcanic equivalent of the gabbros and diabases, that is, it consolidated from a similar molten mass, but one which had found its way to the surface of the earth. Its rapid solidification under slight pressure did not allow of the escape of the volcanic gases, which accounts for the fact that basalt is frequently filled with round or almond-shaped cavities.

Andesite is the volcanic equivalent of diorite; its structure is similar to that of basalt, but its constituent minerals resemble those of diorite. The colour is usually lighter than that of basalt.

Pyroxenites are dark and heavy greenstones in which there is no feldspar; they are composed essentially of augite or some related mineral.

Peridotites are the darkest and heaviest of the igneous rocks, consisting chiefly of olivine with some pyroxenes, and frequently containing iron ore and garnet.

Porphyrite.

While there is no reason petrographically for removing porphyrite from the category of the greenstones, its general appearance justifies a separate position in a work of this sort.

The rock very closely resembles porphyry and differs only in the fact that the feldspar is plagioclase instead of orthoclase. While this difference may seem of little importance to the architect, it must be remembered that porphyrite is a much less durable stone than porphyry as the feldspar is usually in an advanced state of decay. The striations by which plagioclase is identified usually fail, but the dull white colour of the decomposing porphyritic crystals afford a means for the identification of the rock.

Porfido rosso and *porfido verde* of the ancients are famous examples of this stone.

Anorthosites.

Various rocks composed almost entirely of feldspar are usually grouped under this head.

MINERALS AND ROCKS OF THE SEDIMENTARY SERIES.

To this class of materials are ascribed all those deposits which have accumulated at the bottom of bodies of water. It is obvious that these materials must have been derived from the land surface and transported into the lakes and seas, either by solution in the water or by mechanical carriage in the rivers and streams. It is further obvious that any of the minerals which make up the igneous rocks may be removed on the decay of those rocks and thus go to make up the sedimentary series. So great however are the chances of decay and destruction in this process of transportation that it is only the most durable of the original minerals which are able to resist the destructive influences and to find a place in the stratified or sedimentary rocks in an unaltered condition. By far the most important of these is quartz, which is followed by feldspar, muscovite, biotite, augite, and hornblende in such rapidly decreasing proportion that the latter minerals are of rare occurrence only. Some of the accessory minerals of the igneous rocks are however very resistant, so that it is not uncommon to find garnet and magnetite as well as some of the rarer minerals in the sedimentary rocks.

The more or less complete decomposition of the original minerals of the igneous rocks results however in the formation of new minerals which go to make up the sedimentary series. Further, after the sedimentary rock is formed, other new minerals may originate by chemical changes within the rock.

Admitting the possibility at least of the occurrence of any of the original minerals of the igneous rocks in the sedimentaries, it is necessary to extend the list by the addition of a few more.

Calcite.

On the disintegration of an igneous mineral containing lime, that substance combines with the carbonic acid gas of the atmosphere, forming carbonate of lime, which is sufficiently soluble in water to be removed by the rivers and eventually to be deposited on the floor of the ocean where it builds up beds of limestone.

The mineral *calcite* is crystallized carbonate of lime. It is considerably softer than steel and may be cut, though not readily, by an ordinary knife. The mineral is normally colourless, but almost every hue from white to black is known to occur. Clear or opaque-white is the most common colour of well crystallized calcite but pink and grey varieties occur in abundance. Calcite may easily be distinguished from quartz and feldspar by its inferior hardness, by the facility with which it cleaves into rhombohedral blocks, and by the fact that it effervesces violently if brought into contact with any of the strong acids. While the above description applies to the well crystallized varieties of calcite, it must be remembered that the mineral occurs in a great variety of ways, in some of which its crystalline character can scarcely be recognized even with the assistance of a microscope. In this form, it constitutes the bulk of the great beds of limestone as well as other deposits which will be referred to later. Calcite is of very common occurrence in mineral veins, and it even appears in the igneous rocks as a product of the decomposition of the original minerals.

Dolomite.

Dolomite is a carbonate of lime and magnesia and is very like calcite in many respects. The colour and hardness of the two minerals are alike, and even the crystallization, with its characteristic rhombohedral cleavage, will not serve to differentiate them. Unlike calcite, however, the present mineral does not effervesce with cold acid, but if the acid be hot a similar effervescence takes place.

Pure and well crystallized dolomite is not common, but the massive forms build up beds resembling those of limestone; it also forms the bulk of certain varieties of marble.

Gypsum.

This mineral is the sulphate of calcium combined with a fixed amount of water (20·9 per cent.); it is a very soft substance, being easily abraded by the thumb nail. When pure and well crystallized, it is clear and transparent, but it may be tinted with various colours as yellow, flesh-red and grey. The cleavage is pronounced so that a crystal may be split into thin sheets presenting a pearly to shining lustre. This well crystallized form is known as *selenite*, but the mineral occurs in massive and granular forms as well, in some cases building up extensive beds in the stratified series. The fine grained granular type is known as *alabaster*, which is employed for various ornamental purposes.

Kaolin.

On the decomposition of the feldspars, certain of the soluble parts are removed by circulating water, leaving a fine, white, plastic material, which is a silicate of aluminum combined with water. This substance is the mineral *kaolin*, which, together with other related minerals, forms the basis of all clays. The very pure varieties are used in the manufacture of porcelain; others are employed in the firebrick industry, while the very impure types, mixed with sand, lime and other materials, are adapted for the making of building brick. Kaolin is not only the basis of common clay but also of shale and slate.

As already pointed out, the sedimentary or stratified rocks result from the solidification of the masses of material borne into the sea; the more important varieties are described below:—

Sandstone.

The comminuted mineral particles, derived from the original igneous rocks, and washed down by streams into the ocean, build up layers of material which eventually become rock. In distributing these particles, the well known sorting power of water comes into play, whereby the sand-like grains are separated, on the one hand from the coarser fragments and on the other from the finer particles of kaolin. This separation is never very complete; on the contrary, there is built up on the ocean's floor a series of deposits gradating from gravel beds through sand beds into layers of clay. The sandy portion on consolidation becomes sandstone. The character of the sandstone will therefore depend on a great many factors, the chief of which are:

The mineral character of the component grains.

The size and shape of the grains.

The arrangement of the grains within the rock.

The nature of the cementing material which binds the grains together.

The minerals of the grains.—Particles of quartz are by far the most desirable constituents of sandstone; in fact, all the best building stones consist largely of this mineral. Feldspar is frequently present, indeed it is so common that some authors divide the sandstones into two groups—the feldspathic and the non-feldspathic stones. Highly feldspathic stones are not desirable as the mineral is always more or less decayed, rendering the stone very liable to crumble after being placed in the wall. It is not to be inferred that all feldspathic sandstones are unsuitable for building, or that the predominance of quartz will alone render a stone desirable. Some quartz sandstones are so hard that they cannot be economically worked, while some feldspathic varieties have such a satisfactory cementing material that the danger from the decomposition of the feldspar is much reduced. In these stones the increased facility of carving may more than compensate for the less durable character of the constituent grains. Mica, particularly muscovite, is often present in sandstones, and as the fragments have always the flake-like aspect characteristic of broken mica crystals, there is a tendency for the flakes to arrange themselves parallel to the bedding of the rock. In this way there may be developed a tendency for the stone to split parallel to its bedding.

Among the less frequent mineral grains found in sandstones may be mentioned, hornblende, chlorite, garnet, magnetite, and calcite.

The size and shape of the grains.—It is obvious that the constituent mineral grains may vary in size, thus giving rise to coarse and fine grained stones. If the particles have been much rolled by the water before consolidation, they will be globular in shape, while, if the attrition has been less, they will be sharp and angular. Other things being equal, sandstone with rounded grains is more easily worked than if the grains are angular; on the other hand, the interlocking of the angular grains renders the stone stronger. Always remembering the necessity of considering other factors, it may be stated that those stones in which the grains are angular and of different size possess the greatest strength.

The arrangement of the grains in the rock.—In the best sandstones the grains are arranged uniformly throughout the mass. Frequently, however, the coarser and finer particles and even the different minerals are arranged in layers, thus giving a striped appearance to the stone, together with a pronounced tendency to break parallel to the various sheets.

The nature of the cementing material.—Of equal if not of greater importance than the constituent grains themselves is the nature of the material by which the grains are bound together. This cementing material may be silica, carbonate of lime, oxide of iron, or clay. So important is this matrix that we are accustomed to speak of sandstones as siliceous, calcareous, ferruginous, or argillaceous according to the nature of the cement, without regard to the mineral character of the constituent grains.

Siliceous sandstones have the greatest strength, but they are frequently so hard that they cannot be chiselled except at prohibitive cost.

Calcareous sandstones are soft and may be worked with comparative ease; but the readiness of the cement to succumb to the influence of the weather renders such stones much less durable.

Ferruginous standstone has its particles cemented by oxide of iron and always presents a red or brown appearance. The stone is more permanent than the calcareous variety and is somewhat harder to work. In this latter respect a great difference is shown in specimens from different localities.

Argillaceous sandstones, with their clayey cement, present usually a dull and unattractive grey colour. They are liable to absorb water and consequently to disintegrate under the action of frost.

Sandstones may present little or no cement, the grains being held together by the pressure to which they have been subjected in the hardening of the stone. Such stones are extremely variable in their physical properties; some are so friable as to be useless, while others are so hard they cannot be profitably worked.

In colour, sandstones are extremely variable, ranging from almost white to dark brown. Grey, buff, drab, bluish, and greenish types are common, as well as the white and the red and brown varieties. The colour is not always uniform but may show variations in the different constituent layers, thus producing striped stone of different degrees of fineness. Mottled varieties occur in which the colour is distributed in a cloud-like manner, as in certain Medina sandstones from Grimsby, Ont.

Freestone is a name applied to sandstones of a homogeneous and uniform texture which cut with equal facility in all directions.

It is apparent from the statements made above that the adaptability of a sandstone to a given purpose can not be arrived at from a consideration of any one of the four factors mentioned. Keeping in view the purpose to which the stone is to be applied, one must carefully weigh the advantages and disadvantages of his proposed material under the headings given, and to this he must add the important consideration of cost.

Conglomerate.

Whereas the consolidation of a bed of sand results in the formation of sandstone, a gravel bar, similarly hardened, would become a conglomerate or pudding-stone. A conglomerate may therefore be regarded as a sandstone, in which some of the fragments are rounded and of considerable size. The cementing material may vary in the same way as in the sandstone, thus producing siliceous, calcareous, and other conglomerates. A very handsome variety of conglomerate, consisting of bright red jasper pebbles in a white matrix of silica (jasper conglomerate) is much prized as an ornamental stone.

Breccia.

This rock is very similar to conglomerate, but the larger component fragments, instead of being rounded, preserve their original angular outline. A famous example of this rock is Breccia di Verde, quarried in Egypt and much used for ornamental purposes in the south of Europe. Many rocks commonly classified under the rather vague term "marble" properly belong here, such as the beautiful ornamental material from Gragnano in Italy.

Clay and Shale.

As already indicated, clay consists of kaolin or some closely related mineral mixed with varying amounts of sand, lime, and other impurities. Beds of clay which have been hardened by time and pressure are known as shale. Although both these materials are extensively used in building, neither of them is employed to any extent without previous treatment and consequently they do not fall within the scope of this report.

Limestone.

Limestone is composed essentially of carbonate of lime which has been deposited on the floor of bodies of water and has subsequently hardened into rock. The precipitation of the lime may have been effected directly from the water or by the agency of animal or vegetable life, *i.e.*, the limestone is a chemical precipitate or it is composed of the shells and other hard parts of animals as well as the hardened tissue of certain plants. The first variety is sometimes called *chemical* or common *limestone* and the second *organic* or *fossiliferous* limestone. As both methods of formation may assist in building up the same rock, this distinction is of little real value, nevertheless the latter term may be applied with advantage to those limestones which are conspicuously full of fossil remains. Besides occurring in the two ways indicated above, carbonate of lime forms many other kinds of deposits which are often classified as varieties of limestone. It seems better, however, as we are here dealing with the sedimentary rocks only, to defer the description of these other forms of calcite.

Compact limestone is only occasionally pure carbonate of lime, in which case it has a high value for the manufacture of chemical products. The variations in the composition of limestone may be considered from two points of view, first, a chemical variation due to the substitution of magnesium carbonate or iron carbonate for part of the carbonate of lime, second, a mechanical variation due to the admixture of sand, clay, and other substances.

The substitution of a small amount of magnesia for a part of the lime makes a magnesian or dolomitic limestone, but if the magnesium carbonate reaches a percentage of 45·65 we have a true dolomite. This latter term is, however, applied to rocks in which the magnesia content is much below that figure—18 to 40 per cent according to Buckley. That author also states: "For scientific as well as practical reasons, it would be best, as far as possible, to distinguish limestone and dolomite as different kinds of rocks. If the rock is essentially pure calcium carbonate, it should be called a limestone. If the rock is essentially calcium-magnesium carbonate, it should be termed a dolomite. If the dolomite becomes important, but not predominant, the limestone should be known as dolomitic or magnesian limestone. If the percentage of calcium carbonate is less than that of the calcium magnesium carbonate, the rock should be called a calcareous dolomite."[1]

The substitution of carbonate of iron for part of the lime carbonate is of frequent occurrence and is very undesirable in a building stone, as the iron, in this condition, is easily oxidized with a consequent production of stains.

From the second point of view—that of mechanical admixture—limestones or dolomites present varieties which may be designated by the name of the preponderating impurity present. Thus we have clayey or argillaceous limestones, sandy or arenaceous limestones, ferruginous limestones, and bituminous limestones.

Any considerable amount of clay is not desirable in a limestone as it softens the rock and renders it more liable to disintegration. This effect is also dependent on the distribution of the clay in the rock and is less noticeable if the clay is evenly distributed than if it occurs in thin seams or in the form of irregular patches. A very fine grained, uniform. magnesian limestone, with a small amount of clay, is known as *lithographic limestone*, the best varieties of which are obtained in Bavaria. *Hydraulic limestone* is of variable composition but it usually contains a considerable percentage of clay; when burned it yields a cement capable of setting under water.

The admixture of sand with limestone may occur to any extent, so that we have all gradations between pure limestone and sandstone with just sufficient lime to cement the grains together. Many of these rocks make excellent building material, but they are liable to occur in thin beds which renders difficult the obtaining of dimension stone. Thin-bedded arenaceous limestones have been much employed for the making of flagstones.

Ferruginous limestones contain an appreciable amount of iron. As already stated, the iron may occur in the form of the carbonate, replacing part of the carbonate of lime; it may also be present in the form of oxides or sulphides. If in very fine grains and evenly distributed, the weathering of the iron-containing minerals may result only in a deepening of the tone of the rock; but if the ferruginous minerals, particularly pyrite or the closely

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[1] The Building and Ornamental Stones of Wisconsin, Wisconsin Geological Survey Bulletin, No. IV.

related mineral marcasite, are aggregated into spots, discolouration will result for the same reasons and in the same manner as in the case of the igneous rocks.

Bituminous limestones contain a varying amount of bitumen derived from the decay of organisms which were imbedded in the rock at the time of its formation. The stone is darkened by the presence of this matter, which may be recognized by its odor on freshly broken surfaces. Highly bituminous limestones are unsuitable for building, as dark stains on the surface result from its exposure to the weather.

Limestones, besides varying in the manner described above, present also different varieties of structure. The compact fine grained form may, by secondary crystallization, become filled with larger crystals of calcite, or may pass entirely into crystals, when it is known as crystalline limestone, which is commonly regarded as a metamorphic rock, and will, therefore, be considered under another head.

Some limestones, instead of being compact, have the lime carbonate aggregated into small spherules about the size of fish eggs and is, therefore, known as *oolitic limestone*. This rock is less durable than compact limestone, but it possesses the great advantage of being capable of fine carving. *Pisolitic limestone* is the name applied to a similar rock in which the spherules are as large as peas. Fossiliferous limestones are built up very largely of the shells or other parts of animals capable of extracting lime from the water of the seas or lakes. Different examples receive the name of the type of organism entombed; thus we have the *nummulitic limestone* of Egypt, *crinoidal limestone*, and many others. Some of these rocks take a fine polish and are accordingly known as *marbles*, but the proper usage of this term is by no means established. The so-called *Purbeck marble* is "composed of numerous shells of calcareous spar, embedded in a dark blue or compact greyish limestone, which takes a good polish."[1]

A rock so diversified as limestone must necessarily present many different colours. While grey and drab are the prevailing tints, yellow, blue, and green are of frequent occurrence. In selecting a limestone with respect to colour one must remember that a hue, not displeasing in a small specimen, may be far from attractive in the wall of a building.

Chalk.

Chalk is a soft form of limestone composed almost entirely of the shells of minute organisms. Although a very undesirable building material, its use for purposes of construction is not unknown.

Alabaster.

The fine granular variety of gypsum known as alabaster is the only form of that mineral used to any extent as a decorative material. Ornamental alabaster may be pure white or it may be clouded or veined with different

[1] Hull: The Building and Ornamental Stones, p. 117.

colours. Reddish and yellowish varieties are also known. The softness of alabaster and the ease with which it can be carved render it particularly suitable for the production of small statuettes and even articles of personal adornment.

ROCKS AND MINERALS OF METAMORPHIC ORIGIN.

Rocks of either igneous or sedimentary origin are often subjected to such severe treatment, in the long course of their geological history, that the original character is much altered. The folding and crushing of the earth's crust, the immense weight of overlying material, and the contact with hot molten rock from the interior may be mentioned among the numerous causes contributing to the change. Such altered rocks are said to be *metamorphosed* and the rocks themselves are referred to as *metamorphic.*

The original minerals of the rocks are sometimes decomposed, with the consequent production of new minerals, but, although the list of such minerals is not inconsiderable, it would be beyond the scope of this work to discuss the subject from this point of view.

Gneiss.

Gneiss is the metamorphic representative of the granites and consists of the same constituent minerals as that rock. The difference is one of structure rather than of composition, for the various minerals of a gneiss are arranged in parallel layers (laminated structure) instead of being uniformly scattered through the mass as in the case of granite (granitic structure). Just as granite varies in colour, texture, and mineral composition, so does gneiss. We have seen that an increase in size of certain minerals in a granite results in a porphyritic granite; in precisely the same way common gneiss may become porphyritic gneiss. The laminated structure which is characteristic of gneiss may have been induced by metamorphism in a rock which was originally a granite, or the gneiss may have been formed from a sedimentary rock by the most intense metamorphism. In this latter case the characteristic minerals were formed during the course of alteration.

Quartzite.

Siliceous sandstones, subjected to metamorphism, have the constituent grains pressed very closely together. The induration is further increased by the addition of secondary silica between the particles. A very hard and compact stone results, which is practically indestructible and is adapted for both building and decoration. Its extreme hardness makes it susceptible of a high polish but the cost of cutting is, of course, very great. One of the best known American examples is the pink and red variety from Sioux Falls in South Dakota.

Marble.

Although the term "marble" is frequently applied to handsome varieties of sedimentary limestone, particularly the fossiliferous examples, it seems advisable to restrict the name to the metamorphosed limestones—to those in which the crystalline structure has been induced by metamorphism. If a bed of limestone has been rendered crystalline in this manner it is customary to speak of it as crystalline limestone, and to further restrict the term "marble" to the fine grained varieties. The use of the term in the more general sense, as designating any kind of limestone capable of receiving a polish, is however so common that it will frequently be employed in that sense, although for purposes of classification the restricted meaning is preferable.

Marble, therefore, in the narrow sense, is a fine, even aggregate of calcite crystals which has been produced from ordinary limestone by the action of heat and pressure. When pure it is snow white and is known as statuary marble. The famous Parian and Pentellic marbles of ancient Greece, and the Carrara marble of Italy, are among the best known examples of this stone. Differences of texture can be detected in these white marbles as well as in commoner kinds. The chief of these peculiarities is the presence or absence of glistening reflections from the individual crystals. The very finest marbles are dull and therefore destitute of these glistening facets. On the other hand, the glistening marbles are admired for certain architectural purposes.

From the high grade of statuary marble down to the commonest kinds which are suitable for exterior work only, a whole series of varieties are recognized. In fact every marble district produces its own types, which are not directly comparable with those from other regions. As an example of the variability of the stone within a restricted area may be cited the fact that the Vermont Marble Co. recognizes twenty-two different grades of marble in the West Rutland quarries alone. The different coloured marbles sometimes present the different hues—pink, red, grey, blue, etc., throughout the mass. More often, however, the colouring material is disposed in a cloud-like manner through the stone. This arrangement of the colouring matter is due to the aggregation of the impurities originally present in the limestone and their conversion into new minerals by the process of metamorphism.

Marble is found only in regions which have been subjected to severe strain, in consequence of which the originally level beds of limestone have been bent and folded to such an extent that they are sometimes vertical instead of horizontal in position.

The Crystalline Schists.

The same process which produces a laminated gneiss from a massive granite will induce a similar structure in the other igneous rocks. These laminated or foliated rocks constitute a large and complicated group known as the *crystalline schists*. The commonest variety, which may be regarded as a typical example, is mica schist, which consists essentially of quartz and mica, and presents a strong lamination, in consequence of which it may easily be split into thin layers. The schists are sometimes used for flagstones and for curbing, but they are not employed to any extent as building material.

Slate.

Highly metamorphosed beds of shale which have been subjected to a strong lateral pressure become much hardened and at the same time acquire a tendency to cleave in a direction at right angles to the line of pressure. It should be clearly understood that the familiar sheets of slate are not the result of bedding planes but are consequent upon the development of "slaty cleavage" which takes place in a direction in no way related to the planes of stratification. Slate deposits are therefore always found "standing on edge;" they are usually of limited width, but may extend for many miles along the direction of cleavage. Green to grey varieties are by far the more common, but purple, red, and mottled slates are quarried to a considerable amount.

Serpentine.

By a process of metamorphism the minerals which compose the heaviest and darkest greenstones, such as the peridotites, are converted into a softer greenish or yellowish mineral known as serpentine. This alteration takes place on such a large scale that whole mountains are thus transformed. Serpentine has a greasy or wax-like aspect and is variable in hardness; very seldom, however, is it too hard to be abraded by a knife. Although sometimes of a uniform colour it is more often clouded and variable. It frequently happens, that in the alteration of the original rock, the resulting serpentine is filled with bands and veins of white calcite, in which case it is known as verde antique or ophiolite. This rock, as well as many of the clouded varieties and even the massive uniform kind, is a very desirable material for interior decoration and for the making of portable pedestals, clock cases, etc.

Talc and Soapstone.

Talc is a soft material easily cut by a knife. It usually presents shades of green, and, when well crystallized, has a bladed and lamellar structure. The more massive compact varieties are known as soapstone. In composition, these minerals are allied to serpentine, being hydrated silicates of magnesia. Like serpentine also, the origin of the present minerals is to be sought in the alteration of earlier rocks. They are found, therefore, only in highly metamorphosed regions, as along the chain of the Appalachian mountians. "Its softness, flexibility, and smoothness, in connexion with its resistance to high temperatures and acids, are the qualities which render it most useful. Being soft and sectile, it is easily sawed or carved into any shape, and is extensively used for washtubs, sanitary appliances, laboratory tanks and tables, electrical switchboards, hearthstones, mantels, fire-bricks, kiln linings, furnaces, cupolas, converters, gas burners, foot warmers, slate pencils, and 'crayons' for marking, iron, glass, and fabrics."[1]

[1] J. S. Diller, Mineral Resources of the United States, 1908, Vol. II, p. 869.

The purest and softest varieties are pulverized and used for toilet powder and other purposes. While normally white, talc frequently shows a green colour, and in certain instances presents a variegated aspect, owing to the presence of bands or clouds of different hues.

MINERALS OCCURRING IN DEPOSITS OF RESTRICTED EXTENT IN CAVITIES IN OLDER ROCKS.

The great dislocations of the earth's crust which have resulted in the upheaval of mountains and other extensive deformations have not been accomplished without fracturing the rock of which that crust is composed. The result is that numerous fissures have from time to time appeared. Underground water, also, percolating through the rocks, has gradually worn out passages, particularly in limestone, which in many cases have reached a sufficient size to receive the name of "caves." These openings, whether resulting from the one cause or the other, have, in many cases, been subsequently filled by material deposited from the water which necessarily finds its way into any openings in the rocks. Substances thus deposited are generally crystalline in structure and frequently make handsome ornamental material when polished. It is not uncommon for valuable minerals to form the whole or a part of such deposits, in which case we have the "veins" from which a considerable part of the world's supply of metals is derived.

The Onyx Marbles.

Rain water, on falling through the air, becomes slightly acidulated by the absorption of carbonic gas and is thus rendered capable of dissolving carbonate of lime from the limestone rocks. Surface water, therefore, which has found its way into interstices in limestone becomes charged with carbonate of lime in solution. Upon reaching any place, such as the interior of a cavern or an open fissure, where evaporation may take place, the water is no longer able to carry its full load of carbonate of lime and this substance is therefore deposited. The pendant stalactites on the roof of limestone caves, as well as the corresponding upwardly directed stalagmites, originate in this way by the dripping of calcareous water from the roof. The whole of the roof, floor and walls of a cave may, in this way, be covered with a deposit of calcite which eventually increases until the opening is entirely filled. The rock so produced is known as "cave onyx."

Hot spring water, forcing its way upwards, may in a similar manner dissolve limestone from the rocks encountered, and may, on cooling and on relief from pressure, deposit part of its load in a somewhat similar manner. It is probable, however, that the deposition takes place, in this instance, at the bottom of small pools rather than in caves as in the former case. The material thus produced is also known as onyx, but as it is of hot spring origin it might be distinguished as *travertine onyx*. It must be remembered that neither of these rocks is onyx proper, which is a very different material composed of silica. As applied to the substances under consideration, Merrill prefers to use the term "onyx" in an adjectival sense only and to speak of the rocks as *onyx marbles*.

These rocks consist essentially of carbonate of lime in a delicately crystallized condition. Originating as they do, from the slow deposition of material over the surface during growth, they always present a delicately banded appearance, which, combined with the translucency of the substance, constitutes their chief charm as decorative stones. Although normally white, these stones may be tinted with various colours, or they may be veined and mottled by the unequal distribution of the colouring matter or by the subsequent infiltration of colouring oxides along the lines of incipient cracks. The travertine variety is usually more compact than the cave deposit and it is more likely to be capable of economic exploitation. Further, the hot solutions which give rise to the travertines have a greater solvent power than the cold water of the cave deposits; in consequence, more colouring matter is dissolved and the resulting rock presents greater variation in its colour effects.

Onyx marble is one of the most highly prized and extensively used of the decorative stones. From the time of the Oriental monarchies down to the present day its use has been continuous for purposes of interior decoration and for the production of objects of art.

In this country, we are acquainted more particularly with the onyx marble quarried in Mexico and commonly known as Mexican onyx. Although some deposits are known in the United States, they have not been largely exploited and their commercial value is as yet unproved. The chief of the old world deposits are found in Algeria, Egypt, Persia, and Italy.

For a full account of this beautiful stone the reader is referred to "Stones for Building and Decoration," by G. P. Merrill, and to "The Onyx Marbles" by the same author. This latter work constitutes a part of The Annual Report of the United States National Museum for 1893. The short account here given has been derived from these sources.

Varieties of Silica.

Next to the onyx marbles the best known decorative materials occurring in the manner under discussion are varieties of silica (dioxide of silicon). Sometimes the silica is crystallized in the form of quartz, in other cases it is indistinctly crystalline, and still again it may be quite without crystal form and may contain a small amount of water.

Quartz. Cavities in rocks, whether lineal or not, are sometimes filled wholly or in part by crystalline silica in the form of quartz. Most frequently this quartz is dull white or of such a colour as to be useless for purposes of ornamentation. Occasionally, however, it is beautifully clear (rock crystal), pink, (rose quartz), smoky, (smoky quartz), yellow, (cairngorm stone), and amethystine (amethyst, but not the true or Oriental amethyst). A discussion of these substances would lead us from a consideration of decorative materials to a dissertation on gem stones; for often the individual crystals are of sufficient purity and beauty to be employed for personal adornment. Less perfect crystals, or crystal aggregates, either by themselves or mingled with other minerals, constitute a very handsome decorative material within the proper sense of the word. The vein-stuff from some of the old silver mines on the north shore of Lake Superior presents in places a mosaic of amethyst crystals imbedded in a matrix of clear quartz and other minerals. This rock when cut and polished is a very attractive and unique material.

Chalcedony. This stone probably consists of an intimate mixture of crystallized and amorphous silica. It has a milky white appearance and sometimes a bluish cast. The finest specimens are procured from Monte Verdi in Tuscany. Many varieties are known, the red being called carnelian, and the green *chrysoprase.* A light green variety is known as *plasma,* which when variegated by bright red spots of jasper, receives the name of *heliotrope* or *blood-stone.* The stones described below are of practically the same nature as chalcedony but are characterized by a banded appearance.

Jasper. Jasper is a cryptocrystalline variety of silica, coloured yellow, red, and brown by oxides of iron. It may be massive and of uniform colour or it may present stripes of red, yellow, and other tints (riband jasper). Egyptian jasper occurs in nodules in trap rocks and presents a concentric zonal structure in different colours. The origin of jasper is, in some cases, like that of agate, which it much resembles except for the fact of being opaque; in other cases, however, it has originated by the metamorphism of sedimentary beds. Certain of the altered sediments of Keewatin age, known as the "iron range" rocks, present bands of jasper alternating with iron ore and other rocks. This material, which has been called "jaspylite," has a possible use as a decorative stone; it will be referred to more fully when the ornamental stones of Northern Ontario are reviewed.

Agate, onyx, and sardonyx. Like chalcedony, these stones are varieties of silica, in part amorphous and in part crystalline. They all present a laminated appearance owing to the fact that they have been formed by slow deposition from siliceous water. Frequently the different laminae have a different colour and structure, and it is on this basis that the varieties are founded.

Agates usually occur filling almond-shaped cavities in greenstone of volcanic origin. They are used in making articles of personal adornment, and are occasionally of sufficient size to be cut into small objects for decorative purposes. The trappean rocks of Lake Superior, and of Digby in Nova Scotia, have yielded some excellent examples of agate.

Onyx and sardonyx instead of presenting curved layers as in agate have the different bands disposed in flat planes. The latter stone is distinguished by the possession of red bands (carnelian).

Malachite and Azurite.

These minerals are compounds of copper, carbonic acid and water. Malachite is bright green, and azurite azure blue to Berlin blue. They are both somewhat softer than glass and may be cut by a knife. The minerals are found either alone or associated with each other, the former being by far the more abundant. They both result from the decomposition of original copper ores, whereby the copper dissolved in water is redeposited in the form of carbonates. In consequence of this manner of origin the minerals present the same wavy and banded structure exhibited by onyx marble. When cut and polished the effect of the wavy and concentric structure, with the varying shades of green and the different degrees of translucency, is very striking.

The largest masses of malachite are procured from fissures in the Ural mountains at Nijni Tagilsk. The Burra-Burra mines near Adelaide in Australia have also produced excellent material. In small amounts it occurs in many copper mines, and both Hall and Merrill refer to its occurrence in America. The following description of a deposit in Arizona is given by Douglas D. Sterrett in The Report of the Mineral Resources of the United States for 1908: "This variety appears to be a badly altered, fine grained, white porphyry which has been brecciated, decomposed, partly silicified, and the seams filled in with azurite and malachite. Portions of this rock are soft, while parts which have been silicified are harder through the presence of much free quartz. The azurite and malachite occur in veinlets or seams and irregular masses through the rock. The veinlets range from paper thickness to an eighth of an inch thick and are very numerous in some specimens. . . . . . Brecciation of the rock and cementation by copper carbonates has been far reaching, so that some of the material has a marked speckled appearance."

Malachite, as a decorative material, is essentially Russian, and is largely employed in that country for the making of vases, clock cases, tables, fireplaces, and various small ornaments. (See Hall, Building and Ornamental Stones, p. 190.)

In general the substances filling mineral veins is of a distinctly crystalline character. The metallic minerals do not usually fill the whole of the available space but are associated with a considerable amount of barren matter known as "gangue." The gangues are often composed of several different minerals, which, together with the ore, are sometimes arranged in a particular way with respect to each other. In consequence of this, banded, brecciated, concretionary, and other varieties of structure are presented. Vein-stuff of this kind, particularly when the various minerals are differently coloured, may be worked up into ornamental material of a unique and valuable kind. Vein-stuffs from some of the silver mines of Lake Superior present filaments of native silver and threads and leaves of other silver ores imbedded in a gangue of white and pink calcite, the whole forming a very handsome decorative stone.

Rhodochrosite and rhodonite, the carbonate and silicate of manganese respectively, are pink minerals belonging to the present category of vein filling material. Although liable to fade on exposure, they have been employed to a small extent for decorative purposes.

Fluor spar or fluorite is a compound of calcium and fluorine. The mineral nearly always crystallizes in cubes in which there is a strong tendency for the corners to break off on account of cleavage planes being developed in that direction. The hardness is greater than that of calcite but less than that of quartz. The colour ranges from clear-colourless through shades of blue, green, yellow, and purple. Not only are different crystals differently coloured but the same crystal may show different tints in zones, so that cut and polished surfaces, whether of single crystals or of aggregates, present a very attractive appearance. Fluor spar may occur alone, or mixed with other minerals in veins as well as in cave deposits. The chief source of this material is Derbyshire in England, on which account it is sometimes referred to as Derbyshire spar.

Barite is a sulphate of barium and is known as heavy spar on account of its high specific gravity. While normally white and well crystallized, it may occur in the form of stalagmites or stalactites in cave deposits. In this form of occurrence it is frequently of a rich mahogany colour and presents wavy lines of growth as in all stalactitic deposits. It has a minor use in the making of small decorative objects.

Jade or Nephrite.

This mineral is essentially a form of amphibole related to hornblende, but as it represents, in all probability, a metamorphosed product from earlier minerals it is considered here. Its occurrence with talcose and serpentinized rocks in highly altered districts further supports this view. In composition, jade is a silicate of aluminium and soda, it is remarkably hard and tough and has been used from times of the most remote antiquity, particularly among the Chinese, for the manufacture of objects of art. In colour the stone varies from white to different shades of green, but is occasionally of different hue, a pale amethystine variety being much prized. Among the localities in which objects carved from this material have been found, G. P. Merrill mentions Brittany, Switzerland, Silesia, New Caledonia, New Zealand, China, Turkestan, Siberia, and Alaska.[1]

The Myitkyine district of Upper Burma produced jade to the value of £18,997 in 1907. A. W. G. Bleeck has thoroughly investigated these deposits and concludes that the jade arose from the alteration of rocks containing soda, feldspar, and nepheline.[2] In view of the occurrence of similar rocks in Ontario his observations are interesting.

Pyrophyllite and pinite are minerals very similar to talc in composition and in physical characters. Owing to their softness and smoothness of grain they are adapted for carving into small objects and have been employed for

[1] G. P. Merrill, Stones for Building and Decoration, p. 348.
[2] Rec. Geol. Sur., India, Vol. 36, Pt. 4, 1908, pp. 254–285.

that purpose by the Chinese. A compact variety, occurring at Deep River, N.C., has been extensively employed in the manufacture of slate pencils.

Lapis-lazuli.

Lapis-lazuli is a hard tough blue substance of a vitreous aspect. It is not of uniform composition and is not to be regarded as a distinct mineral but rather as a mixture of different substances. Although highly esteemed as an ornamental material, its excessive cost prohibits its use except for the most delicate purposes. The supply comes largely from Persia, Siberia, and China, and a company has recently been formed to exploit deposits in the Death Valley, San Bernardino county, California.

Turquoise in Matrix.

The beautiful blue gem stone, turquoise, does not properly fall within the scope of this work. Inferior varieties, however, and rock traversed by fine threads of the mineral, constitute decorative material of great value. The chief supply of the gem stone is obtained in Persia. While America has produced small amounts of good stone, the chief demand has been for the variegated matrix which is produced in Arizona, New Mexico, Nevada, and Colorado.

MISCELLANEOUS MATERIALS OF DIFFERENT ORIGIN.

Meerschaum.

In composition, meerschaum is closely related to talc, pyrophyllite and pinite. Its softness, smoothness, and exceedingly fine texture render it susceptible of very delicate carving. The mineral is extensively used, more particularly in Germany, for the production of small decorative objects.

Amber.

Amber is a fossilized vegetable resin. It can scarcely be called a gem stone and yet it is not commonly considered a decorative substance. In this country the only familiar use of amber is in pipe stems, but in Europe many small ornamental objects are carved from it.

Fossil Wood.

The trunks and limbs of trees belonging to past ages, have, in some cases, been converted into stone by the gradual replacement of the woody tissue by silica. So perfect has this process been that the rings of growth and even the actual cells of the original wood are shown in the petrified material. Owing to unequal distribution of colouring oxides, particularly iron, very beautiful variegated effects are produced. Fossil wood of this kind is as hard as quartz, is capable of receiving a high polish and is a very desirable decorative substance. By far the largest and most important deposits of this kind are the "petrified forests" of Arizona.

Volcanic Tuff.

Ashes and larger fragments (lapilli) ejected from volcanoes of recent activity, and cemented by lime, silica, and other material, is sometimes employed for building purposes.

Field Stones.

The loose stones so generously scattered over a large part of Canada and so universally used in the construction of foundations, and even dwelling houses and churches in rural districts, can not be ascribed to any particular type. A great many different kinds of stone may be obtained from among these loose pieces within a very limited district. All of these materials have been derived from the northward of the localities in which they are now found and have been borne to their present position by the action of ice.

At a comparatively recent date, geologically speaking, the climate of North America became so cold that great glaciers gathered in the mountains, and gradually increased until they covered the whole of Canada and the northern states of the Union. In their resistless march southward, these giant glaciers scoured the rocks over which they travelled, transported large pieces far to the south of their point of origin, and, on retreating before the breath of a more genial climate, left their burden of stones as well as vast masses of clay scattered over the face of the country. This geological event is known as the Ice Age or Glacial Period, and to it we owe not only our scattered building stone, but much of our rich agricultural land, as well as many of the geographical and topographical features of the country.

CHAPTER II.

Structural and Geological Features of Rocks which Affect their Use as Building Stone and their Method of Quarrying.

The smaller and rarer deposits, referred to previously as occurring in cavities, will not be considered for the purposes of the present chapter. The geological characteristics of such deposits are so variable that the method of exploitation must be worked out for each example. Many of these materials are *mined* rather than *quarried*, and it is not proposed, in the present work, to undertake a description of such operations. Observations of this character, when necessary, will be given in the description of individual occurrences.

The great bulk of our building stones is obtained from the igneous or from the sedimentary rocks, with a smaller amount from the metamorphic series. Each of these classes, while they have certain features in common, present structural phenomena of a different kind, and, in consequence, are best considered separately.

THE SEDIMENTARY ROCKS.

The *sedimentary* rocks are also referred to as the *stratified* series; the former name is given in consequence of their formation from sediments and the latter because these sediments are deposited in strata, layers, or beds. In the first place it must be remembered that these strata, whatever may be their present position, were originally horizontal. In the second place the various strata may be thick or thin, thus giving thick or heavily bedded, and thin bedded stone. Limestones, being formed farther out to sea, are more likely to be thick bedded than the other types. Alterations in the conditions of sedimentation are responsible for the occurrence of beds of sandstone, limestone, and shale in more or less quick succession; such deposits are said to be *interbedded.* Limestone interbedded with shale, or shale with sandstone are more likely to occur than sandstone with limestone. As each stratum or bed is derived from some point of origin, it is manifest that no layer can have a very great horizontal extent but must *thin out* and disappear sooner or later. By reason of their formation in deeper water and their deposition from matter held in solution, limestone beds are usually of greater extent than those of sandstone or shale. As the fine particles of clay which go to make up shales remain suspended in the water longer than the coarser grains of sand, beds of shale are likely to be of greater extent than those of sandstone. Breccias and conglomerates, necessarily formed near the shore, are usually of limited extent.

The various layers, whether thick or thin, are separated by planes of parting called the bedding planes. Stratified rocks naturally split most easily in this direction. The distance apart and the clean development of bedding planes is one of the most important features contributing to the value of a quarry. If the planes are too close together, the rock is thin bedded and the extraction of dimension stone is impossible. On the other hand, if the bedding planes are too far apart, the blocks of stone must be broken horizontally by artificial means, which adds materially to the cost of quarrying. We have previously considered the bedding planes as separating different kinds of rock, it is apparent, however, that the same kind of rock, *e.g.* sandstone, may be divided into beds in a similar way; indeed the whole mass of a layer may show evidence of bedding throughout, so that it possesses, at any level, a tendency to split parallel to its bedding, or, in other words, possesses a rift in that direction. The planes of parting are therefore merely well developed bedding planes, which may manifest themselves in a less pronounced manner throughout the thickness of a comparatively solid bed. Owing to the greater or less development of this minor stratification it is bad practise to lay up masonry with the stones "on edge;" as exfoliation is almost sure to result under the influence of the weather. The ease with which stratified rocks split parallel to the planes of bedding may not always be due to stratification. In some cases it is a secondary effect, produced probably by the great weight of the over-lying material; this kind of parting is known as "cleavage."

The drying and hardening of the stratified rock is accompanied by a shrinking which causes the bed to split vertically, usually in two directions approximately at right angles to each other. These partings are known as *joints*, which may be equally well developed in both directions, or one may be more pronounced than the other. The result of the development of jointing is to divide the beds into a series of roughly rectangular blocks. If the jointing is just right, it wonderfully assists the quarrying of dimension stone; if there is too much of it, the layer is rendered useless. In former days good jointing greatly enhanced the value of a quarry, as the blocks of stone could be removed, by its assistance, at a minimum cost. As the jointing planes are, however, never mathematically correct, the quarried blocks were only roughly rectangular and required to be dressed into shape. With the perfection of modern quarrying machinery, whereby the stone can be cut out in blocks with parallel faces, the presence of jointing is not so desirable. In fact, in the larger quarries, any jointing whatever is regarded with disfavour. Whether or not jointing is a desirable property must be determined by the quality of the stone, the purpose to which it is to be applied, and the scale on which it is proposed to carry on quarrying operations. If the purpose is to obtain stone on a small scale for local building, a reasonable amount of jointing will assist quarrying and enhance the value of the deposit; if, on the other hand, a fine grade of stone, properly bedded, is to be exploited on a large scale, jointing will detract from rather than add to the value of the quarry.

Although all beds of stone must have been level when originally deposited, they usually depart from that position. The angle which the bed makes with the horizontal is known as the *dip*. This departure from the original position has been caused by the bending and warping of the earth's crust whereby the beds have been forced out of their natural position and made to assume an inclination varying from a few degrees up to 90°. In some extreme cases, the beds have even been overturned. The compass direction along which an inclined bed cuts the horizontal is known as the *strike.* This line is necessarily at right angles to the direction of the dip. Thus, if a bed inclines 10° (or at any other angle) in a southwesterly direction, its upturned edge must come to the surface in a line running northwest. Of such a bed it is customary to say that its strike is northwest and its dip is 10° southwest. A clear understanding of these terms is necessary in order that we may conveniently put into words the position of any bed of rock. If beds of rock are horizontal, it is apparent that the top layer only can be seen, but if they are inclined one can see layer after layer by traversing the country in a direction at right angles to the strike. In *prospecting* for stone, therefore, inclined rocks present a great advantage; on the other hand, horizontal rocks, if the valuable layer happens to be at the top, are the most easily *exploited.* In this connexion it must be remembered that the upper layer of rock is very likely to be spoiled by the long ages during which it has been exposed to the weather. Frost and percolating water may have cracked, bleached or otherwise altered it beyond the possibility of economic use. Few indeed are the quarries that have produced good dimension stone from the surface.

Otherwise good stone is sometimes spoiled by the presence of *concretions, i.e.,* spherical or irregular aggregations of matter foreign to the stone, such as nodules of clay in limestone or sandstone. Large and cavernous fossils in a silicified condition render the stone cherty, hard to work, and of inferior appearance when dressed. Percolating water may soften, harden, bleach, or stain the rock through which it has passed. These, and many other points, as well as the intimate chemical and physical character of the rock itself must be carefully considered before deciding on the point at which a quarry is to be opened.

THE IGNEOUS ROCKS.

It has already been pointed out that igneous matter may cool under different conditions, giving rise to three types of rock; the first of these, represented typically by the granites, forms great irregular or lenticular masses deep down in the earth's crust. The second type, represented by the porphyries, occurs in sheet-like masses, filling fissures in the older rocks (dykes). The third class of igneous rocks comprises those which have consolidated after flowing out on the surface. It is apparent that the *form* of the deposits is different in the different types; other structural peculiarities are also shown by these different classes.

Taking granite as an example of the deep-seated type of rock, it is supposedly a uniform, homogeneous, and continuous mass. This conception must however be modified by the recognition of some features of great practical importance. Being of deep-seated origin, it is apparent that the occurrence of granite at the surface has been made possible only by the removal of a vast mass of overlying rock. It is generally found that granite exposures present a dome-like shape (bosses.) Where these domes have been for long ages exposed to the weather they are observed to exfoliate in concentric layers like the successive sheets of an onion. The Metoppos hills in Southern Rhodesia exhibit this phenomenon in an ideal manner. In Canada, this structure is not so easily observed owing to the great erosion of the Ice Age, but quarrying operations show that it is an almost universal attribute of granite rocks. The masses of granite are made up of a series of concentric sheets separated by well marked division planes. These sheets are analogous to the beds of the stratified rocks, but it is quite erroneous to term them "beds," as that expression is applied only to deposits of a sedimentary origin.

So important is this division of granite masses into layers or sheets that it has received much attention both from the scientific and economic point of view. Dale, in his work on the granites of Maine, has gone exhaustively into the subject. After giving the opinions of a large number of writers as to the cause of this peculiar and extremely useful property of granite masses, he sums up his observations on 100 granite quarries in Maine as follows:

"1. There is a general parallelism between the sheets and the rock surface, resulting in a wave-like joint structure and surface over large areas.

2. The sheets increase in thickness more or less gradually downward. In the coarse grained granites of Crotch and Hurricane islands the increase is abrupt.

3. The sheets are generally lenses, though in some places their form is obscure. Their thick and thin parts alternate vertically with one another. The joints that separate these superposed lenses, therefore undulate in such a way that only every other set is parallel.

4. On Crotch island the sheet structure extends to a depth of at least 140 feet from the surface.

5. There are indications here and there that the granite is under compressive strain, which tends to form vertical fissures or to expand the sheets so as to fill up small artificial fissures."

Dale's summary of the possible causes of the sheet structure is as follows:

"1. To expansion caused by solar heat after the exposure of the granite by erosion.

2. To contraction in the cooling of the granite while it was still under its load of sedimentary beds, the sheets being therefore approximately parallel to the original contact surface of the intrusive.

3. To expansive stress or tensile strain brought about by the diminution of the compressive stress in consequence of the removal of the overlying material.

4. To concentric weathering due to original texture or mineral composition.

5. To compressive strain akin to that which has operated in the folding of sedimentary beds.

6. To the cause named under 1 at the surface, but to the cause named under 5 lower down."

Jointing occurs in granite as well as in the sedimentary rocks; it results from a shrinking consequent upon the cooling of the mass rather than as a result of drying as in the sedimentary rocks. The joints of granite are often irregular, and, while they may doubtless be taken advantage of in quarrying the stone, they are not now considered so indispensable as in the days before the introduction of power machinery. The writer has been assured by large granite operators that they much prefer the stone to be as free as possible from vertical jointing. In any case excessive jointing, with irregular and frequently highly inclined planes, renders the extraction of dimension stone almost impossible.

Joints are sometimes so close together along certain zones in a granite mass that the rock is broken into small and useless blocks. Such a fractured zone is called a "heading." A heading appearing at the surface may abruptly disappear at a limited depth; while others not showing on the surface, may just as abruptly appear as quarrying operations are pushed to greater depths.

Not only are the rocks cut by joint planes, but the mass may have slipped along these planes, so that the portions on the two sides are displaced with regard to each other. In such cases a "fault" is said to have occurred. Faults are made evident, not only by the displacement of the rock, but by a grooving and polishing of the surface where the two sides have rubbed together (slickensides).

The granite for several inches on each side of a joint is frequently traversed by small cracks, either diverging from the main joint or lying parallel to it. Minor fractures of this character are called "sub-joints." The more pronounced joints, extending for considerable distances are known as "major-joints," while the shorter ones aie called "minor-joints." Frequently the two sets of joints correspond with the directions of strike and dip, and they are then known as "strike-joints," and "dip-joints" respectively.

The jointing of volcanic rocks usually expresses itself by a tendency to cleave into polygonal columns. This structure is excellently shown by the Giant's Causeway, it may also be well seen in the Palisades of the Hudson and in the trap rocks of Thunder Bay. The almost universal presence of this kind of jointing in trappean rocks, while it makes quarrying comparatively easy, renders difficult or impossible the extraction of large blocks.

While the sheet structure and jointing actually divide granite masses into blocks and thus facilitate quarrying, there exist also tendencies to split in certain directions which are of scarcely less importance. That direction in which the granite splits with the greatest facility is known as the "rift." A second direction, at right angles to the rift, permits of splitting with a degree of ease second only to that of the rift; this direction is the "grain" of the rock.

In the quarry, the rift is either approximately vertical or horizontal; in the latter case it is frequently parallel to the sheets. The fact that the rift is sometimes vertical and therefore at right angles to the sheets, and the observation that the rift sometimes crosses the sheeting planes at an acute angle, shows that there is no necessary connexion between the rift and the sheeting. In some cases the microscopic foliation which produces the tendency to split parallel to the flattened mineral constituents (rift) may be observed with the naked eye.

The grain is always disposed at right angles to the rift. As the rift represents that direction in which the minerals are *flattened* or *foliated*, the grain probably occurs in the direction in which these same constituents are *elongated* but always perpendicular to the planes of flattening. Dale states that in twenty-nine out of fifty-three quarries in Maine the rift is vertical, while twenty-four show horizontal rift and vertical grain.[1]

Rift and grain are not necessarily present in all granites; they may, one or both, be developed with varying degrees of distinctness, or they may be entirely absent.

The third direction at right angles to both rift and grain is known as the "head." Most granites are split in this direction only with the greatest difficulty, but certain rhyolites, according to Buckley, cleave in all three directions. To these the terms "rift," "run," and "head" are applied.[2]

Finally it must be noted that the homogeneous character of granite is sometimes obliterated by the presence of "flow structure" which causes a stretching out of the minerals in certain directions, resulting in an indistinct laminated appearance.

Between true granite and its metamorphic, laminated equivalent, gneiss, all sorts of gradations are known, which present with gradually increasing distinctness the characteristic structure of the latter rock.

As already shown, the magma which results in a granite may only in part consolidate under the typical conditions. Part of the same mass may find its way into fissures and may eventually form quartz-porphyry. Between the two typical rocks, transitions must occur, in consequence of which we sometimes find true granite in *dykes* and porphyritic granite in masses like common granite. These dykes, or lineal sheets of rock lying in fissures in the old rocks, may vary in size from almost microscopic dimensions to hundreds of feet in width and miles in length; they may stand vertically or they may dip at any angle.

All the structural features described for granite are shown in like degree by syenite; the deep-seated greenstones while generally similar, differ in some respects which need not be considered here.

The volcanic rocks being surface flows differ in many respects, the most striking peculiarity being the character of the jointing, which has already been referred to.

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[1] Granites of Maine, p. 28.
[2] Buckley, p. 460.

THE METAMORPHIC ROCKS.

The metamorphic rocks resulting as they do from the alteration of previously formed rocks either igneous or sedimentary, occur only in regions which have been subjected to great strain.

The gneisses and crystalline schists are the metamorphosed equivalents of the granites and other igneous rocks. The alteration has shown itself in the rearrangement of the mineral constituents so as to produce a banded, laminated, or schistose structure. In most cases the crumpling and folding of the earth's crust has so upturned and contorted the original rocks that the planes of the schistosity are usually tilted at high angles. Naturally the rock splits most easily in the direction of lamination but joints may cut the mass into blocks as in the other types of rock.

Marble, in the narrow sense, is limestone, rendered crystalline by metamorphic agencies. The deposits are usually of restricted width, but may extend for miles along the strike. The stone is usually associated with gneisses, clay slates and other altered rocks, as well as dykes of eruptives. Together with the beds with which the original limestone was interstratified, the marble is found dipping at high angles, curving and folding in accord with the mountain structure of the region. On opening a marble quarry this inclination must be carefully determined as it affects not only the method of extraction but the cost of production as quarrying operations are proceeded with. In marble quarries the original bedding planes of the limestone have been largely obliterated as planes of actual parting, nevertheless the least difference in the quality of the original stone is shown in the marble. In this way the bedding planes may be found and may be made use of to assist quarrying even when the actual parting has been sealed by the excessive alterations. Joints and fissures traverse marble as well as all other rocks. Here they are particularly undesirable as they permit percolating water to injure the quality of the stone, and their value, as aids to quarrying, is more than offset by the breaking of the marble into small or irregularly shaped blocks.

Slate deposits represent that part of an original bed which has been pinched and compressed along the line of most intense strain in the folding of the crust. Such lines usually run for considerable distances parallel to the chief axis of the mountain chains of the district. In consequence slate deposits are usually narrow but may have a long lineal extent. The tendency to break into sheets, to which slate owes its chief value, is manifested along the direction of the chief axis of the deposit. The cleavage planes stand vertically or at high angles, and are therefore virtually at right angles to the bedding planes of the original shale. This tendency to break into sheets is produced by the enormous pressure to which the rock has been subjected; it is a common property of matter to assume this structure when subjected to intense pressure, *i.e.*, it becomes cleavable in a direction perpendicular to the line on which the compressive forces act.

Slate deposits are frequently jointed and the joint planes usually run across the strike, that is, at right angles to the cleavage planes. In view of its method of formation, it is not surprising that the cleavability and consequent value of the slate varies greatly along the strike. At one point, the deposit may produce an excellent slate and a very short distance along the strike may be useless, owing either to imperfect cleave, excessive faulting, the development of cracks and fissures filled with quartz or other mineral, or to the presence of nodules of iron pyrites.

The friable nature of slate renders improbable the obtaining of good stock near the surface; the above mentioned variability along the strike should warn intending operators to make a careful examination of the slate belt before deciding on the location of a quarry.

CHAPTER III.

Chief Requisites of Building Stone and the Methods of Testing.

Structural stone is employed for so many diverse purposes that the characteristics which make a stone desirable necessarily vary with the nature of the structure to be erected. For instance, in the building of piers for railway bridges, strength and durability are far more important requisites than the uniformity of colour and the fineness of grain which render a stone particularly adaptable to architectural purposes. Further, a stone employed for interior decoration might admit of far less durability than would be demanded of material for outside construction. But, in most cases, such a stone would be expected to exhibit a greater beauty and a superior adaptability to fine chiselling.

While recognizing, therefore, that the requisites of a stone may vary greatly with the object to which it is to be applied, we may consider those features which generally determine the selection of a stone under the following heads:

(1) Strength.
(2) Colour.
(3) Durability.
(4) Cost of cutting.

(1) Strength.

It is apparent that in using a stone for any purpose one must select a material strong enough to resist the various pressures to which it is to be subjected in the building. A wide margin of safety must be allowed to meet the varying conditions and to provide for a deterioration in strength which may result from alterations in the stone after it is placed in the wall.

The minimum strength permissible in a stone destined for a given position can be determined only by a trained architect, or by one versed in the mathematics necessary for the calculations involved. There is plenty of evidence in cracked lintels and broken arches throughout the province, either that these determinations were not made at all or that they were disregarded in the selection of the stone.

In stone, as in other materials, strength is not a single fixed attribute, but may manifest itself in different ways. The resistance of material to compression is one kind of strength, while its resistance to a bending strain is another kind which does not stand in any necessary relation to the former. According to most authors the important kinds of strength in building stone are the following:

(a) Crushing strength—the resistance to compressive strain.
(b) Transverse strength—the resistance to forces tending to bend the stone.
(c) Elasticity.

Crushing strength. Each stone of a wall is subjected to a pressure represented by the weight of the overlying masonry and is therefore liable to be crushed if its resistance to this pressure is insufficient. The maximum pressure, stated in pounds per square inch, that a stone will stand is known as the crushing strength. Buckley states that the stone at the base of the Washington monument sustains a pressure of 314·6 lbs. per square inch, and that, in the tallest buildings, the maximum pressure at the base is not more than half of this or 157·3 lbs. per square inch. Assuming, as a wide factor of safety, that a stone should have twenty times this strength, a resistance of 3,146 lbs. per square inch will answer all requirements for ordinary buildings.[1] Watson says: "It is now generally agreed that a stone possessing a compressive strength of 600 lbs. per square inch, is sufficiently strong for all ordinary building purposes."[2] There is no stone quarried in the Province of Ontario that does not, in its compressive strength, far exceed these figures, even the more conservative estimate.

In "Stones for Building and Decoration" Merrill gives a long list of tests on American stone, from which the following summary is derived:—

	Maximum	Minimum	Average (roughly)
Granite, 100 tests	28,000	6,117	17,000
Limestone, 80 tests	25,000	3,550	14,000
Sandstone, 132 tests	20,000	1,149	8,500

While the maximum and minimum figures are of little importance, it is a fair assumption that the average represents approximately the crushing strength of the three classes of stone. The important point is, however, the fact that any of these stones is sufficiently strong for ordinary building.

While any reputable stone, as far as the present feature is concerned, may be used in the construction of ordinary walls, it does not follow that they are all applicable to those especial architectural elements, such as pillars, which are intended to sustain an enormous weight. Likewise they are not all suitable for railway piers, in which a great weight is sustained at one point, and in which the jar and shock make further demands on the strength of the stone.

While most stone is sufficiently strong for ordinary building it does not follow that the determination of the crushing strength is a matter of no importance in the selection of stone for such purposes. Stones possessing a high crushing strength are usually denser and heavier than those of lower strength, and in consequence are more durable. Care must, however, be

[1] Bull. Wis. Survey, No. 4, p. 38.
[2] Geol. Sur. Georgia, Bull. 9A, p. 52.

exercised in taking the crushing strength as a measure of durability, for many exceptions to the above generalization are known to occur.

In order to determine the crushing strength, cubes of the stone are prepared. Care must be taken that the sides are as nearly parallel as possible and that no flaws or imperfections occur in the material selected. Although cubes of any size may be used, it is now becoming a general practice to cut them to a two inch standard. The blocks are then placed between the bearing faces of a testing machine and pressure gradually applied until the specimen succumbs. The pressure at which this event takes place is the ultimate load that the block will stand. A two inch cube presents a face of four square inches if exactly cut, in which case the crushing strength per square inch is one-fourth of the ultimate load. It is almost impossible, without excessive expense, to cut the cubes exactly, but an accurate result is reached by measuring the bearing faces and making the necessary calculations.

In determining the crushing strength of stone, as in all measurements for comparative purposes, the conditions should be uniform throughout; unfortunately the absolute standardizing of conditions is practically impossible in the case of stone, as may be seen from the following partial list:—

The stone should be quarried in the same manner. It is not fair to compare a stone blown out by dynamite with one carefully quarried without the use of explosives.

The stone should be seasoned under the same conditions and for the same length of time.

The cubes should be prepared by the same mechanical means.

The cubes should be equally dry.

The tests should be conducted at a uniform temperature.

The pressure should be applied in the same direction with respect to bedding planes, direction of rift, etc.

The bearing faces of the machine used should be of the same material.

The bearing faces of the cubes should be absolutely parallel. As this is mechanically impossible, it is customary to introduce a thin layer of some material between the cube and the machine in order to compensate inequalities. This material should be the same.

It is advisable that the same type of testing machine be used.

With regard to the first condition it is manifest that a collector must take the material as it is presented in the quarry. The results will at least show the strength of the stone as it is put on the market, even if they do not represent the maximum strength of the material under the best conditions of quarrying.

The conditions to which a stone is exposed between the time of its quarrying and the making of the test, and the length of that interval, affect very materially the crushing strength. Many stones become much stronger with lapse of time, while others, especially if exposed to varying weather, decrease considerably in strength. The standardizing of these conditions is perhaps more essential to comparative results than that of any other in the list, and, at the same time, it is the most difficult to accomplish. For the purpose of this report freshly quarried stone was obtained from all those quarries which were in actual operation. In many cases, however, material was collected from old quarries in which no work has been done in years. It is so unjust to compare such stone with the product of quarries in actual operation that the results in the case of stone which has been exposed are indicated by a distinguishing mark in the accompanying tables.

All the cubes tested for this report were prepared by sawing and by rubbing down with fine carborundum powder on glass plates.

In order to standardize the amount of *water* in the stone, the cubes were kept at the temperature of the laboratory for several days before testing; by this means the water was probably not all expelled, but the amount was reduced to the percentage that the specimens would ordinarily carry in dry air. It was thought that the amount of drying necessary to expel all the water might induce certain changes which would affect the results of the crushing tests. With regard to the direction in which the pressure is applied, it is manifest that great differences must result when the pressure is applied in different directions with respect to the grain of the rock. As a rule, stone possesses a much higher crushing strength in a direction at right angles to the bedding planes than in any other direction. In the case of the stratified rocks many authors present two sets of figures, one indicating the strength at right angles to the bedding and the other in a direction parallel to it. In the former case the test is said to be made "on bed," and in the latter "on edge." For this report the tests were made "on bed" only.

In the case of the igneous rocks it is likewise necessary to record whether the test is made normal to the rift or in some other direction.

The bearing faces of the machine should be flat steel plates. Attempts to use softer material in order to compensate for inequalities in the cubes have not met with success, as the spreading of the wood or other substance employed tends to spread the cube of stone and thereby reduces its strength.

The mechanical difficulties of preparing absolutely plane and parallel faces for bearing surfaces on the cubes are so great that some method of compensation for unavoidable irregularities is required. Some investigators coat the surfaces with a thin layer of plaster of Paris, while others place a sheet of thin blotting paper between the cubes and the steel plates of the machine. The latter method has been employed for the purposes of this report.

Many authors make a practice of recording the load under which the first crack occurs as well as the ultimate load. In a number of preliminary experiments, made to ascertain the best way to conduct the crushing tests, it was found that invariably a lower ultimate load was sustained in those cases in which a crack appeared at a considerable interval before the point of collapse. A practically simultaneous first crack and ultimate load always gave a higher result, and further, such tests agreed among themselves. As no agreement could be obtained in those cases where an interval occurred, attention was directed to the production of more perfect cubes and finer bearing faces made parallel to 1/10 m.m. and then rendered as plane as possible. Absolute perfection in this last respect is more important than in the case of parallelism, for, if there is a slight inclination in the bearing face it can be corrected by an adjustable head on the testing machine. Fully as important as perfection in the cubes is the nicety of adjustment of the bearing faces of the machine. The final tests for this report were made in the following way. The cube was protected from the actual bearing plates of the machine both above and below by plates of steel, planed, case-hardened, and polished. The lower plate rested on an adjustable head and the upper head was brought down so that a hair line was visible between the upper steel plate and the face of the head. Any slight variation in bearing could then be corrected by moving the lower adjustable head. The upper head was then raised and sheets of blotting paper inserted between the faces of the cubes and the steel plates, before proceeding with the test. By this means it was found possible in nearly every instance to render the first crack and the final collapse practically simultaneous. As an instance of how the niceties of bearing affect the appearance of the first crack and the ultimate load, the following examples will suffice, although the principal involved held throughout the experiments.

Light brown dolomite beds, Marshall's quarry, Hamilton Ont.—

Size of Cube	First Crack	Ultimate Load	Crushing strength in lbs. per sq. in.
i. 4·181 sq. in.	41,000	60,900	14,566
ii. 4·00 "	60,000	73,600	18,400
iii. 3·696 "	72,250	72,250	19,548

i—Crushed between blotting paper and the faces of the heads.
ii—Crushed between blotting paper and improvised pieces of steel.
iii—Crushed between blotting paper and carefully prepared case-hardened, plane steel plates.

The appearance of a crack may be due to incipient flaws in the stone, and the record of such crack and the ultimate load may be of value, but such records are too variable to be used for comparative purposes in contrasting the load before and after freezing. Further, it was found possible in nearly all cases to prepare and crush cubes so that the first crack and the ultimate load were practically simultaneous; the conclusion is evident that lack of perfection in bearing is more responsible for the appearance of cracks than imperfections in the stone itself. In the tables accompanying this report most readings which show the appearance of a crack are omitted; where it has been necessary, owing to lack of material or time, to make use of such readings, the fact is indicated by an asterisk. I am, on the whole, forced to believe that the only reliable results are those obtained with a simultaneous first crack and final collapse.

A broken cube tends to assume the form of two pyramids with their apices at the centre and their bases against the bearing plates of the machine. Dr. Buckley considers these residual forms as indicative of the strength of the stone, for he found that examples with a compressive strength of less than 10,000 lbs. formed two well defined pyramids, while those which broke between 10,000 and 20,000 lbs., presented forms intermediate between pyramids and cones. "Crushing samples with a compressive strength of over 20,000 lbs. per square inch, generally results in only one pyramid, with more of a conical than pyramidal outline. When a stone reaches a crushing strength of over 30,000 lbs. per square inch, the breaking results in the production of a single small upper cone." It was observed that the limestones of high strength from different parts of Ontario resulted in a series of vertical columns with scarcely any appearance of either cone or pyramid.

Transverse strength.—The transverse strength of a stone is an expression of its ability to withstand a bending strain, or in other words, its power to sustain a load when supported at the ends only. Insufficient strength, in this respect, is the cause of the cracking of lintels so frequently seen, which unfortunate happenings can easily be avoided by using a stone of sufficient thickness to resist the strains as calculated by the architect.

The transverse strength is determined by breaking rods of the stone in a testing machine. They are supported on steel edges of one-quarter inch cross section, placed as far apart as the specimen will permit. The load is applied by a similar steel edge bearing on the centre. The maximum strain which a stone will stand is called the modulus of rupture and is calculated for a square inch of cross section by means of the following formula:—

$$W = \frac{2\ b\ d^2}{3\ k} R$$

$$R = \frac{3\ k}{2\ b\ d^2} W$$

W = load at centre in pounds,
b = breadth in inches,
d = depth in inches,
k = length,
R = modulus of rupture in pounds per square inch.

The transverse strength of a stone is not necessarily related to the crushing strength, although in a general way the two factors are comparable. Buckley found that a few tests of Wisconsin granite gave results varying from 2,300 to 4,000 lbs. per square inch. In the case of limestone he obtained extremes of 1,164 lbs. and 4,659 lbs. per square inch. Sandstones gave a much lower result, varying from 362·9 lbs. to 1,324 lbs. per square inch.

For this report, the traverse tests were made in an Olson machine. In nearly all cases the supports were five inches apart, the strips were approximately one inch thick and two inches wide. Thirty-three limestones showed a minimum of 818, a maximum of 4,291, and an average of 2,224 lbs. per square inch. Ten sandstones showed a minimum of 417, a maximum of 2,186, and an average of 1,283 lbs. per square inch. Eight crystalline limestones gave a minimum of 1,091, a maximum of 3,737, and an average of 1,907 lbs. per square inch. Three granites gave the following results, 3,382, 2,791, 2,480 lbs. One Grenville gneiss showed a transverse strength of 1,546 lbs. per square inch.

Elasticity:—In determining the crushing strength of stone it is found that the cubes are gradually compressed as the load is increased. In other words, the bearing plates of the machine come closer and closer together until the rupture of the cube is effected. Delicate instruments are provided by means of which the amount of compression suffered by the stone under any load may be measured. The decrease in length of a bar of material thus subjected to pressure, divided into the original length of the bar, and multiplied by the load in pounds per square inch, gives what is known as Young's modulus or the modulus of elacticity or compressibility.

$$E = \frac{P\ L}{D}$$

E = Modulus of elasticity.
P = Load in pounds.
L = Length of the test piece.
D = Decrease in length.

If the pressure is removed before the point of rupture is reached, the cube of stone partially recovers its original shape. The amount that it falls short of complete recovery is called by Merrill the "set," which may be defined as the permanent compression induced by the pressure.

In the case of Wisconsin stones, Buckley found that 21 granites and rhyolites gave an average modulus of elasticity of 1,111,000 lbs. per square inch. The lowest figure was 156,000 lbs. and the highest 2,070,000. In the case of eleven limestones the average was 786,000 lbs., the lowest, 31,500 lbs., and the highest 1,835,700 lbs. Twenty eight sandstones gave an average result of 165,000 lbs. per square inch, the highest being 400,800 and the lowest 32,000 lbs. per square inch. In this connexion Buckley observes that "In a general way the modulus of elasticity corresponds with both the crushing and transverse strength of the various rocks. We have seen that both the crushing and transverse strength were lowest for sandstone, and, similarly the sandstone has the lowest modulus of elasticity. On the other hand, it has been pointed out that the crushing and transverse strength are very high for the granites and limestones, all of which give correspondingly high results for the modulus of elasticity."[1]

The modulus of elasticity is not commonly determined, but it is of value to architects and builders "in calculating the effect of loading a masonry arch, or proportioning abutments and piers of railroad bridges, subject to shock, etc."

A most extended and refined examination of the elastic constants of rocks has been made by Professor Frank D. Adams and Professor E. G. Coker, in the laboratories of McGill University.[2]

This work should be carefully consulted by any one desiring minute information regarding the elasticity of rocks. While the object of the authors was to determine the cubic compressibility, *i.e.*, the amount of reduction in volume suffered by a cube of stone subjected to pressure from all sides, they obtained their results by an indirect method which consisted in measuring not only the decrease in length of a bar of stone subjected to pressure but also the lateral extension of a bar under that pressure. As the care in preparing material and the delicacy of the measuring instruments could not be surpassed, the results of the investigation must be regarded as of the highest order.

In addition to determining the modulus of compression the following factors were also obtained:—

m—The ratio of longitudinal compression to lateral expansion per unit of length. This was obtained directly by measuring the lateral expansion.

From E and m the following constants were obtained by calculation.

σ—Poisson's Ratio; this is the reciprocal of m.

D—Modulus of Cubic Compression - $\frac{1}{3}\frac{m}{m-2}E$. The reciprocal of this gives the decrease in volume of a cubic inch of the material for a pressure of one pound per square inch, applied on every side.

C—Modulus of Shear - $\frac{1}{2}\frac{m}{m+1}E$, which is the quotient of torsional stress to torsional strain.

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[1] Building and Ornamental Stones of Wisconsin, p. 371.

[2] An investigation into the Elastic Constants of Rocks, more especially with reference to cubic compressibility, Carnegie Institution, June, 1906.

The following table is the summary of results given on page 69 of the work:—

ELASTIC CONSTANTS OF ROCKS.

Summary or Results (average) expressed in inch-pound Units.

Specimen	E.	σ	C.	D.
Wrought Iron	28,100,000	0·2800	11,000,000	21,300,000
Cast Iron	15,000,000	0·2500	6,000,000	10,000,000
Black Belgian Marble	11,070,000	0·2780	4,330,000	8,303,000
Carrara Marble	8,046,000	0·2744	3,154,000	5,946,000
Vermont Marble...........	7,592,000	0·2630	3,000,000	5,341,000
Tennessee Marble..........	9,006,000	0·2513	3,607,000	5,967,000
Montreal Limestone........	9,205,000	0·2522	3,636,000	6,167,500
Baveno Granite	6,833,000	0·2528	2,724,800	4,604,000
Peterhead Granite..........	8,295,000	0·2112	3,399,000	4,792,000
Lily Lake Granite	8,165,000	0·1982	3,380,000	4,517,500
Westerly Granite...........	7,394,500	0·2195	3,019,700	4,397,500
Quincy Granite (1)	6,747,000	0·2152	2,781,600	3,984,000
Quincy Granite (2)	8,247,500	0·1977	3,445,000	4,555,000
Stanstead Granite	5,685,000	0·2585	2,258,700	3,940,000
Nepheline Syenite	9,137,500	0·2560	3,635,000	6,237,500
New Glasgow Anorthosite ..	11,960,000	0·2620	4,750,000	8,368,000
Mount Johnston Essexite ...	9,746,000	0·2583	3,872,600	6,750,000
New Glasgow Gabbro	15,650,000	0·2192	6,365,000	9,555,000
Sudbury Diabase...........	13,763,000	0·2840	5,364,000	10,626,500
Ohio Sandstone	2,290,000	0·2900	888,000	1,816,000
Plate Glass	10,500,000	0·2273	4,290,000	6,448,000

(2) The Colour of Building Stone.

In deciding the sort of stone to be used for a particular building the question of colour will be one of the first to arise. No stone will be selected which falls below the requirements in strength and durability, but many varieties may be submitted from among which the most desirable colour will be chosen. In the selection of colour, architects are controlled more or less by the prevailing style, at certain times brown sandstone has been deemed the only "correct" material for many kinds of buildings. At present there seems to be a strong tendency towards the use of the lightest coloured stone possible. With regard to the intrinsic suitability of certain colours to certain types of building, the present writer does not feel competent to speak. It will suffice to point out to the general reader that architects clearly recognize the adaptability of certain colours to certain purposes and that a transgression of the rules of harmony in colour is as fatal to the appearance of a building as to that of any other work of art. Another factor that should be considered in choosing the colour of stone is the conditions to which it is to be exposed, for instance, it does not seem wise to expose a light coloured and porous stone to the smoke and fumes of a railway station.

The colours presented by various kinds of stone are so variable that general remarks are of little value. Uniformity of colour is desirable and, on a broad scale, it is essential, but if the variation of colour manifests itself only as minute streaks and spots, the stone is still acceptable, for the tone of the whole building will be uniform at a short distance. For instance, the yellowish and streaked Nepean sandstone, so largely employed in public buildings in Ottawa, loses little by the lack of uniformity in colour, and the same may be said of the purplish streaked sandstone quarried near Perth, Ont. On the other hand, the using of individual blocks of stone of a different colour among a more uniform lot produces a very unsightly effect. In many of the limestone quarries the different beds are used indiscriminately, with disastrous results as to colour. This desire to utilize at once the whole product of a quarry is more destructive of uniformity of colour in buildings than any cause with which I am acquainted. If the various beds in a quarry vary in colour, the product should be classified, and the stone from a single bed used for an individual purpose. There are, however, several good reasons why this is not done. In the first place, in most of the smaller quarries, the stone for a building is actually quarried for that particular building, frequently by contract. It is therefore difficult, in fact, economically impossible, to supply stone from a single bed alone; the result being that all the beds are used, frequently with very unsightly effect. The only cure for this evil lies in more extensive operations and accumulation of stock of the various kinds of stone. A second practical reason why stone of different colour is employed in the same structure lies in the fact that certain of the beds are of the proper thickness for the making of sills, lintels, etc. Differences of colour are almost universally overlooked in the construction of the smaller buildings in order to make use of stone of convenient thickness. The only remedy for this practice lies in the willingness of builders to pay more for the stone. From the above remarks it will be seen that a quarry which presents the same colour throughout the various beds is very much more valuable than one which does not.

While many of the colours presented by stone are acceptable, at least for certain purposes, some tints are in themselves objectionable, particularly muddy shades of yellow and green. There are also differences in appearance, which cannot be described as mere colour. For instance, many of the grey sandstones are bright and cheerful in colour while others present a dull or "dead" aspect. Two limestones, not materially different in colour, may nevertheless differ greatly in the "liveliness" of their appearance. In this connexion it is well to bear in mind that it is a somewhat difficult matter to form a conception of the artistic effect of a whole building from the inspection of the colour of a small specimen of stone. The aspect, if not the real colour of stone, also varies greatly according to the manner of dressing; a building of bush-hammered stone will present a very different colour from a structure of the same stone with rock-face. Finally, there are few stones which maintain their original colour for a long series of years, in fact it is often more important to ascertain the eventual colour that a stone will assume than to learn its hue when freshly quarried. Any description of colour is inadequate to convey to the mind of a reader an exact conception of the appearance unless accompanied by a reference to some well-known tint. In this report the colours of forty-five stones are shown in three plates. These colours are also made use of in the description of the other stones.

Colour of Granites.—In the case of the granites, composed as they are of different minerals, the colour effect is necessarily spotted or speckled. The coarser the grain of the granite the more pronounced is this appearance. The very fine granites, in which the individual minerals are about seven one-thousandths of an inch long, lose this speckled appearance and appear almost homogenous when viewed from a short distance. A granite in which the feldspars measure less than one-fifth inch may be called "fine;" if they measure between one-fifth and two-fifths of an inch the stone is "medium"; if the feldspars exceed two-fifths of an inch in length the stone is "coarse."

As already seen, the actual colour of the component minerals of a granite varies greatly. The quartz may be clear, or milk-white, or slightly tinted; for instance, in the Kingston granite the quartz is bluish. It is to the colour of the feldspar, however, that most granites owe their characteristic appearance. This material usually makes up the bulk of a granite, so that its colour, modified by that of the other minerals, determines the colour of the rock. The commoner colours of feldspar are red and white and we have in consequence red and white granites, but the latter are grey rather than white, owing to the effect of the other minerals in modifying the white of the feldspar. Light grey and dark grey varieties differ only in the degree that the white of the feldspar is reduced by the presence of black mica. In the red granites the feldspar itself varies greatly in the intensity of its colour showing tints from a light pink to a deep blood red. As in the case of the grey granites, the red of the feldspar is modified by the presence of varying amounts of black mica. The uniform appearance of granites is frequently marred by the presence of "knots," which are segregations of the original magma in which a much higher percentage of black mica is present. The development of an indistinct banded structure or parallel arrangement of the individual components detracts from the appearance of a granite. Many of the Ontario granites show this peculiarity, which is an evidence of their gradual passage into gneisses.

The feldspar individuals, more particularly in the syenites, possess other colours than white and red. Grey, blue, and bluish grey are the commoner tints, but an almost endless number of colours may occasionally be recognized. Many of these feldspars possess a pronounced iridescence, so that the polished surface of the stone presents a sheen when viewed from different positions. The beautiful monumental syenites from Norway owe their chief charm to this peculiarity of the feldspar.

Whatever the colour of the granite, the stone usually presents a much lighter colour when bush-hammered than when polished: this difference of colour between the polished and the hammered work is taken advantage of in order to form a strong contrast in finishing monuments.

The so-called black granites which are really igneous rocks of very different composition, including such stones as diabase, gabbro, diorite, etc., derive their dark colour from the large amount of black hornblende or augite present.

Colour of Sandstone.—The constituent grains of the better grades of sandstone are nearly always quartz although other minerals may be present in small amounts. As the quartz grains are normally either colourless or white, it is to the colour of the cementing material that we must look for the general colour of the rock. This material is commonly either clay or iron oxide or lime. The lighter coloured white and grey sandstones are cemented by clay or lime or an admixture of both, but those in which lime predominates are not only brighter in appearance but more durable. Very argillaceous sandstones are dull in appearance and are liable to speedy disintegration. Sandstones having iron oxide as a cementing material usually show some tone of red or brown. If the whole of the cement is ferric oxide the stone is bright red, but by an admixture with other substances it may fade to a pinkish colour, or may range through shades of chocolate to a dark brown.

Sandstones frequently present a banded structure showing variations in colour. The stone from near Perth, Ont., for instance, is of a whitish colour with purple bands, and much of the Nepean sandstone is banded with yellow. In a finer way, the lines of original sedimentation are manifest on the face of blocks of sandstone as fine parallel streaks of slightly different colour: much of the Medina sandstone from the Forks of the Credit, Ont., is marked in this way (reedy). It is seldom that all the beds in a quarry of coloured sandstone present the same tint, and even the same bed frequently shows a different colour in different places. Not only by banding is the uniformity of sandstones marred but also by the presence of spots or blotches usually of a lighter colour than the main portion of the rock. The mottled Medina sandstone at Grimsby and at Merritton, Ont., shows a brown base with irregular white blotches scattered through it.

While the majority of sandstones present a colour from white to grey or from pink to dark brown, some well known stones are of an entirely different tint. For instance, the "bluestone" of the State of New York is a sandstone in which quartzose and feldspathic grains are cemented by a matrix of hornblende fibres together with less important substances. The "Sillery" sandstone of Quebec is greenish in colour, and yellowish tints are shown by the stone from many localities.

Colour of Limestones.—Perfectly pure limestone is white in colour and all departures from white must be considered as due to the presence of some kind of impurity. The colouring material may be chemically combined with the carbonate of lime in the form of carbonate of iron or manganese, or it may be present as a foreign material mingled with the particles of lime carbonate.

By far the commonest impurity in limestone is clay, whereby the colour is altered to the familiar "greyish" or "stone" colour. Carbonaceous matter is frequently present, resulting in stone of a very dark colour as in the case of many of the Black River limestones of Eastern Ontario. Much of the so-called blue limestone owes its colour to the same ingredient. Yellow limestones are dependent for their colour on some form of iron and the same is generally true of greenish stones. Red limestone is of less frequent occurrence, but examples are not unknown; the colour in this case is owing to the presence of iron in a thoroughly oxidized condition. Although many different tints are occasionally met with in limestones, white, yellow, and bluish-grey must be regarded as by far the most common.

Colour of Marbles.—Pure marble is pure white, but the departures from this colour are so numerous and due to so many different causes that general remarks are of little value. The question of colour in marbles is therefore more easily discussed when specific cases are considered.

(3) The Durability of Stone.

A stone may be easily and cheaply quarried, it may present a most pleasing colour and it may be capable of being worked with the greatest facility, but if it is unable to resist the attacks of time and weather its use can be attended with disastrous results only. The question of durability is therefore one of the greatest practical importance, and it is for the determination of this quality that most of the tests commonly applied to stone are directed. The chemical character of the material, its porosity, hardness, weight, and a number of other factors are involved in the comprehensive term "durability." The determination of all the factors involved results, however, in such a complex and frequently conflicting series of results that the durability might still be in question. It is therefore found to be more satisfactory to apply direct tests than to attempt to ascertain the ultimate durability by means of a large number of separate determinations. The only really satisfactory test of durability is that of experience; in consequence, one must resort to an examination of old buildings constructed of the stone under examination. In this way evidence may be found of discolouration, of cracking, of exfoliation, of softening, and of many other evils which limit the life of building stone. In drawing conclusions from such observations one must be careful, however, to make due allowance for bad quarrying, improper seasoning, imperfect masonry, and injudicious selection of the stone for the work in hand. Observations on buildings in New York has shown that the average "life" of stone in that climate is approximately as follows:—

	Life in years, *i.e.*, the length of time before repairs are necessary.
Coarse brown-stone	5 to 15
Fine laminated brown-stone	20 to 50
Compact brown-stone	100 to 200
Blue stone (sandstone) untried, probably centuries.	
Nova Scotia sandstone, untried	50 to 200, perhaps
Ohio sandstone (best siliceous variety) perhaps from one to many centuries.	
Coarse fossiliferous limestone	20 to 40
Fine oolitic (French) limestone	30 to 40

	Life in years *i.e.*, the length of time before repairs are necessary.
Marble, coarse dolomitic	40
Marble, fine dolomitic	60 to 80
Marble, fine	50 to 100
Granite	75 to 200
Gneiss, 50 years to many centuries.[1]	

Although this list is incomplete and uncertain, it serves to emphasize the fact that no stone is able to withstand for any length of time the alternate heat and cold and wet and dry of a climate similar to that of Canada. Whether concrete blocks and other forms of artificial stone now so largely employed will prove more durable remains for the test of time to disclose. Observations in old graveyards throughout the country show that the lettering on marble becomes illegible and that limetone bases chip and crumble within a comparatively short period of time. The longer cycles of time represented by geological periods prove that the hardest and most durable stone will succumb to the action of destructive agents if the length of time is sufficient. We must not expect therefore to obtain stone which will remain unaltered for hundreds of years, but we should exercise the greatest possible care to employ the most durable material available.

The durability of stone may be considered under two heads, (1), the durability of colour, and (2), general durability—the resistance to decay, etc.

The Durability of Colour in Stone.

The colour that is assumed by a stone a few years after being quarried is perhaps more important than the colour of the fresh material. Many stones become mellow and improve in appearance, while others lose their brightness and assume a dull and muddy look. In all classes of stone the presence of iron in an unoxidized condition as ferrous oxide or ferrous carbonate is imimical to the permanence of colour. The iron salts mentioned above are soon oxidized by the weather and result in yellow and red stains. The amount of unoxidized iron or "ferrous" salts present in a stone should therefore always be ascertained by analysis. Iron in the form of marcasite (ferrous sulphide) which usually occurs in scattered crystals or patches, is even worse than carbonates or oxides, for while the former may result in uniform staining, the latter causes unsightly blotches and may even form dirty streaks running down the wall. Pyrite is much more durable than marcasite, and if in small and scattered grains may not result in serious discolouration, but if it occurs in considerable amount, the stone is decidedly objectionable. The first test of durability of colour is a chemical analysis to ascertain the amount of ferrous salts present, the second is some attempt to produce in a

[1] Stone for Building and Decoration, Merrill, p. 453, also Report Tenth Census, U.S.A., Vol. X, p. 391.

short time the same corroding effect as the weather. Dried and weighed specimens are placed in an enclosed place where they are subjected for several weeks to the fumes arising from bottles of nitric and of hydrochloric acid. The strong oxidizing action of these fumes simulates the attacks of the weather over a more extended period and shows itself in the corrosion and discolouration of those components of a rock which are subject to decay and change of colour. This test has frequently been applied by authors, but it appears somewhat too drastic for stone which is intended for ordinary construction. Carbonic acid gas is believed to produce an effect more comparable with that of the weather. The change in colour produced by treatment with water containing carbonic acid was found to be exactly the same, in those cases where a means of comparison was at hand, as the change produced by natural weathering. In consequence the more important stones were submitted to treatment by carbonic acid in the manner described on page 69.

The results of this test are shown in Table V, and are frequently referred to in the description of individual stones.

In this connexion, it should be observed that a stone may undeservedly receive a bad name, owing to the staining that has been communicated to the wall from foreign sources. Mortar often contains ferrous salts, the oxidization of which stains the neighboring stone. In a similar way, discolouration results from the seeping of solutions from backings, through to the facing stone.

Durability of Colour in Limestone—

Freshly quarried limestone, whatever its colour, has usually a much brighter and cleaner appearance than is presented by the same stone after exposure to the weather. The change shows itself, sometimes by a softening and mellowing which is desirable rather than objectionable. Nearly all the Black River limestone gradually assumes a much whiter appearance, in some cases becoming quite white. This uniform whitening of stone is well shown by the material from the Longford quarries in Ontario and may be observed in the King and the Queen St. subways, Toronto. A rather fortunate result of this alteration is the rendering more nearly uniform of the stone from different beds: the lithographic limestone from near Marmora, Ont., presents a uniform appearance in old buildings, but newer structures show plainly that the stone has been quarried from slightly different beds. Care must be taken to distinguish between actual change of colour and darkening due to dirt absorbed from the atmosphere. This latter manner of alteration is not dependent on the chemical character of the stone but is related to the available pore space in which dirt may lodge. Other things being equal, porous stone will become dirty much more rapidly than compact varieties. From the colour standpoint, therefore, stone of a porous nature should never be used where it is to be subjected to an undue amount of smoke and dust. The presence of pyrite and marcasite in limestone is attended with the same disastrous results as in other stones.

Durability of Colour in Sandstone—

From what has already been said it is apparent that the durability of colour in sandstone depends for the most part on the durability of the material composing the cement between the grains. The commonest change in white and light grey stones is the gradual assumption of a yellowish colour owing to the oxidizing of ferrous salts. White stone, apparently homogeneous when fresh, gradually shows more and more distinctly the lines of stratification. This change is likewise due to the alteration of unoxidized iron into oxidized and more strongly coloured forms. White sandstones with much clay in the cement soon crumble and exfoliate, assuming at the same time a rough and muddy aspect. It should not be overlooked that certain spots and blemishes in sandstone disappear with the ripening of the stone. White sandstones much disfigured by brown spots are quarried near Rideau lake in Ontario. After exposure to the weather these spots become almost imperceptible and should not therefore greatly detract from the value of the stone. The red sandstones are usually of permanent colour, if the grains are of quartz; but certain inferior red stones in which considerable red feldspar is present are not so desirable. The mottled sandstones are very liable to suffer a deterioration in the colour of the lighter parts owing to the oxidizing of iron. The white spots in the mottled brown stone from Grimsby and Merritton gradually assume a dirty yellow colour. Many sandstones are very porous and so rapidly become filled with dirt that a dark grey colour is soon developed even where the atmosphere is comparatively pure. The greater porosity of sandstone renders it more liable to discolouration by absorption of dirt than either limestone or the granites. Pyrite and marcasite are as injurious here as in other varieties of stone.

Durability of Colour in Granites—

All good granites are reasonably permanent in colour; those with white mica should retain their original colour longer than those with black mica. The chief alteration in colour will come from the gradual decay of the feldspars which lose their brilliancy and assume a dull and clayey look. A microscopic examination of the fresh stone should be made to see if any incipient decay has appeared in the crystals of feldspar. The further decay has advanced the more years must be deducted from the probable future life of the stone.

It is to the presence of pyrite, however, that one's attention is ordinarily directed in speaking of the permanence of colour in granites. If this mineral is present in large amount the stone is objectionable and cannot be employed for outside work. The colour test already referred to is particularly applicable to the granites, as the corrosive fumes quickly search out the oxidizable particles from among the hard and permanent minerals which compose the mass of a granite.

The General Durability of Stone.

By durability is meant the power to resist the action of the weather and such other influences as may tend to promote decomposition or disintegration in the stone. In examining into the durability of a stone it is evidently necessary to consider the use to which it is to be put; a stone intended for purposes of interior decoration does not require the weather-resisting power of one destined for outside work; material to be used in the construction of steps where it is to be subjected to the constant abrasion of passing feet, requires a different sort of durability from material intended for the construction of walls; further, stone used in walls will require different properties according as it is placed above or below ground. It will therefore be noted, in the first place, that the determination of certain durability factors is of general value only, and that it is advisable, when it is proposed to make use of a certain stone, that the stone be subjected to tests with a full knowledge of the intended use in view.

Durability is too complex a property to be expressed in any single factor; it must, therefore, be expressed in different ways and the prospective user of the stone must put the greatest weight on those factors which are most liable to come into play when the stone is placed in position. In making use of any of the factors as here expressed it is essential that the operator acquaint himself with the exact conditions under which the various tests were made; serious errors in the interpretations of the figures given may result by disregarding this warning.

It has been customary to draw conclusions as to the durability of stone by observations on the changes produced in rocks by the passage of geological time. That such observations are of little or no use is seen by the finding of a commission appointed by the Prussian Government to inquire into this question. This commission reported against the use of such information for the following reasons:—[1]

(1) The alterations produced in stone by the agents acting in the crust of the earth are not comparable with those caused by the action of the atmosphere on stone placed in a building.

(2) Changes are produced in the course of the geological ages which cannot possibly be effected in the length of time that a building stands.

(3) The obtaining of a measure of the time necessary for distinct alteration to appear in a building stone and for the time required for the alteration to proceed through different stages is not assisted at all by observations on geological weathering.

The tests usually conducted in order to arrive at a knowledge of the durability of stone are as follow:—

Microscopic examination.
Determination of the weight of the stone.
Determination of specific gravity.
Determination of porosity.
Determination of frost-resisting properties.
Determination of softening effect by soaking in water.
Determination of effect of corrosive gases.
Determination of effect of extreme heat.

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[1] Hirschwald, Bautechnische Gesteinuntersuchungen, p. 1. (Gebrüder Borntraeger, Berlin, 1910.)

The Microscopic Examination of Stone.

In order to examine a stone microscopically, a very thin slice is mounted on glass and observed through a special type of microscope. In this manner it is possible to ascertain with certainty the mineral character of the constituents of the rocks. As already pointed out, the different minerals have essentially different powers of resistance and therefore an exact knowledge of the mineral constituents will aid materially in forming an opinion as to the general durability of the stone. It is generally admitted that, in the case of the igneous rocks, all the commonly occurring minerals are sufficiently durable for purposes of human construction. The examination of such rocks is therefore conducted for the purpose of ascertaining the presence of injurious constituents not essential to the rock in question. Further, such an examination is of great value in that it will reveal the extent to which alteration has already proceeded when the stone is freshly quarried. A knowledge of the grain of the rock and the manner in which the grains are related to one another may be ascertained with the microscope and may be of value in predicting the durability of the stone. In the case of the stratified rocks a microscopic examination will reveal the mineral character of the constituent particles, their size, shape, and relative position, the nature of the cementing material and the character of the pore space.

Weight of Stone per Cubic Foot.

It is necessary for architects to know the actual weight of the stone used for certain purposes in order to calculate the amount of masonry that may be placed on pillars, arches, etc. As all stone is more or less porous and as the pores may be more or less filled with water, it is obvious that the stone will vary in weight according to the amount of water present. The figures of actual value are the weights of the material under the conditions to which it is to be exposed, but such figures cannot be given in a general report. The only uniform way in which the information can be given is the weight of the perfectly dry stone, for that figure alone is constant. In order to obtain the weight, a cubic or rectangular piece is carefully measured and dried for some time at 110° C. It is then weighed and the weight of a cubic foot calculated. As it is somewhat difficult to measure a piece accurately and also difficult to expel all the water from a piece of considerable size, more accurate methods have been devised. Buckley's method as applied to the building stones of Wisconsin is as follows:—

"In determining the weight per cubic foot of the different samples of stone tested in this report, the weight of a cubic foot of water was multiplied by the specific gravity of the stone, which gives the weight of a cubic foot of stone, provided there were no pore spaces. In order to obtain the actual weight there was deducted from this the weight of a quantity of stone, of the same specific gravity, equal in volume to the percentage of pore space in the stone. The result was the actual weight of the stone free from interstitial water."[1] (For the determination of pore space, see page 61.)

The Specific Gravity of Building Stone.

The specific gravity or density of a stone is its weight compared with the weight of an equal volume of water. Thus if a certain volume of stone, dry, weighs 3 lbs., and an equal volume of water weighs 1 lb., the specific gravity of stone is 3. A direct comparison can only be made with perfectly compact stone without any pores; as such stone does not exist, the pore space must be allowed for in making the calculations. The comparison is made between the actual volume of the stone substance and an equal volume of water, not between the gross volume of a piece of stone with its pore spaces and an equal volume of water. If the stone were a compact homogeneous substance the determination would be made in the following way:—First, weigh the piece of stone in air; second, suspend it by a fine thread in water and weigh it, the weight in water will be less on account of the buoying effect of the water. In fact, it will weigh less by the actual weight of the water it displaces, the difference of the two weights is the weight of the water displaced, or the weight of a volume of water equal to that of the stone. The specific gravity is therefore the weight in air divided by the loss of weight in water. Owing to the presence of pore spaces in the stone it is evident that this method might give very inaccurate results. There are two common ways of overcoming this difficulty; one is to see that the pore space is free from water when the stone is first weighed and that this space is full of water when the stone is weighed in the water. The freeing of the pore space from water can be accomplished, if the piece is not too big, by drying it at 110° C. for some time before weighing. The complete filling of the pore space with water for the second weighing is more difficult. Buckley accomplished the desired result by slowly immersing the specimen in boiling water under the receiver of an air pump in which the pressure was maintained at one-tenth atmosphere for 72 hours. He is confident that under these conditions the pore space was absolutely filled with water.[2]

The specimen, thus filled with water, is weighed in water as already described and the specific gravity calculated as before.

A second method of eliminating the troublesome pore space is to grind the stone to a powder, whereby the pores are destroyed, and then determine the specific gravity of the powder. This is done by means of the specific gravity bottle, which is a small bottle provided with an accurately ground stopper through which is a very fine hole. The bottle is first weighed, then filled with distilled water and weighed again. The small hole in the stopper

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[1] The Building Stones of Wisconsin, p. 70.

[2] A full description of the method with figure of apparatus may be found on page 66 of The Building Stones of Wisconsin.

allows the surplus water to pass out so that the bottle is absolutely full up to the top of this little hole. The bottle is then emptied, thoroughly dried, and a certain amount of the powdered stone put in and then weighed. The bottle containing the powder is now carefully filled with water and weighed again. The specific gravity is then computed as follows:—

Weight of dry bottle with stone minus the weight of the bottle alone gives the weight of the stone. W.

Weight of bottle with stone and water minus the weight of the stone gives the weight of bottle plus enough water to fill it after the stone is put in. Y.

The weight of the bottle full of water minus Y gives the weight of the water displaced by the stone. Z.

The specific gravity is therefore $\frac{W.}{Z}$

The Porosity of Stone.

Authorities agree that there is no stone in which the constituent particles are so closely set that no interspace exists. Even in the hardest and freshest granite a small amount of water and gases is present, indicating the existence of minute spaces. Experiments on Mount Airy, North Carolina, granite, by Watson, Laney, and Merrill, show that the perfectly dry stone absorbs water to the extent of only about 0·05 per cent of its weight, and even less porous granites are known; on the other hand, certain sandstones absorb water up to 20 per cent of their weight.

As a good illustration of the porosity of sandstone may be mentioned Pettenkoffer's experiment, which was used for demonstration by the present Director of the Mines Branch when Professor of Geology in Victoria University. In this experiment a block of sandstone six inches thick is clamped between iron plates, each of which is provided with a pipe for the entrance or exit of gas. Ordinary illuminating gas is allowed to enter by one pipe and it is found that at the expiration of six minutes the gas may be ignited and will continue to burn at the other.

These interstitial spaces in stone are objectionable because they allow of the infiltration of water, which works for evil in two ways. In the first place, the water, holding gases in solution, slowly acts on the constituent grains and cement, and furthers the decay of the stone. In the second place, the expansion of the water on freezing exerts a pressure of such magnitude as to cause disruption of the stone. It was formerly stated that the amount of pore space was a direct measure of the durability of the material; such statements are no longer made, as it is now recognized that the character of the pore space has a far greater influence on the durability of the stone than its mere percentage amount. This matter will be more fully discussed in the section dealing with the frost resisting power of stone.

The determinations of porosity usually made consist in ascertaining the total pore space and expressing it as a percentage of the rock, and in determining the percentage by weight that the absorbed water bears to the dry weight of the stone—the ratio of absorption. The latter expression is usually about one-half of the former but it varies with the specific gravity of the stone.

The total pore space is ascertained in the following way:—The specific gravity is ascertained as already indicated and the test piece, full of water, is weighed. The difference between this weight and the dry weight of the sample gives the weight of the included water. If this latter figure be multiplied by the specific gravity of the stone we obtain an expression which represents the weight of the stone which would be required to fill the pores. If this amount be now added to the weight of the dry sample the result is the weight of that sample, provided that there were no pores spaces. This weight divided by the weight of the stone required to fill the pores and multiplied by 100 gives the percentage of pore space in the stone.

In the case of 34 Ontario limestones the percentage of space was found to vary from 0·066 to 15·88. Ten sandstones showed a variation from 4·947 per cent to 17·517 per cent. In the case of the crystalline limestones and marbles the percentage of pore space ranges from 0·016 to 1·06 per cent, and in the case of the granites from 0·201 to 0·628 per cent.

The ratio of absorption is ascertained by dividing the weight of the water in the pores by the weight of the dry stone and multiplying by 100 in order to express the result as a percentage. As in the case of the porosity, the ratio of absorption may be very small or it may amount to several per cent. Buckley gives the ratio of absorption of fourteen Wisconsin granites as ranging from 0·17 to 0·5 per cent. Merrill finds that Maryland granites absorb from 0·196 to 0·258 per cent of water after soaking for 24 hours. According to Thomas L. Watson the ratio of absorption of granites from Georgia ranges from 0·060 to 0·093 per cent. Other granites have a ratio as low as 0·006 per cent, and some absorb so little water that its amount is practically indeterminable. The average ratio of absorption of three Ontario granites tested for this report was 0·106 per cent. Limestones range from 0·2 to over 8 per cent according to Buckley who likewise found that the sandstones of Wisconsin vary in this respect from 2·22 per cent to over 15 per cent. Thirty-four determinations of the ratio of absorption of Ontario limestones show a range of from 0·024 per cent to 6·09 per cent, while ten determinations show the range of Ontario sandstones to be from 1·98 per cent to 8·01 per cent. The crystalline limestones show a much lower ratio, the highest result obtained being 0·4 per cent, and the lowest 0·005 per cent.

In order to ascertain the character of the pore space an apparatus was constructed to test the permeability of the stone. For this purpose slices three mm. thick were cut in a direction at right angles to the bedding planes. Through these pieces water was forced under a pressure of 15 lbs. to the square inch and the amount of flow in one hour recorded. The results show conclusively that the permeability is in no relation to the porosity of the stone.

It was found that for stones with a less amount of pore space than one per cent the apparatus was not sufficiently delicate to give appreciable results, the stone being practically impermeable. A table is inserted in the appendix showing the results of the tests made; the following examples, however, will suffice to indicate the lack of relationship between the porosity and the permeability:—

Stone	Porosity per cent.	Permeability: cubic-centimetres of water passing through a plate of 3 mm. thickness in one hour under a pressure of 15 lbs. to the sq. in.
Guelph limestone	15·883	90·5
Guelph limestone	14·62	155·1
Chazy sandstone	17·517	2·25
Medina sandstone	10·44	2130·00
Niagara limestone	10·443	12·75
Beekmantown limestone	1·313	·72
Potsdam sandstone	4·947	1·75

In conducting this experiment it was hoped that an expression might be arrived at which would represent the relation between the fine and the coarse pores, as only the latter could allow an appreciable amount of water to pass through. The figures obtained do not show any relation to the loss of crushing strength on freezing (vide postea) and bear only a rough relation to the "saturation coefficient." The results may, however, be of certain value in the case of stone intended for use under water or in the construction of dams.

A peculiar feature in connexion with this experiment was the impossibility of obtaining duplicate results. Eventually it was found that this lack of uniformity was due to the fact that the permeability gradually decreased in every example tested. Readings taken at minute or three minute intervals showed, *in every instance*, a less and less amount. This would seem to indicate that small particles lie free in the interspaces and that the pressure of water packs them down in the cavities thus checking the rate of flow.

The thought is naturally suggested that a factor of durability might be arrived at by determining in a mathematical way the rate *of decrease of permeability*. For it is reasonable to suppose that a stone in which the permeability rapidly diminishes is a less desirable material than one in which that decrease is slower. A very permanent stone might be expected to show no decrease at all. The question, however, requires further investigation.

The Frost-Resisting Properties of Stone.

The alternate heating and cooling to which a stone is ordinarily subjected causes a contraction and expansion which works to the detriment of the material. If, however, the stone is perfectly dry the injury is insignificant when compared to that which results if water be present. The amount of water which can or may be present in a stone is necessarily related to the pore space so that the question of resistance to frost is intimately connected with that of porosity. Neither the percentage of pore space nor the ratio of absorption is any guide as to the frost-resisting power of the stone. The character of the pore space may, however, furnish a means of predicting how the stone will act under the influence of frost. Buckley points out that the pores in a stone may be considered as of two kinds according to their size. The larger pores, those over 0·002 cm. in diameter, he designates as the capillary pores; on draining, these part with most of the contained water—the water of *saturation*—retaining a part only—the water of *imbibition.* Pores of smaller dimensions than 0·0002 cm. are known as sub-capillary; they contain only water of imbibition and consequently remain full under ordinary draining, parting with the water slowly and with difficulty. "It would appear from the above that the most important fact in estimating the danger from freezing and thawing is the rapidity with which the rock gives up its included water, which depends, as stated above, mainly on the size of the pore spaces. The second factor of importance is the amount of water contained in each of the pores at the time of freezing. Third, and last in importance is the total amount of pore space. The higher the percentage of pore space, provided the pores are of equal size and the degree of saturation be equal, the greater the danger from freezing."[1]

The injury effected by freezing is due to the expansion of water in passing into the condition of ice. This expansion is equal to one-tenth of the volume of the water. If now, the pores of a stone be filled to nine-tenths of their total capacity, there is still room for the water to expand and the stone will suffer no injury on freezing. If, however, the pores are more than nine-tenths full the danger line is passed and the stone will be more and more liable to injury the more nearly the pores are completely full. If a stone be more than nine-tenths saturated, whether by natural or artificial means, it is sure to suffer injury. The practical question therefore is not to determine the effect of frost on a saturated stone but the effect on a stone which is charged with the amount of water it would absorb under normal conditions. In relation to the total pore space, this amount is much smaller than is ordinarily thought. In this connexion Hirschwald states: "At the end of December, at the time of the beginning of frost, test pieces of sandstone and granite were cut from the building of the Technical High School, in Berlin, and the amount of water present determined at once. These pieces were obtained at a height of 20 cm. above and also at a depth of 20 cm. below the ground level. Between November 1 and the end of December, when the specimens were taken, there had been a rainfall of 80 mm., and on certain days a precipitation of 6·4 mm.

"It was found that the sandstone specimens contained only from 1–24 to 1–28 the amount of water they were capable of absorbing by one hour's soaking in water. The absorbed water in the granite amounted to one-third

[1] The Building and Ornamental Stones of Wisconsin, p 22.

the amount obtained by an hour's soaking, but the specimen from the foundation stone which reached under the ground gave almost as much water as the stone was capable of absorbing by an hour's immersion."

Now, when a stone is immersed in water for a short time, the pores do not by any means become filled; only the finer pores—those capable of drawing in the water by capillarity—contain an appreciable amount of water. The air contained in the larger pores prevents their filling by water, so that the absorbed water represents the finer pores only, that is to say, the sub-capillary pores of Buckley. In the walls of a building it is only, therefore, a small proportion of the sub-capillary pores that become filled with water under normal conditions. The worst condition possible, and one which can scarcely be obtained in stone above the ground, is the complete filling of these fine pores. It is apparent, therefore, that a stone which has a large proportion of fine pores is in greater danger from frost than one in which the proportion of fine pores is lower. If now we can determine the ratio which exists between the fine pore space and the total pore space, we obtain a factor which will indicate the ability of the stone to withstand the action of frost. To obtain this factor Hirschwald proceeds in the following way. The dried and weighed test-cube is immersed in water for from one to two hours if the intention is to use the stone above ground, and from three to thirty days if the stone is destined for underground work. The cube is then weighed and the increase taken as representing the fine pore space, or at least the pore space that would be filled under the worst possible natural conditions. The cube is then completely saturated by water by treatment in a vacuum and under strong compression; it is again weighed and the increase over the dry weight taken as representing the total pore space. The quotient obtained by dividing the increase representing the fine pores by the increase representing the total pores gives the proportion of the fine pore space to the total pore space and is known as the *coefficient of saturation.* From the observations already made on the theory of the expansion of water on freezing, it is seen that if the quotient is greater than 0·9 there is no room for the water to expand and the stone is in danger of injury. On the other hand, if this quotient falls below 0·9 no injury can result from the action of the frost on the stone. Hirschwald further states that since, in general, it is impossible to fill all the pores with water it is safe to write the critical point as 0·8 instead of the theoretical 0·9. This conclusion is supported by the results of about 1,200 tests.

Most of the samples which have been tested for this report have been submitted to the operation described above and the results recorded as the "saturation coefficient," a table which will be found in the appendix and reference to which is made in the case of each of the stones examined.

In determining this coefficient, one inch cubes were used. They were dried at 110° C. and weighed; after two hours' immersion in distilled water at the temperature of the laboratory they were again weighed and the increase ascertained. This amount was divided by the weight of water in a similar cube when saturated under reduced pressure; this figure was obtained by calculation from the results of the tests made in order to ascertain the pore space and specific gravity. An analysis of results shows that the four granites and gneisses range from 0·67 to 0·8 which brings them all fairly close to the danger line. Seven crystalline limestones range from 0·44 to 0·94 and it is seen that the finer grained types give higher results than the coarse varieties, and therefore stand in greater danger of injury by frost. The sandstones range from 0·21 to 0 57 and are therefore in little danger of serious injury. The limestones show a great diversity ranging from 0·11 to 0·91. It is to be remembered that these results are applicable only to stone which is intended for work above ground. In testing for underground work the cube must be soaked for a long time, as already explained, whereby much higher results would be obtained.

The question of determining by actual experiment the frost-resisting power of stone is fraught with difficulties, many of which have been entirely overlooked by writers on the subject. The basis of all such determinations is the ascertaining of the crushing strength of stone before and after freezing. Now, while careful determinations of crushing strength are sufficiently exact for ordinary purposes, it is apparent both from my own work and from published lists that inherent variations in the stone and the mechanical difficulties of producing exact bearings make the results of crushing tests too inexact for definite comparative purposes. This difficulty can be removed only by averaging a large number of results. In the second place the stone must contain water in order that injury may result. The question at once arises as to *how much water* the stone should contain. It is apparent that in order to obtain results of certain value that the water content should be the same as that which the stone is likely to hold in the position in which it is to be placed. It has already been shown that this amount is but a small fraction of that which the stone is capable of absorbing. Now, with this small content of water, a specimen would require to be frozen such a great number of times in order to give appreciable results, that it is manifestly impossible to conduct the experiment. If, on the other hand, the stone be allowed to absorb all the water it is capable of holding by ordinary soaking, it will contain an amount far in excess of that which it would be likely to absorb on ordinary exposure to the weather. Finally, if the stone be entirely filled with water by treatment under vacuum, etc., it will contain an amount of water which, except in the case of the very fine grained stones, it can *never* absorb under atmospheric conditions. In the course of a few years, however, building stone is subjected to a very great number of freezings and thawings and we must therefore decide to what extent the results of a few freezings of unnaturally saturated stone are comparable with a great number of freezings in a normal state of saturation. It is at once apparent that there is no real comparison possible. In order to ascertain the relation between the theoretical frost resisting power as expressed in the coefficient of saturation and the results of crushing tests of frozen samples the time honoured method described below was adopted.

A two inch cube was carefully prepared and dried in the air bath at a temperature of 110°C. for 24 hours, after which it was allowed to cool in a dessicator and was then weighed. The cube was then saturated with water under reduced pressure for 36 hours after which it was exposed to 40 alternate freezings and thawings. The specimen was again dried in the air bath and crushed in precisely the same manner as the unfrozen examples of the same stone. The results of these tests are shown in Table III of the appendix.

In the case of granites, gneisses, crystalline limestones, and marbles there was a uniform loss of strength, but in the case of the limestones and sandstones, while the majority of the specimens lost in strength, there were some which increased to an appreciable degree. As there could not well be an instrumental error to account for the high result of the frozen specimens, new cubes were made of the stones in question and the crushing strength of the unfrozen sample again determined with the greatest nicety possible. *In every instance* a result nearly identical with the original test was obtained, so that we are forced to conclude that, in some cases, stone actually increases in strength by being subjected to the operations described. It is not to be inferred that the freezing and thawing has produced this result; the explanation more likely lies in the heating and drying. An increase in strength after freezing has been recorded by various authors, but it has generally been attributed to lack of carefulness in preparing the material. Buckley evidently considered such results anomalous, for he explains them as due to imperfect cubes or to the manner of operating the testing machines. Merrill gives a table in which five stones out of fifteen increase in strength,[1] but he does not offer any explanation of the apparent anomaly. It would be an easy matter to decide whether the increase is due to the heating and drying or to some other causes, by preparing a number of cubes of the same stone and freezing them, in some cases after drying, and in other cases without subjecting them to that operation. The necessity of preparing this report for the press prevents the carrying out of this experiment at present, but it is hoped at a future time to carry on a series of tests to determine the point in question.

The alternate expansion and contraction to which a stone is subjected in the freezing test, together with the expansive forces of the included water on being converted into ice, doubtless breaks off innumerable tiny particles in the interior of the stone. In order to obtain thirty daily freezings the stone is kept saturated for a month so that the water it contains has ample time to attack the loosened particles. The stone is then dried for 24 hours at a temperature of 110°C. and thus an excellent opportunity is furnished for the setting of any dissolved matter and the consequent recementation of the stone. That such a series of events does take place in certain stones is well shown by the following example. At the time the old lithographic quarries near Marmora, Ont., were in operation, the fine dust obtained in working the stone was barrelled with the intention of using it as a polishing material.

[1] Stones for Building and Decoration, p. 471.

Several of these barrels were left in the mill, and by the simple process of becoming damp and drying out, protected from both sun and rain, the contents have been converted into a solid mass rivalling the stone itself in hardness.

Two specimens of almost identical appearance, one of which gained in strength under the freezing test, while the other lost materially were reduced to powder, wetted, raised to a temperature of 100°, again wetted and allowed to soak for a few hours. On being raised to a temperature of 110°C., the pellet obtained from the stone which gained in strength showed a very much greater coherence than that from the other.

If it should be definitely established that the operations of drying, freezing and thawing, and again drying, tend to raise the crushing strength of certain stones, it follows that the recorded loss of strength does not really represent the loss due to freezing, but that loss, less an increase due to the resetting of the disrupted particles.

In this connexion may be mentioned the fact that most of the sedimentary stones lose appreciably in strength on being wetted: this loss of strength is due to the softening of the cementing material which holds the grains together. On again drying, the stone assumes its original hardness and coherence. Is it not reasonable to suppose that, in certain cases dependent on the chemical character of the cement, changes may occur which make the rock even stronger than before? Such changes are well known to geologists, as for instance, the conversion of amorphous carbonate of lime into the crystalline variety.

In the freezing and thawing test as generally conducted we have therefore two grave sources of error. In the first place there is no relation between the effect of a few freezings of artificially saturated stone and the effect of numerous freezings of the same stone under atmospheric conditions. In the second place, the operations of thoroughly drying, saturating, and again drying *may* in themselves materially alter the strength of the stone. It is believed therefore that the saturation coefficient is a much better indicator of the frost-resisting properties of a stone than any experimental determinations yet employed.

It is interesting to note that a method formerly used to simulate the action of frost consisted in soaking the specimen in a concentrated solution of sodium sulphate, which was then allowed to crystallize in the pores. In this way a pressure was exerted which was believed to be analogous to that of ice. The results, however, showed a much higher result than those of natural freezing and the method was abandoned. In view of what has been said this result was to have been expected, for the pores were completely filled and the partial relief by evaporation and draining which must occur to a greater or less extent in the natural method was largely prevented.

Of much greater value than the determination of loss of strength are general observations on the behaviour of stone when subjected to the freezing test as well as the loss per cent which the stone suffers under the operations. In all the samples examined for this report the loss of weight was recorded and will be found in Table III of the appendix.

A summary of the results of different authors is given below as a general indication of the behaviour of stone under the freezing and thawing test:—

Buckley, Building Stones of Wisconsin, p. 404:

Eighteen granites gave a loss per cent varying from 0·0 to 0·05. Nine of these granites show an average loss in crushing strength of 6,500 lbs. per square inch, as a result of the freezing.

Eleven limestones show a loss per cent in weight varying from 0·0 to ·30, and eight samples show an average loss of crushing strength of 11,000 lbs. per square inch.

Twelve sandstones show a loss in weight varying from 0·0 to 0·62 per cent, and six samples show a loss in crushing strength averaging about 2,000 lbs. per square inch.

Watson, Laney and Merrill, Building and Ornamental Stones of North Carolina, pp. 235-236:

Four sandstones gave an average loss per cent of 0·02.

Of the 32 limestones tested for this report the average loss was only 900 lbs. per square inch, while the loss per cent in weight varied from 0·0 to 0·35 per cent.

Seven sandstones showed an average loss in strength of 1,300 lbs. to the square inch, and a loss per cent in weight ranging from 0·014 to 0·253.

Five crystalline limestones lost in strength an average of 1,000 lbs. to the square inch, and ranged in loss per cent of weight from 0·102 to 0·0425.

Two granites show an average loss in strength of 2,000 lbs., and in weight of 0·005 per cent.

It will be observed that the average loss for the Ontario material is considerably less than that given by the authors quoted.

The Softening Effect of Soaking in Water.

Hirschwald regards the softening effect of soaking in water as one of the most important means of determining the durability of stone; in order to ascertain this effect in a manner that may be expressed in figures, he proceeds as follows:—

Two strips of the stone are prepared with a cross diameter of about 16 square centimetres; one of these is kept dry and the other allowed to soak in water for 28 days. The tensile strength of the two specimens is then ascertained. The quotient obtained by dividing the tensile strength of the wet specimen by the strength of the dry specimen is called the *coefficient of softening*, and is considered as indicative of the general durability. A comparable result may be obtained in a simpler way by ascertaining the number of turns required to sink a drill a fixed depth into the wet and into the dry stone. Time has not sufficed for the making of the apparatus required for the carrying on of these tests and consequently they have not been applied to the Ontario stones.

Corrosion of Stone by Gases.

The atmosphere consists essentially of oxygen, carbonic acid gas, and nitrogen; the last of these is practically inert, but both the oxygen and carbonic acid act as chemical agents towards effecting the destruction of stone. As an accessory constituent of the atmosphere, water is always present; on settling from the atmosphere the water whether as rain, dew, snow, or hoar frost is charged with a certain amount of both oxygen and carbonic acid gas. The water, therefore, which enters the interstices of stone, or which may act on the surface only, is not pure water but a mild acid and an oxidizer as well. It is to the presence of these chemical agents in the water that is due the oxidizing of the uncoloured salts of iron into the coloured salts, and also the gradual change of silicates, such as feldspar, into a soft clay-like material. Pure water is able to dissolve limestone scarcely at all, but ordinary rain water, with its little charge of carbonic acid, effects the solution of limestone with comparative ease. The great caves of Kentucky have been cut out of beds of limestone by the solvent water of percolating rain water. It is not to be expected therefore that buildings constructed of limestone will escape. As there is no means of avoiding the carbonic acid, the builder must exercise all possible precautions to guard against the soaking of water into the walls of the building. This simply brings us back to the question of porosity which has already been considered. Other things being equal a porous limestone will dissolve more quickly than a compact one. The percentage of carbonic acid in the atmosphere of large cities is slightly greater than in the open country, the difference, however, is much less than is ordinarily supposed. The average volume per cent of carbonic acid gas in the atmosphere is 0·03 to 0·04 per cent. In London on clear days it is 0·038 per cent, on dull days 0·045 per cent, and on cloudy days 0·051 per cent. The direct action of the gas cannot therefore be greatly different in cities and in the country. Experiments have been made to determine the effect of an atmosphere of carbonic acid in the presence of moisture on samples of limestone and marble. The tables published show little deterioration in the short period of time over which the experiments extended.

As it is not only in a moist atmosphere but when the stone is soaked with water that the carbonic acid produces its injurious effects, it was decided to determine the corrosive action of this material on specimens immersed in water. For this purpose cubes were prepared having an approximate size of one cubic inch and therefore presenting six square inches to the action of the solvent. The cubes were dried at 110° C., and carefully weighed; they were then measured and the exact superficial area determined. The specimens were suspended by threads in a large bottle filled with distilled water into which a stream of carbonic acid gas was conducted. The water was renewed every four days and the action allowed to continue for four weeks. At the expiration of this time the specimens were removed, washed in distilled water, and rubbed with the tips of the fingers to remove loose particles, as such grains constitute an essential loss as well as the particles which fall from the cubes while suspended in the bottle. After thorough drying, the specimens were weighed and the loss noted. A very interesting and valuable series of figures was obtained, which is believed to express, as well as any single set of results can, the relative durability of the different stones tested. In the table given in the appendix the loss is expressed in grams per square inch of surface exposed. While the actual loss is in itself small in most cases, the figures regarded in a comparative way show a wide divergence in the resistance of the different stones to the action of carbonic acid, which must be regarded as the most potent agent in promoting the decomposition of stone. An analysis of the table shows that the limestones and dolomites varied from 0·005 grams to 0·33 grams, that the sandstones show a range from 0·0018 grams to 0·1135 grams, and that the crystalline limestones and dolomites vary from 0·0019 grams to 0·9 grams. It is interesting to note also that the granites and gneisses were effected to an extent ranging from 0·000164 to 0·0045 grams per square inch of surface.

The change in colour brought about by the action of the carbonic acid is very distinct and corresponds closely with the alteration resulting from natural weathering of long duration in all cases known to the writer; it is inferred, therefore, that this test furnishes a ready means of determining the change in colour that will take place on exposing a stone to the weather. A table is inserted in the appendix expressing the change in colour as thus determined.

It is well known that dolomite is much less easily dissolved by carbonic acid than calcite and it would seem therefore that dolomite is the more durable material. In all the tests made the dolomites lost far less in weight and suffered less change in colour than the limestones, in spite of which, authors state that it has not been proved by experience that limestones are less durable than dolomites. It is apparent that one must remember the nature of the stone when using these figures for comparative purposes. It would be absurd to state that a limestone which loses ten times as much as sandstone is ten times less durable. But, it is believed that, within the group of limestones, those which suffer the greater loss are the less durable. Likewise, the sandstones which lose a greater amount are less durable than those in which the loss is not so large.

In cities where large amounts of coal are consumed the air is contaminated with sulphurous acid which is a much stronger corrosive than carbonic acid. It is advisable to ascertain, in the case of stone intended for use near railway stations and manufactories, its resistance to the action of such fumes. Buckley performed this test by placing small cubes of stone, carefully dried and weighed, in a large glass bottle in which smaller bottles of water with open mouths served to keep the atmosphere moist. Sulphurous acid gas was then introduced, and allowed, with occasional renewals, to act on the stone for 44 days. The specimens were then removed, washed, dried and weighed and the loss noted. Discolouration, development of cracks, etc., were also observed. Buckley found that some of his samples increased in weight while others lost; they were all, however, more or less discoloured and etched.[1]

The Custom House at Niagara Falls, Ont., is constructed of Queenston limestone. This stone, in most structures, presents a good appearance after many years of exposure, but in the building mentioned, the dressed work shows bad exfoliation as well as corrosion along the bedding planes of the stone. There is little doubt that this unfortunate result is to be attributed to the sulphurous acid fumes from the locomotives of the nearby Michigan Central Railway.

Effect of Heat on Stone.

Like nearly all substances, stone expands when heated and contracts on cooling; the frequent repetition of this process from day to day cannot fail to impair the strength of the stone. The deterioration usually manifests itself by scaling and exfoliation. In some cases also, incipient cracks are developed which permit of the more ready access of water thereby facilitating decay. In climates where there is a considerable difference between the temperature of night and day, more attention must be given to the selection of stone of slight expansibility than in more uniform climates. Another injurious effect of the expansion and contraction is to open the joints between contiguous blocks of stone. Small as the opening is, it is sufficient to allow the entrance of water with all its harmful after effects. The amount of expansion of the different types of stone has been determined by different authors. The figures obtained by W. H. Bartlett are most commonly quoted as follows:—

Granite expands	·000004825	in. per foot for each degree.
Marble "	·000005668	" " " "
Sandstone "	·000009532	" " " "

It should also be noted that delicate experiments have proven that stone once expanded by heat never quite contracts to its original size. The difference may be only infinitesimal, but it is sufficient to show that the stone has suffered some permanent injury. Numberless repetitions of the same treatment cannot fail to weaken the whole stone throughout its mass. It is generally considered that fine grained and homogeneous stone is less liable to injury than coarser and less uniform varieties.

The excessive heating of stone when subjected to fire causes a relatively large expansion, followed by rapid contraction. The change may be extremely sudden, as when the flow from a fire hose comes in contact with the hot stone. The fire resisting properties of stone are therefore a matter for serious consideration on the part of builders, particularly in large cities. It may as well be plainly stated that no stone will pass through a serious fire uninjured. The amount of injury resulting from a fire of given intensity varies greatly with the character of the stone. Some stones withstand fairly well a temperature as high as 1200° F., while others are totally destroyed at

[1] The Building Stones of Wisconsin, p. 74.

a much lower temperature. With regard to the heat resisting power of the different types of stone there seems to be some difference of opinion. It would seem, however, that limestone and marble, if the heat has not endured long enough to calcine the stone throughout, are more durable than granite and sandstone. Certain siliceous examples of the sandstones and conglomerates are, however, able to withstand a very high temperature.

Tests to determine the fire resisting power of stone are made by subjecting prepared cubes to a temperature of 500° F., which is gradually increased up to 1200° or 1500°. The specimens are then allowed to cool naturally or they are rapidly cooled by being plunged in water. Buckley found that all three types of stone were practically destroyed at temperatures between 1200° and 1500° F.

CHAPTER IV.

Chief Requisites of Slate and the Methods of Testing.

While some of the properties of ordinary building stone are equally essential in the case of slate, the special purposes to which this material is applied demand a somewhat different set of properties and entail a different series of tests.

The requisites of good slate are that it should be sufficiently cleavable, that it should be durable in both colour and in general resistance to weathering, and not so friable as to crack when nail holes are punched in the sheets. The methods of testing in order to determine the value of slate are summarized by Dale[1] as follows:—

Sonorousness.—The test is performed by suspending a sheet of slate and striking it with a hard object; good slate should give out a clear note. Mica slates are as a rule more sonorous than clay slates.

Cleavability.—Should be determined by a good workman using a thin chisel about two inches wide.

Cross fracture.—This is to determine the grain. In practice, the workmen, more particularly the block men, soon become familiar with the degree of development of grain by experience with the stock. It is of importance to an operator to know the strength of the grain, for it materially affects the ease with which blocks can be prepared. Several scientific methods have been devised to determine this property. The simplest of these is that of Jannetaz,[2] which is based on the difference in the facility with which slate will conduct either sound or heat in a direction parallel to the grain as compared with a direction at right angles to it. A sheet of slate is rendered as smooth as possible and is coated with a thin layer of grease. The point of a hot platinum wire is then placed against the greased surface. From the hot point outwards, the grease gradually melts, but, as the heat is conducted more quickly in the direction of the grain than in the other direction, the melted spot assumes the form of an ellipse rather than a circle. The long diagonal of the ellipse evidently represents the direction of the grain.

Character of cleavage surface.—The surface of the cleaved slate should be examined with a magnifier and the smoothness noted. Generally speaking, the smoother the slate the better; for a plane surface gives less chance for the lodging of material which might assist in the decay of the slate. A good slate also, when scaled along the cleavage, shows thin chips with translucent edges. The general structure of good slate should be so fine that the constituent minerals should not be observable except under the microscope.

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[1] Bull. 275, U. S. Geol. Sur. p. 45.

[2] Relation entre la propagation de la chaleur et l'élasticité sonore dans les roches et dans les corps crystallisé. Bull. Geo. Soc. France, 3rd Ser. Vol. V., pp. 410-426.

Presence of lime.—The amount of carbonate of lime in a slate can be told roughly by treating it with dilute hydrochloric acid. Rapid effervescence indicates a large amount of lime. The presence of considerable lime is not necessarily fatal to a slate, but as a general rule, a slate with little or no lime is likely to be the more durable.

Colour and discolouration.—The colour of the freshly quarried slate should be compared with that of examples which have been exposed to the weather for some years. A slate which deteriorates in colour is less valuable than one in which the tint is more constant.

The durability of colour in slate may be determined by the methods applied to ordinary building stone.

Presence of clay.—An easy method of determining the presence of clay is to breath on a fresh surface and smell it. A distinct clayey or argillaceous odor is perceptible if any considerable amount of clay is present.

Presence of marcasite.—Owing to the rapidity with which marcasite decomposes, with the production of unsightly spots, one should carefully observe with a lens whether any of this mineral is present. Pyrite, as it decomposes less readily, may not be so deleterious if present in fine grains only.

Presence of magnetite.—Grains of magnetite are not particularly objectionable in a building slate, but, for electrical purposes, slates with any appreciable amount of this mineral are to be avoided. To roughly determine the amount present, an inch cube may be pulverized and the resulting powder spread out on a sheet of paper. By passing a magnet through the powder the magnetite may be separated and weighed.

Strength.—The transverse strength is the most important in slate; it may be determined in the ordinary way already described. Merriman and others have devised special apparatus for the determination of the transverse strength of slate.[1]

Toughness or elasticity.—Merriman finds the ultimate deflection in certain Pennsylvania slates, when placed on supports 22 inches apart, to range from 0·072 to 0·313 inch. Certain blue-black slates in Eldorado county, Cal., when split 7 to the inch, and 18 inches square, and fastened solidly at the two ends, are said to bend three inches in the centre without any sign of fracture. J. F. Williams tested beams of slate from Rutland and Washington counties; he cut the material into rods of 1 square inch cross section and 10 inches long. The supports were placed 6 inches apart. Bending without breaking was effected by from 770 to 1,200 lbs., and, when the supports were placed three inches apart, by from 1,710 to 2,400 lbs.[2]

Density or specific gravity.—This is determined in the ordinary way, see page 59 *et seq.*

Porosity.—This property is determined as in building stone.

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[1] The Strength and Weathering Qualities of Roofing Slates. Trans. Am. Soc. Civ. Eng., Vol. XXVII, No. 3, pp. 331–349, Sept. 1892, and No. 6, Dec. 1892, p. 685; also Vol. XXXII, p. 529–539, 1894.

[2] Bull. U. S. Geo. Sur. No. 275, p. 47.

Hardness or abrasion.—Determined as in stone. Merriman found the relative hardness by pressing a weighed piece of slate against a grindstone with a pressure of ten lbs., the stone was then revolved 50 times, and the loss of weight noted.

Corrodibility.—This test is to determine the resistance of the slate to the acids of the atmosphere and water; it is performed by immersing a weighed piece of slate in a solution consisting of 98 parts water, 1 part sulphuric and 1 part hydrochloric acid. After remaining in the solution the specimen is dried for 40 hours and weighed. The operation is repeated a number of times, using solutions of gradually increasing strength. The losses in weight varied with different slates, according to Merriman from 0 to 2·76 per cent.

Microscopic analysis.—See under building stone.

Chemical analysis.—Chemical analysis of slate is not very indicative of its strength or weathering qualities. Probably the chief determination of importance is the percentage of ferrous carbonate, as it is due to the decomposition of this substance that slates deteriorate in colour.

Dr. Andrew C. Lawson, in his report on the Geology of the Lake of The Woods,[1] gives the following simple tests to ascertain the quality of slate:—

1. As a rule, good slate when struck, gives a clear bell like sound.

2. It is generally considered a good sign when it shatters more or less before the edge of the axe.

3. Light blue slate is less absorbent, as a rule, than black-blue varieties.

4. Good slate has a hard rough feel, while an absorbent slate feels smooth and greasy.

5. The absorptive powers of a slate may be tested in two ways:

(1) Place the slate on edge, half immersed in water. If it draws up the water and becomes wet at the top in six or eight hours it is spongy and bad. The extent to which the water extends is roughly the measure of absorption.

(2) Weigh a piece of slate dry and then again after immersion in water for twelve hours, after wiping off the superficial water; if it shows much increase in weight, it is too absorptive to be good.

The degree of induration that the original material has suffered, as well as its chemical composition, control to a great extent the character of the slate. While nearly all slates, as stated above, are formed from original sediments, a few result from the metamorphism of igneous rocks, but for practical purposes these may be neglected. Clay slates are those in which the metamorphism has not been sufficient to develop new minerals and in which the constituent grains are cemented by lime, magnesia, iron, kaolin, etc. The strength, fissility, and elasticity of such slates is consequently low. Mica slates, on the other hand, have been subjected to such powerful metamorphism that the kaolin and grains of feldspar of the original sediment have been caused to crystallize in the form of mica. The flakes of this mineral are arranged in a more or less parallel and overlapping manner, resulting in a much stronger and more fissile slate than in the former case.

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[1] Geol. Sur. Can., Annual Report, 1885, p. 148 CC.

Dale proposes the following economic classification of slates:—

I—Aqueous sedimentary.

A—Clay slates.

B—Mica slates.

(1) Fading.—With sufficient ferrous carbonate to discolour considerably on prolonged exposure.

(a) Carbonaceous or graphitic.

(b) Chloritic (greenish).

(c) Hematitic and chloritic (purplish).

(2) Unfading.—Without sufficient ferrous carbonate to produce any but very slight discolouration on prolonged exposure.

(a) Graphitic.

(b) Hematitic (reddish).

(c) Chloritic (greenish).

(d) Hematitic and chloritic (purplish).[1]

II—Igneous.

A—Ash slates.

B—Dyke slates.

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[1] U. S. Geol. Sur. Bull. 275, p. 6.

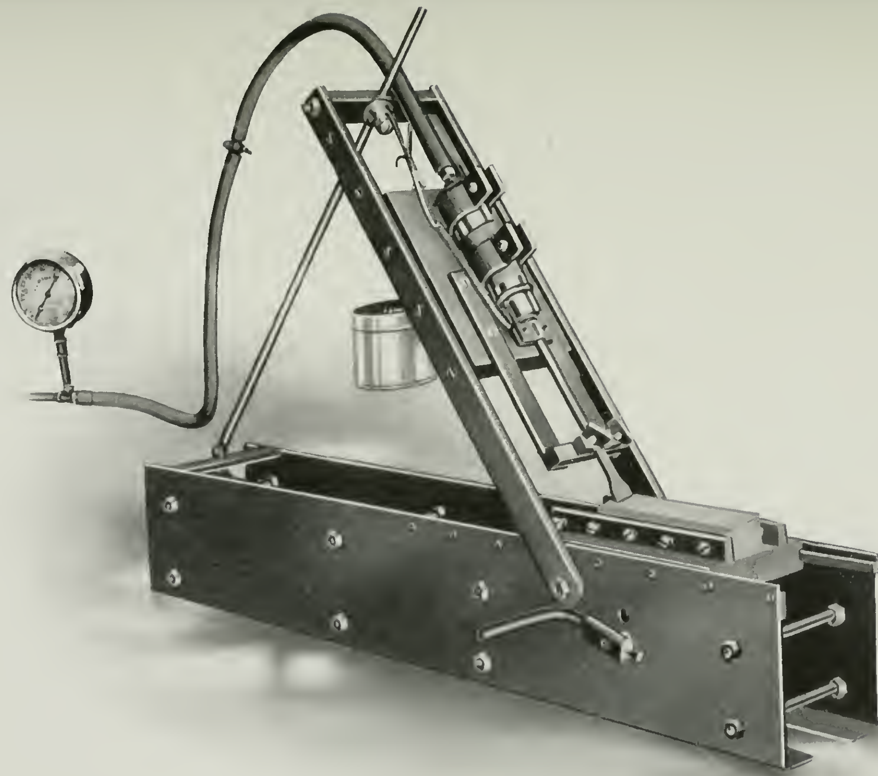
CHAPTER V.

The Cost of Dressing Building Stone.

It has already been pointed out that the nature of the bedding planes, the facility of splitting, and the ease with which stone can be broken across the grain, affect materially the price at which it can be put on the market in the form of coursing or dimension stone. An architect may, however, readily ascertain from the producer, the price at which stone in the above condition can be delivered. He is still confronted by the serious question of ascertaining the cost of reducing the rough blocks to the forms desired. So various are the factors which affect the ease of chiselling different types of stone that it seems almost impossible to establish a numerical scale which will express this factor in a satisfactory manner. Probably the best figures could be obtained by subjecting the different stones to a skilled workman, but necessarily to one who is accustomed to all kinds of stone and who is entirely without prejudice. Further, he must be familiar with the expressing of comparative results and capable of judging accurately between 50 or 100 stones at the same time. If such a man were available, there remains a strong objection to accepting his figures because there is necessarily such a large element of the "personal equation" present. It seems advisable therefore to turn to some mechanical means whereby this equation is reduced to a minimum. The rate at which stone can be sawn is considered by some architects a good guide as to its behaviour under the chisel. How true this may be in the case of a gang saw, I am unable to say, but it certainly does not hold in the case of the laboratory diamond saws with which granite can be sawn with little less rapidity than some types of hard limestone. An attempt to obtain a set of figures for this report which would express the relative ease of chiselling of the Canadian stones led finally to the adopting of the apparatus described below. It must be distinctly understood, however, that the results given are the *results obtained by this apparatus*; how closely the figures approach the results that would be obtained in actual practice by the use of different types of tools at different angles and under different strokes must be left to the judgment of the reader. To show that the figures obtained do not constitute a scientific scale, it may be mentioned that granite, under this instrument, possesses a chiselling factor of zero, which is absurd. Despite these objections the figures are relative *for the conditions described* and should be of value in deciding between the different stones tested.

The bed of the apparatus consists of two pieces of angle iron securely bolted together and screwed down to a solid block of maple resting on a concrete floor. At the top of the angle iron, planed guides are inserted which carry a travelling carriage. This carriage may be moved backwards and forwards by means of a crank actuating a series of cog wheels. The top of the carriage is provided with a longitudinal recess in which a slab of stone may be securely fastened by a series of set screws. Two stout uprights are fastened to the bed by a swivel joint and are firmly bolted together at the top. Between these uprights is placed a heavy block of steel which is capable of movement up and down on planed guides. This upright "back" can be set at any desired angle and securely clamped in position. To the face of the steel block is attached a pneumatic tool, the chisel of which is directed against the face of the slab of stone in the carriage. To prevent the binding of the chisel in the nose of the tool owing to the inclined bearing, it was found necessary to provide a guide for the chisel as near the cutting edge as possible. It was also found that the strokes of the hammer drove the chisel away from the anvil; to obviate this, springs were attached which held the chisel well up in the nose of the tool. After trying different types of chisels one was chosen having a thin blade and a smooth cutting edge, three-fourths of an inch wide. The Barre, size A, pneumatic tool was used and was operated at a pressure of 60 lbs. to the square inch. The back was inclined at an angle of 54°·30 from the bed and the block carrying the tool was counterpoised so that the instrument bore down on the stone with a constant pressure of 12½ lbs. The test was made on strips of stone two inches wide and one inch thick, which were fastened by set screws into the face of the travelling carriage. With the tool in operation, the chisel was allowed to come in contact with the stone, which was then moved forward against the chisel at the rate of three inches in ten seconds. The loss in weight which the slab of stone suffered in this operation represents the "chiselling factor" of the stone. The loss was ascertained in grams and the figures are here recorded directly as the chiselling factor of the stone. The results of these tests are tabulated in the appendix. In the case of limestones, there is a variation from 0·05 to 7·2; the sandstones vary from 0·0 to 5·6; the crystalline limestones from 0·2 to 5; and the granites from 0·0 to 0·5.

It is apparent that there are several possibilities of error in these determinations. In the first place, it is difficult to obtain chisels of exactly the same temper and to sharpen them for each operation in exactly the same manner. Further, a fine edge will produce the highest results with soft stones while a blunter edge is more efficacious with hard stones. In making the tests a fine edge was used throughout, so that the results are probably low for the harder materials, as the first few blows turned the edge and diminished the cutting power of the tool. The reduction of the "chiselling factor" to dollars and cents must be left to the builder who knows by experience what it costs to prepare any given form from at least some of the stones here enumerated. For instance, the stone from the 8 inch bed of The Thames Quarry Co., at St. Marys, is well known to the architects of Western Ontario, while the stone from Wallace's quarry, at Kingston, is equally familiar to the architects of the eastern part of the province. Both of these stones have a chiselling factor of 5·5 and they may be selected as convenient standards of comparison. For instance, the stone from Aylesworth's quarry near Newburgh has a chiselling factor of 2·75 and is therefore twice as hard to cut as the Kingston stone, and should presumably cost twice as much to dress.



Instrument used in determining the Chiselling Factor of Stone.

CHAPTER VI.

Tools and Machinery Employed in Quarrying and Dressing Stone.

The implements used in the stone industry consist of hammers, chisels and drills, and, when power is available, a number of special appliances which reduce greatly the cost of production. A general account of the more important implements is given below.

Hammers.

Striking hammer or sledge.—Weighs from 10 to 25 lbs. Used for striking drills, driving wedges, etc. (Fig. 1, No. 2.)

Buster.—Like a striking hammer but drawn out to an edge at one end. Used in making paving blocks. (Fig. 1, No. 5.)

Hand hammer.—Weighs from 2 to 5 lbs. Shaped like a sledge, but sometimes has one end drawn out to a cutting edge. Used for single-hand striking of drills, tools, etc. Hand hammers vary in design and shape for special purposes. Fig. 1, No. 4, shows the Trow and Holden drilling hammer.

Bull set.—Weighs 10 to 25 lbs. Shaped like a sledge at one end, but the other is drawn out to a narrow flat face with square edges. Used in trimming rough blocks; the square edge is held against the stone and the other end struck by a sledge. (Fig. 1, No. 1.)

Pean hammer or axe.—Weighs 6 to 10 lbs. Has two opposite cutting edges. When roughly serrated it is called a toothed axe. (Fig. 1, No. 3.)

Face hammer.—Weighs 15 to 25 lbs. Usually made with square or rectangular faces, but one end may be drawn out to a cutting edge. The most used of any hammer in the quarry, employed for roughly squaring blocks. (Fig. 1, No. 6.)

Cavil.—Like a face hammer but with one end shaped into a blunt conical point.

Mash.—A special type of face hammer used in the paving block industry. The sides are parallel towards the square face but the other end is formed into a cutting edge. Resembles the face hammer.

Side hammer.—A plane rectangular hammer used in making paving blocks. (Fig. 1, No. 7.)

Mallet.—A wooden hammer used for striking tools in working soft stone.

Pick.—Resembles a short stout pick axe.

Bush hammer.—Hammers for surfacing stone are made with a series of pyramidal points on the faces. These points may be 4, 9, 25 or 36 to the square inch. The stone is brought to a smooth, plane finish by the successive use of finer and finer hammers. The difficulty of keeping these tools sharp has led to the use of an improved form in which the cutting face is made up of a series of sharp edges, being the ends of a series of steel plates. These

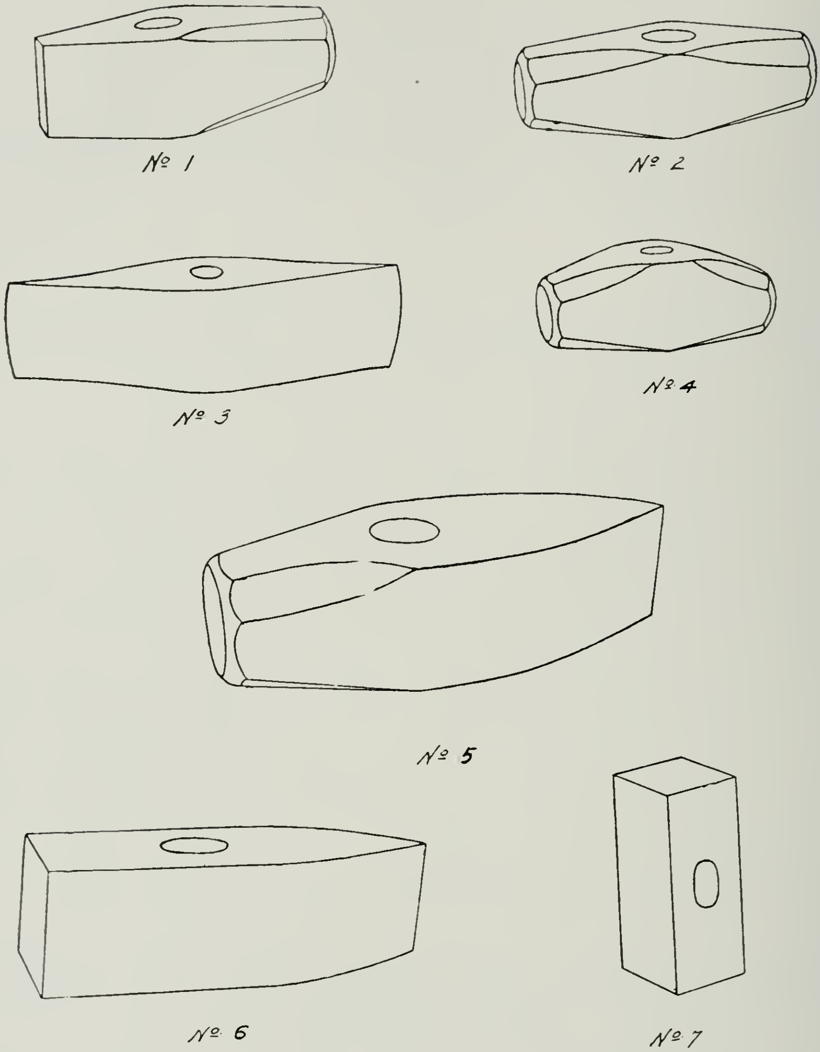


FIG. 1. Hammers used in the Stone Industry.

1—Bull set.

2—Striking hammer or sledge.

3—Pean hammer or axe.

4—Drilling hammer.

5—Buster.

6—Face hammer.

7—Side hammer.

plates are known as "cuts," which are bolted together and rest against a hardened steel "gib." In weight these hammers vary from 4 to 12 lbs.; the lighter ones are used for the finer work and may contain as many as 20 cuts to the inch, although they are seldom made an inch wide. The heavier hammers are usually about an inch wide and may contain as few as four cuts. (Plate IV.)

Chisels.

Chisel or drove.—This tool is manufactured in a great variety of widths and in different designs for different purposes. Its essential is the possession of a sharp straight cutting edge.

Pitching chisel.—The cutting face is rectangular with sharp angles. Used for trimming stone to a line.

Chipper.—A lighter tool for a similar purpose.

Set.—Practically the same as the pitching chisel.

Point.—As the name implies, this tool is drawn out to a pyramidal point. It is much used in producing the finish known as point work and generally for reducing rough surfaces before using the bush hammer.

Splitting chisel.—A great many types of chisel are used for splitting; they are all modifications of the ordinary chisel. A very thin and broad kind is used in the slate industry.

Tooth chisel.—Like an ordinary chisel but with the cutting edge toothed. Used on soft stone only. (See pneumatic tools.)

Plug drill.—A short drill, made usually of $\frac{3}{4}$ inch steel, drawn out rather fine. The type of bit varies with the stone. Used for drilling short holes for "plug and feathers" work.

In all large plants the use of the hand chisels has been greatly lessened owing to the introduction of the pneumatic tool (Plate III.) This instrument consists essentially of a steel cylinder provided with a piston to which a reciprocal motion is given by means of compressed air. The chisel is not fitted directly to the piston but is inserted in the nose of the tool. The blows of the piston are communicated to it through an anvil. A great many varieties of pneumatic tools are on the market; of these two types are recognized, the "valved" and the "valveless." They operate on air at from 50 to 100 lbs. pressure to the square inch, and are made in different sizes and of different delicacy of "touch" according to the work to be done. The chisels used with pneumatic tools, while similar to those employed for hand work, differ in some respects, and of course are made to fit into the nose of the tool and not adapted for striking. The chief forms are the following:—

Chisel.—Resembles the hand chisel. Made in various widths, both steel and bit usually varying from $\frac{3}{8}$ to $\frac{3}{4}$ in. (Plate V.)

Cleaning up chisel.—Made of $\frac{1}{2}$ to $\frac{5}{8}$ inch steel, but the cutting edge is drawn out to a much greater width. (Plate V.)

Carver's drill.—Resembles a light plug drill and is usually made of $\frac{1}{2}$ inch steel. (Plate V.)

Tooth chisel.—May have a single row of chisel teeth or may have 4, 6 or 9 teeth on a square face. Made from ½ to ¾ inch steel. This type is used for granite work. (Plate V.)

Marble tooth chisel.—Made thinner and lighter than the granite tooth chisel and with a single row of teeth. The steel is usually ½ to ¾ inches. The blade may be as much as 3 inches in width. The teeth, "bats," are usually 5, 6, or 8 to the inch. (Plate V.)

Double blade chisel.—Like an ordinary chisel but with a double cutting edge. (Plate V.)

Bush chisel.—Made on the same principle as the bush hammer. The jaws are from ¼ to ¾ inch apart. The larger ones may contain any number of cuts up to 15 and the smaller ones up to 5. (Plate VI.)

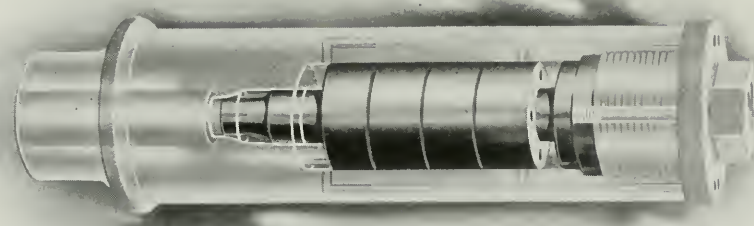
Plug drill.—Same as hand plug drill, but adapted to fit tool. (Plate VI.)

Drills and Rock Cutting Machinery.

Ordinary drills are made from steel bars of any desired length. The bit is made by drawing out the steel to a single sharp cutting edge a little wider than the steel, which is usually ¾ to ⅞ inch in diameter, although much heavier steel is occasionally used. In drilling deep holes it is necessary to use gradually smaller bits as the hole sinks. Such drills are usually held and turned by one man while another or even two others strike with sledges. In drilling short holes for plug and feathers work one man holds with one hand and strikes with the other, using the hand hammer for the purpose. Plug holes are also commonly made with the "ball drill," which is a steel rod about 6 feet long with a bit on each end; it is sometimes of increased diameter in the centre but may be quite straight. The drill is used in the manner shown in Plate XIX. Where compressed air is available an instrument known as the pneumatic plug drill is employed. (Plate IX.) This appliance is made on the same general principle as the pneumatic tool but it is much heavier in construction, weighing about 25 lbs.

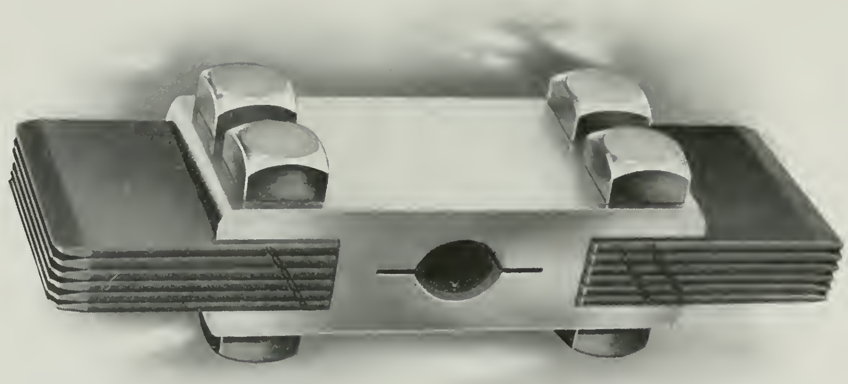
The machine rock drill has probably done more to render possible the excavation of rock on a large scale than any other appliance. The drill consists essentially of a cylinder in which a piston is driven down with the full force of the power available whether steam or compressed air. Recovery is effected by the same agent. Almost every manufacturer of mining machinery produces a drill, differing in many details, so that a close description of any one type would be out of place here. Drills are made varying in weight from 100 to 1,000 lbs., and are capable of sinking to depths of from 4 feet to over 30 feet. The price likewise varies greatly, but good drills cost from less than $200 up to $500 according to size and efficiency. The drills used may be single bitted but the cutting face is usually made either + or × shaped. As in hand drilling, smaller and smaller bits must be used as the hole deepens. It is generally found to be a matter of economy to drill larger holes than in the case of hand drilling. At The Ontario Marble

Plate III.



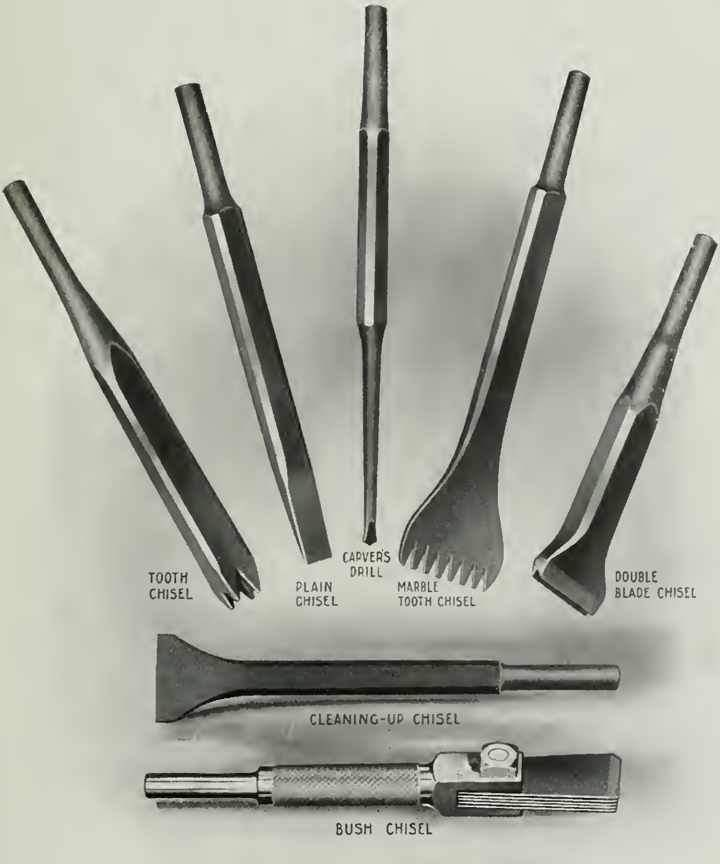
Pneumatic Tool.

Plate IV.



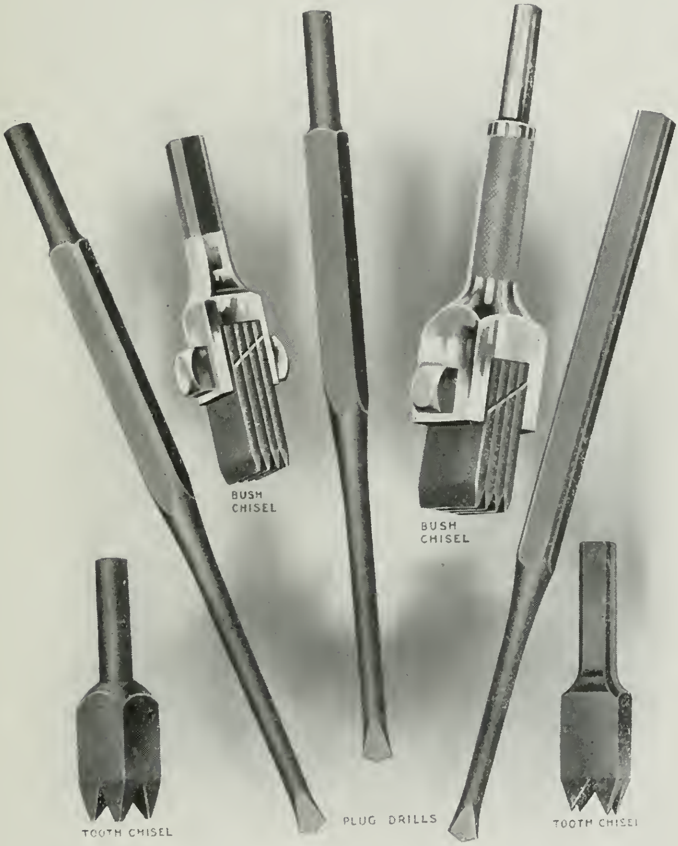
Bush Hammer.

Plate V.



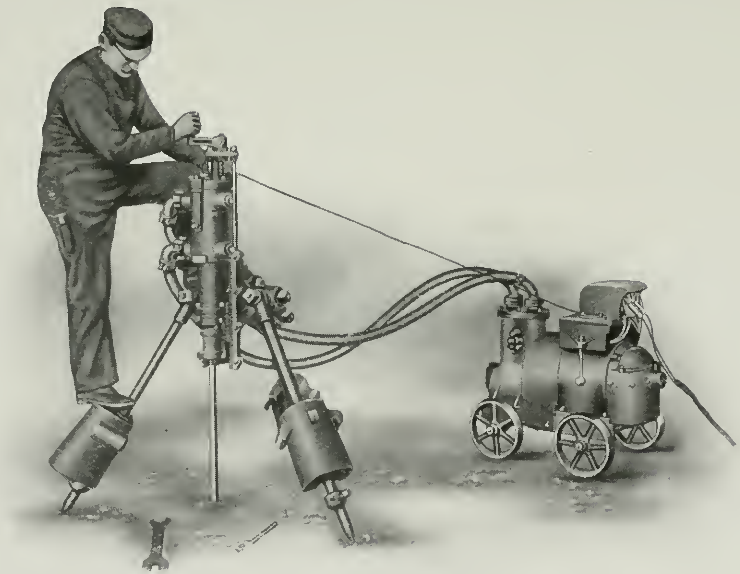
Chisels for Pneumatic Tool.

Plate VI.



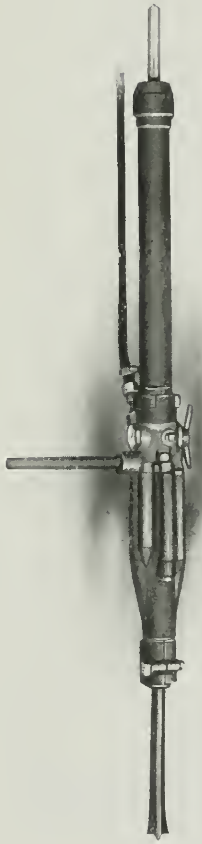
Pneumatic Plug Driller and Bushing Tools.

Plate VII.



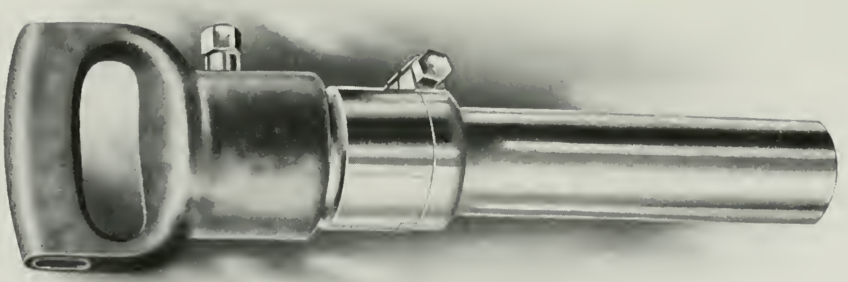
Electric Air Rock Drill.

Plate VIII.



Telescope Feed Hammer Drill.

Plate IX.



Pneumatic Plug Drill.

Company's quarry near Bancroft, the manager prefers a single bitted drill and uses a 2 inch 'starter' with the heavy machines, and a $1\frac{3}{4}$ inch starter with the light machines. At the North Lanark marble quarries a $2\frac{1}{2}$ inch + shaped bit is used with the heavier machines, and a $1\frac{3}{4}$ inch bit for plug and featherswork and for gadding. In the granite quarries at Barre, Vt., a 2 inch bit is commonly employed for the deep holes and a $\frac{3}{4}$ inch bit for plug holes. (Plate X.)

Rock drills of the above type are evidently too heavy to handle without support, they are therefore mounted on special contrivances to suit the kind of work in hand. The most commonly used mount is the tripod, the legs of which are supplied with weights to give the whole apparatus rigidity. A great many types of tripod are available, many of which possess especial features and are adapted to particular purposes. For the present purpose the "Lewis hole tripod" is of interest. This form is supplied with a planed and slotted front bar, so that three or four holes may be drilled close together and strictly parallel. After the holes are drilled a special bit with a rectangular face "broaching bit" is used to knock out the material, "cores," between the holes. In mining the drill is frequently mounted on a straight bar of steel known as a mining column; this bar is wedged against the walls of the drift and thus held rigid. For quarrying purposes this type of mount is seldom used.

In order to drill a number of parallel holes along a straight line the instrument is mounted on a "quarry bar" (Plate XI), which consists essentially of a heavy bar of steel supported at each end by two adjustable and weighted legs. The drill may be moved along the bar by rack and pinion, or, in the case of light drills, by hand. For horizontal or highly inclined drilling the drill is mounted on the quarry bar in a horizontal or inclined position. A lighter type of drill thus mounted is usually employed for horizontal holes made with the intention of "raising" a block. This operation is known as *gadding* and the instrument as a *gadder*.

In very hard rock, such as granite, where a channelling machine cannot be employed to advantage, channels are cut by the use of rock drills and quarry bars. The holes should be sunk, particularly if deep, as close together as possible, so as to have a minimum amount of core, which is afterwards broached out as in the case of Lewis holes. Quarry bars are also used for gadding, usually with a light type of drill, some of which are especially constructed for the purpose so as to permit the drilling of holes as near the floor as possible. Special gadders are made in which the drill is mounted on a standard along which it may be moved. This standard is hinged to a wheeled base and may be set at any angle from horizontal to vertical.

Rock drills are commonly actuated either by steam or compressed air and in most cases are constructed to work equally well with either. Of recent years many attempts have been made to apply electricity to the operating of rock drills. These attempts have not always met with a full measure of success, but the type of drill described below is gaining favor with many operators.

The Temple-Ingersoll Electric Air Rock Drill.—The drill proper is very simple, consisting practically of the cylinder and piston only. It is driven by pulsations of air from a small detached duplex air compressor. Each end of the drill cylinder is connected by hose to one pulsator cylinder; there is therefore no exhaust, the air being used over and over again. The Doolittle and Wilcox Co., of Dundas, have installed some of these machines in the quarry. An electric air drill of this type, by the Canadian Rand Co., is shown in Plate VII.

The hammer drill is constructed on the same principle as the pneumatic tool only much heavier. The drill is not reciprocated with the piston but is struck by the piston through an anvil. This type of drill is very useful for light work. The Canadian Rand telescope feed hammer drill is shown in Plate VIII. The plug drill, Plate IX, is an application of the same principle.

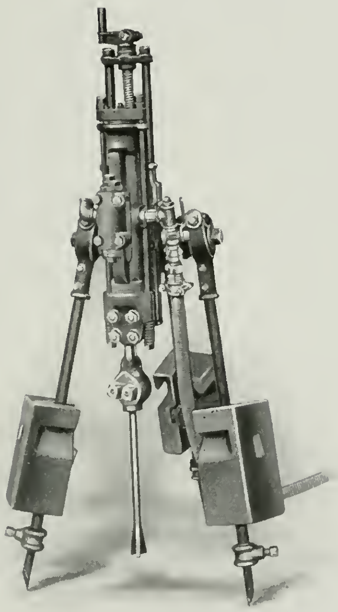
Channelling Machines.

A "channel" is a lineal cut of any desired length and of a depth varying from a few feet up to about 15 feet. The width of the cut varies with the depth; a shallow channel may be only a couple of inches wide, but a deep one must be started with a width of four or five inches when made with a channelling machine.

Channels may be made with the rock drill and quarry bar by drilling a series of holes along a line and "broaching out the cores." Instead of using the rock drill, diamond boring machines travelling on an adjustable track, were formerly largely employed, particularly in marble quarrying. The walls of the older parts of the Vermont Marble Co.'s quarries show the work of this machine. The quarry bar and rock drill are still largely employed in granite quarrying, but for the softer stones—limestone, sandstone, and marble—the modern direct acting channelling machine is universally used. Not only is this machine employed for quarrying purposes, but it finds a large field in excavating rock for canals, etc. The straight and clean-cut wall produced by these machines and the unshattered condition of the wall rock recommend them to contractors on such work as well as to the quarryman proper. A number of channellers are now in operation in the new Livingstone cut for deep draught vessels in the Detroit river.

The channelling machine consists essentially of a truck travelling on rails and provided with a chopping engine capable of delivering powerful blows to the rock as the truck is moved slowly along the rails. By repeated trips back and forth the gash is gradually sunk to the desired depth. The size, weight, power, and design of channellers vary greatly with the character of the rock on which they are intended to operate and on the angle from the vertical which the channel is to assume. It is needless to say that much ingenuity has been displayed by different manufacturers in providing machines of constantly increasing mechanical excellence, of greater flexibility, and of more special adaptation to particular purposes. The simplest kind of

Plate X.

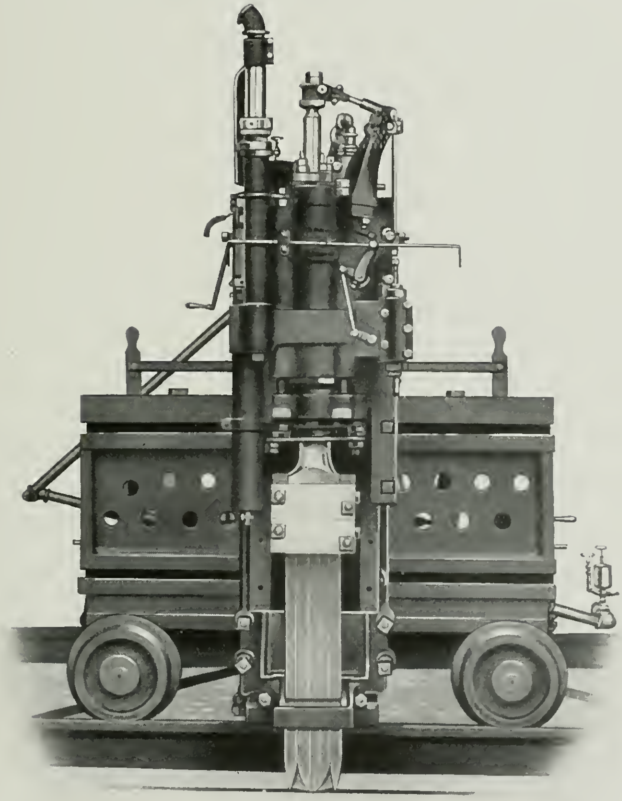


Sullivan Rock Drill mounted on adjustable tripod.

Plate XI.

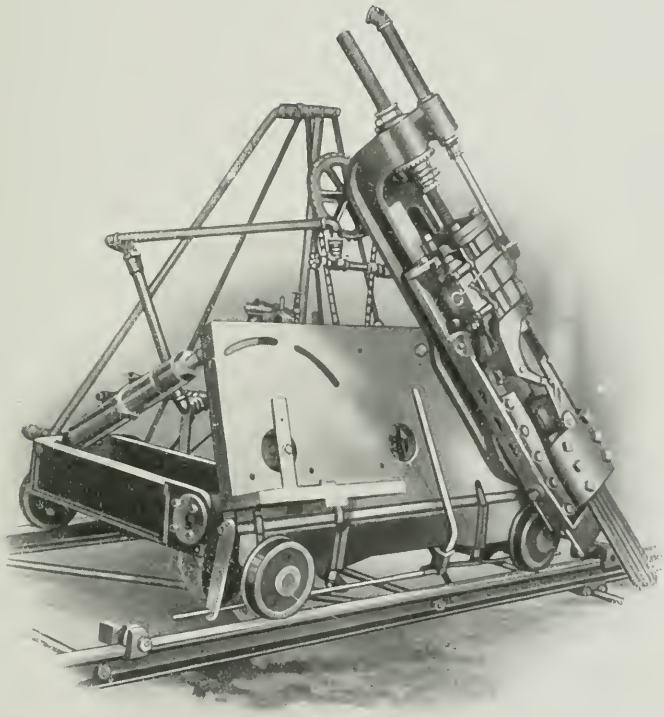
Rock Drill mounted on Quarry Bar.

Plate XII.



Ingersoll-Sergeant H9 Track Channeller.

Plate XIII.



Sullivan Swivel Head Channeller.

channeller, designed for cutting vertical channels only, has the chopping engine attached to a solid upright standard, which is capable of being moved along a heavy steel frame situated at one side of the truck. This arrangement permits the engine to be set at work at either end or at the middle of the truck. In order that an effective blow may be delivered as the channel sinks it is necessary that the engine be provided with vertical motion up and down the standard. In some makes of machines, this feeding down of the cutting apparatus is effected by a separate engine, in others it is done by a feed screw, actuated from still another engine, which, in both types, is also employed to move the whole apparatus along the rails. In using steam as the motive power, the mounting of a boiler on the same truck as the engines is advised by manufacturers as it ensures a supply of dry steam at a constant pressure. Further, the steam is conducted to the cylinders by iron pipes provided with swivel joints whereby the loss and annoyance attending the use of flexible hose is avoided. Nevertheless, in some plants, steam is generated in stationary boilers and conveyed to the machines by hose. In using compressed air from a central station, it is advisable to increase its efficiency by heating it in a special heater mounted on the truck. Manufacturers claim that from 20 to 25 per cent less air is required if the heater is used than if the air is allowed to enter the cylinders direct.

The cutting apparatus consists of a gang of drills, usually five, attached by special mechanism to the end of the piston rod. The drills are made of rectangular steel and are bolted together in line with the channel. The steel is usually $\frac{7}{8}$ inch by $1\frac{1}{2}$ inch for limestone and marble, and $\frac{7}{8}$ inch by $2\frac{1}{2}$ inch for sandstone. Sometimes also different sizes of steel are used in the same set. The drills are all single bitted but the cutting edges are arranged in a special manner. The two outer and the middle bits are placed transverse to the channel but the intermediate ones are drawn out diagonally on the face of the steel. The cutting face of the gang has therefore the following arrangement of bits | \ | / | . Channellers with two sets of gangs on the one truck were formerly employed, but they have largely given place to the single gang machine as here described. With regard to this type of "rigid head" or "fixed back" channeller, the following information from trade catalogues may be of interest:—

Diameter of cylinder	$6\frac{1}{2}$ to 8 in.
Length of stroke	9 in.
Distance of cut from wall	6 to 9 in.
Distance from centre to centre of cut with machine reversed	6 to 7 ft.
Inside gauge of truck	4 ft. 4 in. to 5 ft. 3 in.
Weight without boiler	8,000 to 9,000 lbs.

With regard to efficiency, it is claimed by the makers of a certain type of heavy machine, that it has a record of 700 square feet in oolitic limestone in a day of 10 hours. In sandstone of medium hardness an efficiency of from 260 to 300 square feet per day is claimed. (Plate XII.)

The rigid-head channeller is incapable of cutting in any direction but the vertical; the necessity of making inclined cuts has led to the production of the swivel head or swing back type. (Plate XIII.) In these machines the upright frame or "washboard" is hinged on the truck, whereby the cutting steels may be directed outwards at an angle. In some cases also, the upright support carrying the engine may be directed at an angle in the plane of the washboard. As the presence of a boiler on the truck would interfere with the swinging of the back, these machines are usually supplied with power from an outside source. The extreme angle of inclination possible varies with different makes, being determined by the amount and arrangement of machinery on the truck. One make of machine allows an inclination of 15° with a boiler and 45° without. Swivel head machines are also made with removable back braces so that the cutting apparatus may be directed in a horizontal direction. For this purpose also special undercutting channellers may be procured in which the engine normally works in a horizontal plane.

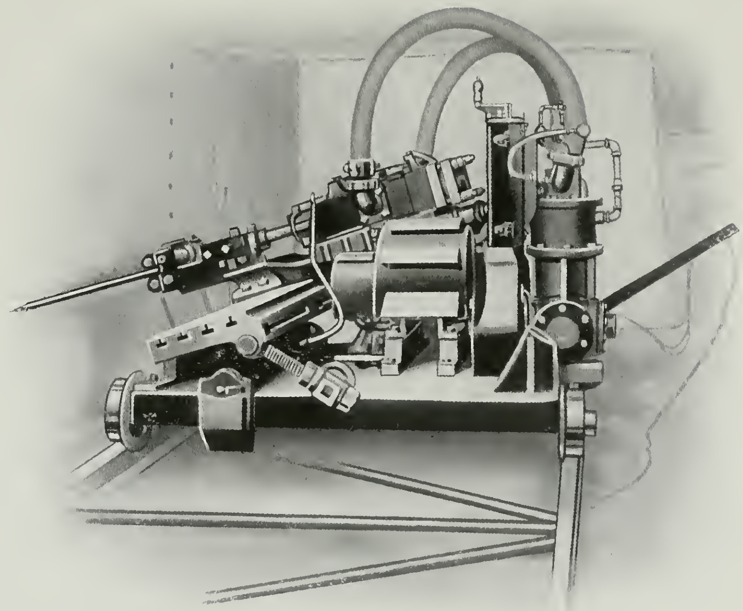
Many manufacturers supply a light type of machine, possessing the greatest possible flexibility, and especially adapted to work under the varying conditions of marble quarrying. A very light machine, designed to work on hillsides, is constructed in much the same manner as the swivel head machine, but it is provided with a machine cut rack on the inner sides of the rails, into which fit gears on the truck. A modification of the track channelling machine is seen in a light type which dispenses with the track, the engine being mounted on a double quarry bar. The carriage is moved along the bar by means of a travelling feed nut and screw, this apparatus being actuated by a separate engine. The specifications of the various types of adjustable channellers are roughly indicated below.

Diameter of cylinder	$3\frac{1}{2}$ inches to 7 inches.
Length of stroke	$6\frac{1}{2}$ inches to 9 inches.
Weight	1900 to 8,000 lbs.

The channelling machine at work is illustrated in Plates XXVII and XXVIII. The clean cut walls of the quarry and the square blocks of stone produced are shown in Plate XXX and Plate XXXI.

The Gibson-Ingersoll "Electric-Air" Track Channeller (Plate XIV) is constructed on the same principle as the "Electric-Air" rock drill, *i.e.*, electricity is used to actuate a tandem single acting pulsator, from which the pulsations of air pass directly, by means of two short lengths of flexible hose, into the ends of the cylinder of the cutting engine. The air is therefore not exhausted but travels between pulsator and engine in a closed circuit. Many of these machines have been installed in some of the largest marble quarries in the United States and are said to have a greater efficiency per unit of power consumed than either the steam or air driven type. The manufacturers (Ingersoll Rand Co.) recommend the use of either a 220 volt direct current, or a 220 volt, 3 phase, 50 or 60 cycle alternating current.

Plate XIV.



Gibson-Ingersoll Electric Air, Swing Back, Swivel Head Channeller.

The Gang Saw.

The gang saw frame consists of four upright posts of wood or preferably of structural steel, securely bolted to the foundation and strengthened by the necessary side pieces and braces. The space inside the four posts is occupied by a hopper shaped depression in the floor. From the bottom of this depression a pipe line leads to a well to carry off sand and water during the operation of the saw. A horizontal steel sash, of sufficient size to swing freely between the posts, is connected by four hangers to two horizontal steel rods (sway bars). These rods are not fastened to the four posts but to blocks (guide saddles) which slide up and down on guides attached to the posts. The sash, swinging freely by means of the hangers can therefore be raised or lowered by moving the saddles up or down in their guides. This movement is effected by long screws passing through the saddles. The screws are actuated by a special ratchet mechanism which can be readily adjusted to any speed desired. A reciprocating motion is communicated to the sash by means of connecting rods known as "pitmans." There may be one or two pitmans to a machine. In single pitman machines, the pitmans are fastened to the sash at the centre of the head piece; in double pitman machines the connexion is made to the middle of the side pieces. The advantage of the latter system is in saving room as the saw can be placed closer to the actuating crank shaft. Motion in communicated to the pitman by means of a belt driven crank, connected to a heavy fly wheel. (See Plate XV.)

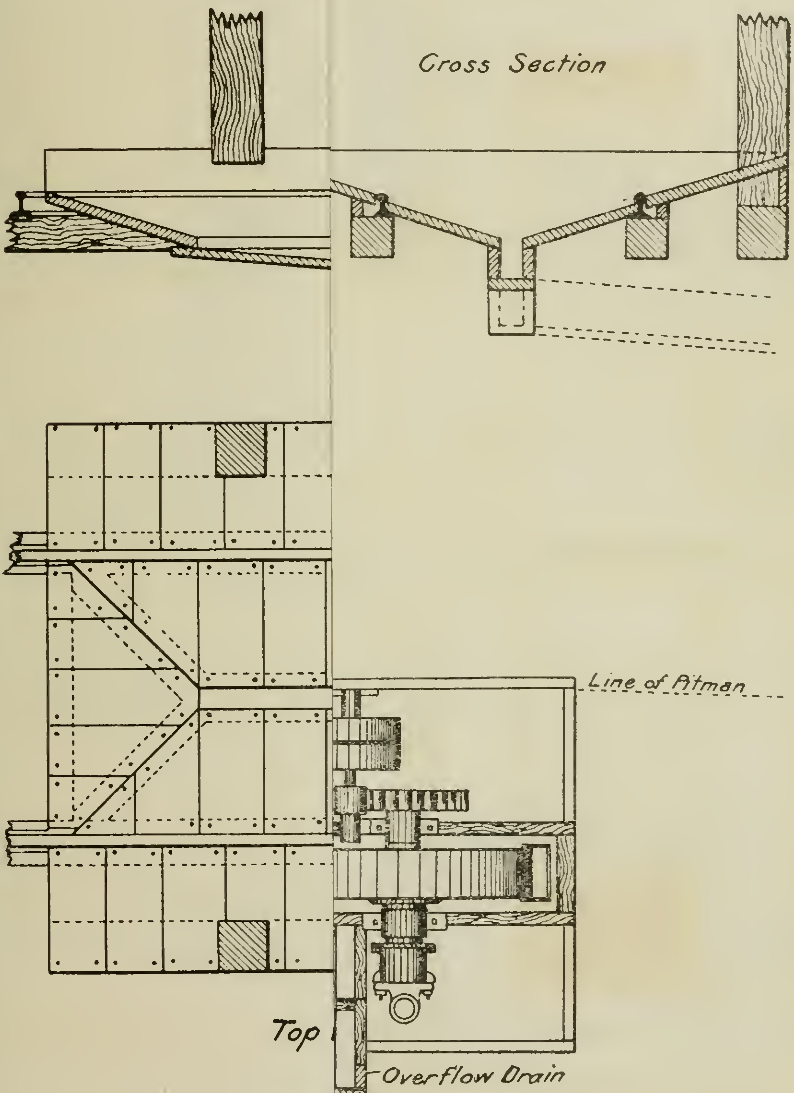
The actual saws are bands of soft steel, three inches wide, and three-eighths of an inch thick. The saws are stretched between the head pieces of the sash and held firmly in position by keys. The saws being adjusted to cut to the desired size, the sash is raised and the block of stone placed in position over the hopper. The screw feed is adjusted to lower the sash at a rate which experience has found suitable to the number of saws in the gang and the character of the stone to be cut. The saw is set in operation and a constant supply of sand and water is fed uniformly over the stone by special distributors. The cutting is effected by the sharp sand which gets into the cuts and is ground between the saw blades and the stone. The overflow of sand and water falls into the hopper beneath the saw and is conducted by pipe to a central well, whence it is pumped by special apparatus and again distributed to the saws.

The type of gang saw described above is generally employed with marble and limestone; for hard sandstone and granite, however, some modifications are found necessary. In the first place a maximum amount of strength and rigidity is given to the frame, and to the working parts. The sash is not supported by hangers but runs on ways between shoes in the saddles. The saw blades are heavier and are notched on the cutting edge. Chilled shot or crushed steel is employed instead of sand.

Gang saws are made in different sizes; manufacturers are generally willing to supply them to order of any size desired. The standard saw of the Patch Mfg. Co., Rutland, Vt., will saw a block of stone 10 feet long, 6 feet wide, and 6 feet high. The longest saw in the mills of the Vermont Marble Co. is 13 feet 6 inches, and the shortest 12 feet. The reciprocating motion is about 18 inches, and an effective speed about 90 strokes per minute. The rate of cutting will of course depend on the number of saws in a gang and as this number varies from 1 or 2 up to as many as 70, no general figures can be of much value. The speed also varies greatly with the nature of the stone being cut. The best idea of efficiency may be gathered from actual experience extending over a considerable period of time. I was informed that 12 gangs turned out 3,746 cubic feet of sawn material in one month at the Central Rutland mill of The Vermont Marble Co. This figure is the actual mill return and represents general work, slabs, blocks, etc. At the mill of the Missisquoi Marble Co. gangs of 40 saws, working on blocks 6 feet long, sink about 1 inch per hour. Once started, the operation of a gang saw is practically automatic and continues night and day until the cut is complete. One man is capable of superintending the operation of six machines, but several men are required, and much time is consumed in setting saws and adjusting the blocks. As one gang of men can do this work for many machines it is obvious that a large mill has a great advantage over a small one. Special makes of sand pumps are used to carry the water charged with sand or shot from the well to the saws. These are either specially designed centrifugal pumps or the so-called *spiral feed* pumps, of which the "Hawley" and the "Frenier" may serve as examples. The arrangement of the gang floor showing the well, the drains and the pump, is shown in Fig. 3, which has been reproduced from the catalogue of Frenier and Son, Rutland, Vt. Figure 2 shows the detail of the construction of the pump. If the feed is to go to several saws, a "distributor" is required to properly regulate the flow to each saw. This consists of a small tank, placed at a level above the saws, from which a separate pipe, controlled by a valve, passes to each gang. In order to scatter the sand and water properly over the blocks of stone a spreader is used. This appliance consists of a light wooden frame which is hung over the block, and which is capable of being raised or lowered according to the height of the stone. The sand and water falls from the distributor pipe on a sharp upper point of this frame, and, by means of strips of wood, is evenly distributed over the block.

The Rubbing-bed.

For smoothing the sawn blocks or slabs of the softer stones, the rubbing bed is employed. (Fig. 4). This machine consists essentially of a round horizontal steel plate to which a rotary motion is given either by overhead or underneath gear. The plate may be from 4 to 14 feet in diameter, and it is driven at a rate of from 44 to 48 revolutions per minute (Vermont Marble Co.) Only the smaller sizes are made with underneath gear. Surrounding the plate is a wooden box to prevent the scattering of water and sand. The block of stone is placed face down on the rubbing bed, and if necessary, is weighted to make it bear properly. Sand and water are supplied and the stone left in position


Cross Section
Line of Pitman
Top
Overflow Drain

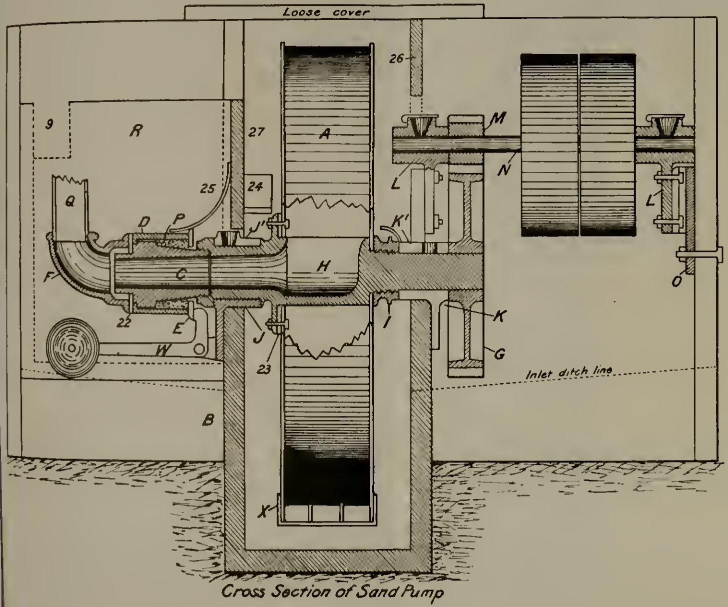


Fig. 2. Details of Frenier spiral feed sand pump.

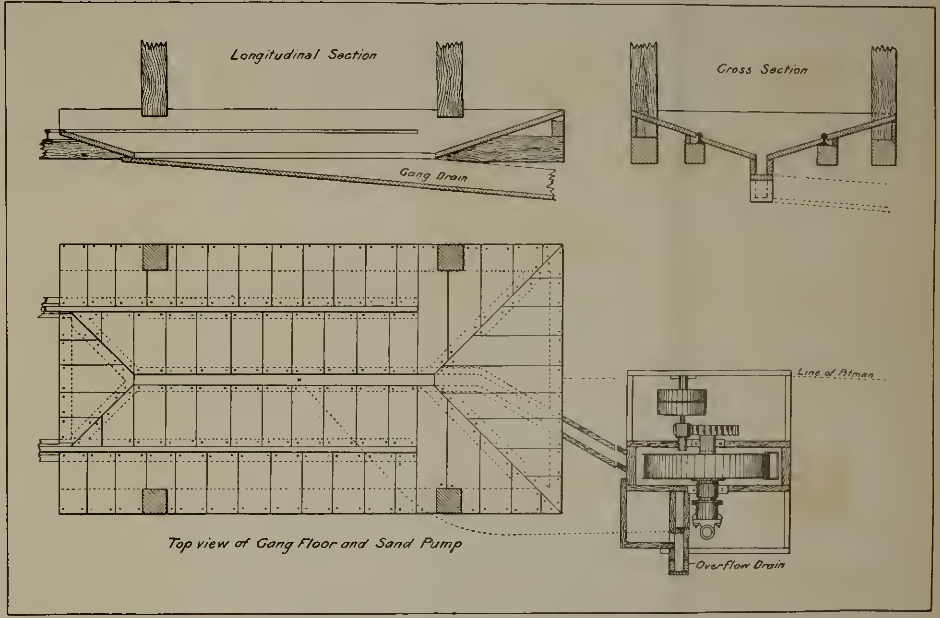
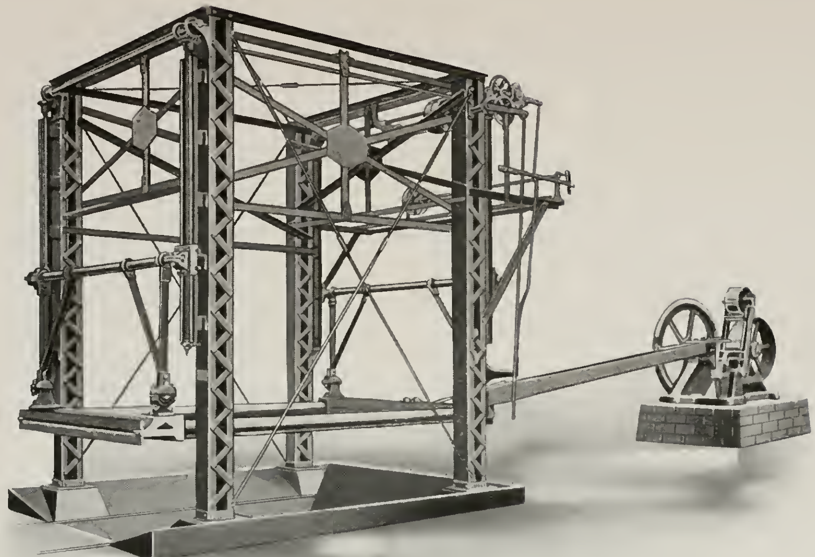


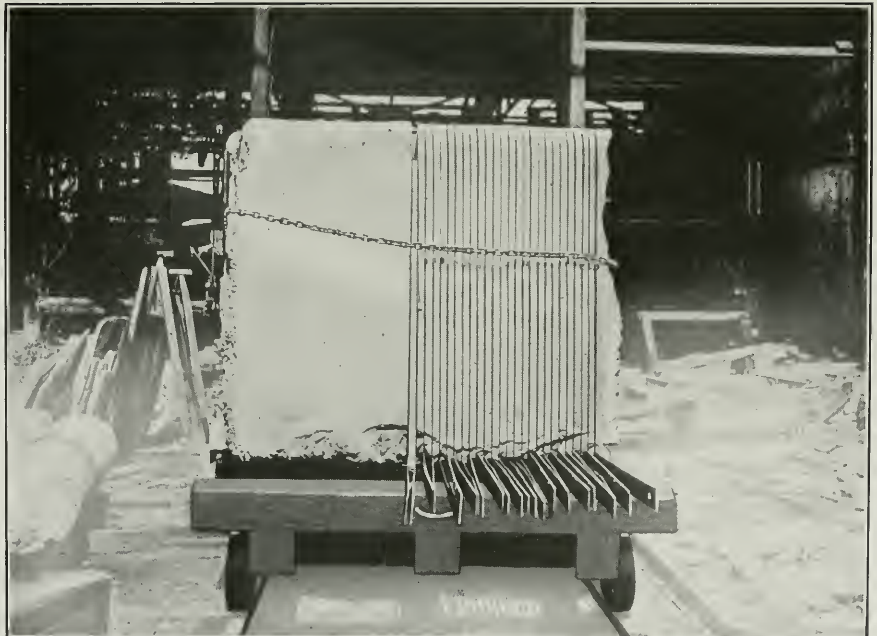
Fig. 3. Plan of gang floor with Frenier pump.

Plate XV.



Patch Merriman Steel Frame Gang Saw.

Plate XVI.



Block of Marble partly sawn into slabs on gang truck, with the saws left in place.

until sufficiently reduced. The finish produced by the rubbing bed is sufficient for outside work in marble and is known as the "sand finish."

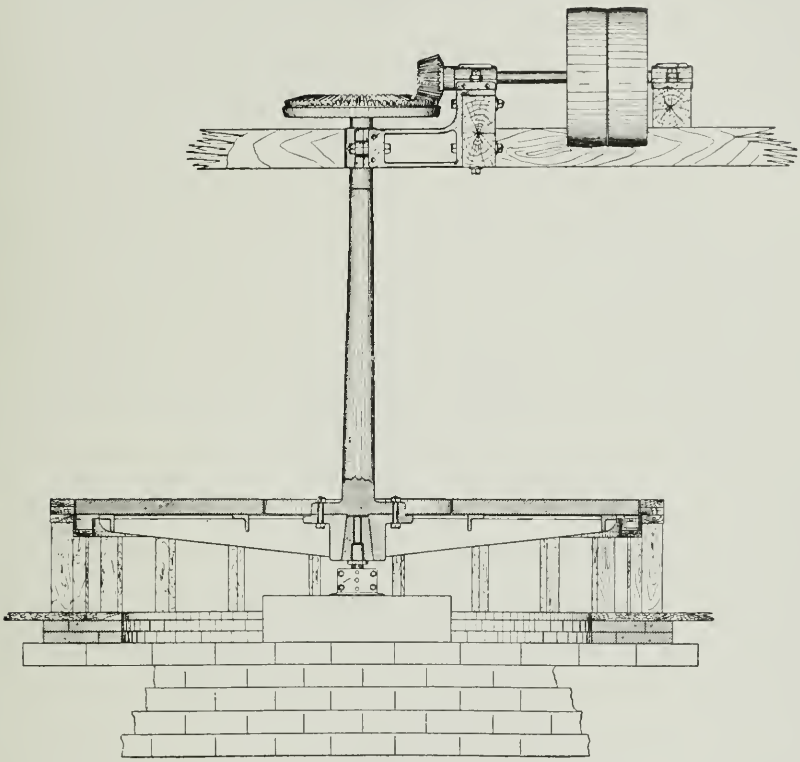


Fig. 4. Overhead rubbing bed.

Gritting and Polishing Machines.

For further smoothing, the stone is taken from the rubbing beds to the gritting machines and thence to the polishers. Whether for granite or for marble the construction of all these machines is much alike, but the weight and rigidity vary with the class of work. Marble gritters and polishers differ in the character of the abrasives used and the speed of rotation. For granite the "head" or actual polishing surface is quite different.

The machine (Plate XVIII), consists of a horizontally rotating disc to which different types of head may be attached. The upright spindle of the disc rotates in bearings at the end of a jointed and adjustable arm so that the polishing surface may be moved over all parts of the underlying stone. For marble gritting the heads are about 12 inches in diameter, with blocks of abrasives arranged in a radial manner with interspaces between. The abrasives most generally used are bricks of carborundum, of which finer and finer grades are introduced as the polishing proceeds. Heads with bricks of black or Scotch hone are used for the final operation. The gritters are run at a speed of 200 revolutions per minute. The polishers or buffers have heads of felt about 20 inches in diameter, and operate at a speed of 400 revolutions per minute. As in hand polishing, putty powder is used to produce the gloss.

In granite work, the rubbing bed is not employed to a great extent, the stone being brought to a plane surface either by hand, or by the surfacing machine. (Plate XVII.) This apparatus consists of an upright standard borne on a stout, wheeled base and provided with an adjustable arm or carrier bar which bears a pneumatic tool at its extremity. In operation, the instrument is wheeled close to the block of granite to be surfaced and the smoothing effected by means of various chisels in the pneumatic tool. Tooth chisels, cross chisels, and bush chisels are generally employed. The heads used in the granite gritting machines are made of iron and are about three feet in diameter; instead of being equipped with blocks of abrasives as in the case of marble they have, on the cutting face, a spiral band of iron about one inch high and one inch broad. This band runs in a spiral manner from the centie outwards to the margin of the wheel, hence they are known as *scroll* wheels. In operation they are fed with crushed steel and water, producing what is known as the "iron finish." For furthei smoothing a similar head, but with concentiic iings instead of the spiral, is employed. The abrasive in this case is No. 80 or No. 90 carborundum powder. For polishing, the head is equipped with a felt surface, which is not continuous but made in radiating sections with interspaces. Putty powder is used with this machine to produce the final gloss.

The Diamond Saw.

For making single cuts, as in fitting together the various parts of a piece of work, the diamond circular saw is employed. In this machine a great diversity of patterns may be obtained. The essential feature of them all is, however, a rotating steel disc in the margin of which a number of carbons are mounted.

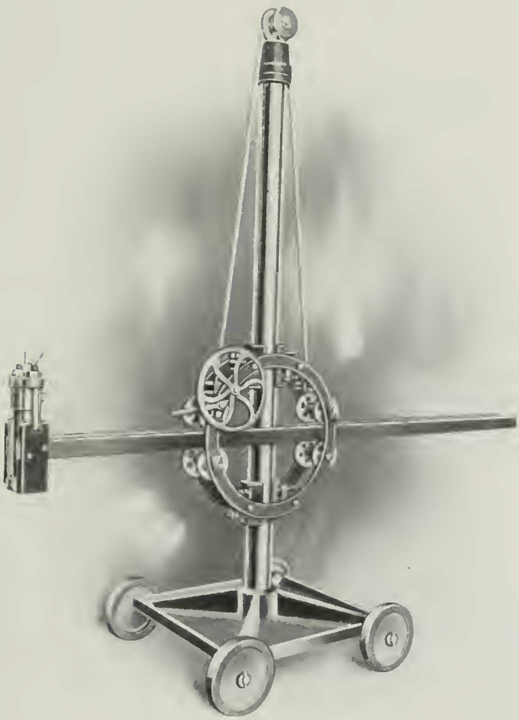
The Planing Machine.

Planing machines are devices whereby a block of stone may be moved to and fro on a horizontal bed and at the same time be subjected to the cutting edges of chisels. They are made in a great number of sizes and designs and are driven either by worm or screw gear. These machines are of necessity heavy and at the same time must be capable of very delicate adjustment. The planers of the Patch Manufacturing Co. vary from 16,500 to 50,000 lbs. in net weight.

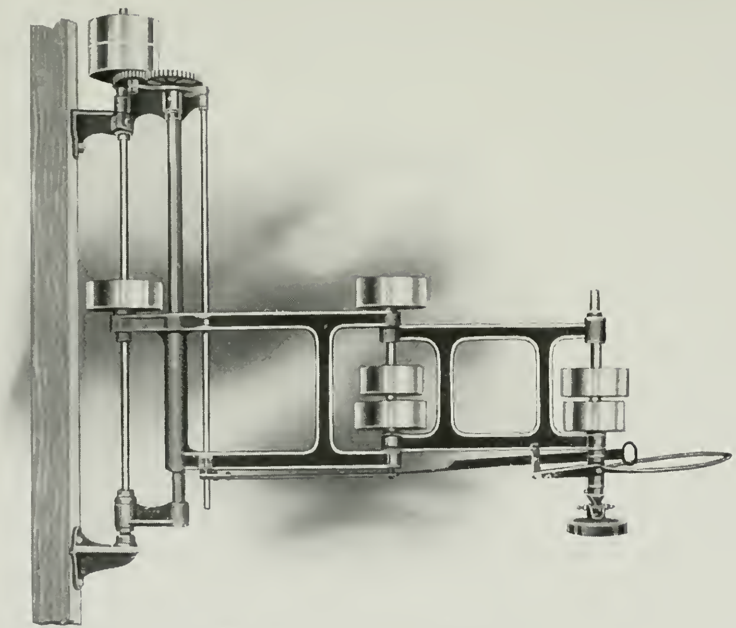
The Slate Saw.

This is another sawing device, suitable only for the softest material such as slate and soapstone; it does not differ materially from an ordinary circular

Plate XVII.



Pneumatic Surfacing Machine.



Marble City Polishing Machine.

saw, except that the work is carried against the saw on a platten actuated by worm and rack. The saw blade may be plain or provided with inserted teeth according to the nature of the material to be cut.

The Carborundum Wheel Machine.

A recent improvement in stone working machinery, which is rapidly becoming deservedly popular, is the carborundum wheel machine. In this machine the work is borne forward and back on a platten as in the planing machine, but instead of being subjected to the action of chisels it is fed against revolving wheels of carborundum. These wheels may have a plain edge of varying width or they may be fashioned in the reverse form of mouldings, etc. By using thin carborundum wheels the same machine may also be employed as a saw. The efficiency of these instruments is said to be much greater than that of the planers which are used for the same type of work.

The Reel Machine.

The reel machine is employed for countersinking and other work of a similar kind. The stone is borne on a horizontal platten which is capable of universal movement in its own plane. This movement is given by means of two worm or screw gears operating at right angles to each other. The cutting is done by special bits fitted into a vertical spindle as in the case of an ordinary machine drill. As the platten moves forward the work is brought against the rotating drill and a swath is cut the width of the bit in the stone. The depth of the swath that can be cut depends on the kind of bit, the character of the stone, and the weight and rigidity of the whole apparatus. Most marble works are equipped with reel machines, which are almost indispensable for the kind of work indicated.

Special machine drills set up in a vertical position are employed to bore holes in plumbers' slabs, and in slabs for electrical switchboards, etc.

Lathes.

Lathes for turning columns and other round work are much used, but as they are only modifications of ordinary lathes, no special comment is required. In granite work the fixed tool of the ordinary lathe is replaced by a steel disc, which is set obliquely against the stone and rotates with it.

CHAPTER VII.

The Quarrying of Stone.

It has already been pointed out that various geological features, as well as the nature of the stone itself, must be carefully considered before deciding on the point at which a quarry is to be opened. It is manifest also that many economic questions will arise in connexion with the locating of a quarry. In quarrying stone, as in the case of the exploitation of metalliferous deposits, the ordinary enquiries as to the cost of labor, fuel, machinery, and material for construction must of necessity be made. The length of the haul to the rail and the distance to the centres of consumption, are, in the case of stone, evidently of greater importance than with metallic products. The owner of a metalliferous deposit can ascertain almost exactly the maximum price to be obtained for his ore when delivered at any point, and further, he is sure of being able to dispose of his product at current rates. The miner is therefore in a position to calculate whether he can stand the cost of haulage or not. The prospective operator of a quarry is in a far less enviable position, for he has to find a market for his product, he has to educate the public to its use, and he has to compete with other stones. Further, he has to make allowances for the variations in public taste. Besides this, the cost of haulage is essentially more important to the quarryman because, in the case of stone, it bears a much higher ratio to the intrinsic value of the product than it does in the case of metalliferous ores.

The question of drainage is extremely important in locating a quarry; given the same market, it is impossible for a wet quarry to compete with a dry one, as the additional expense of keeping the excavation free of water soon compels the cessation of operations. When possible, therefore, a quarry should be located where natural drainage is presented. If such a place cannot be found on the property, the operator must reckon with the cost of pumping, and he should assure himself that his competitors are not more favorably situated in this respect.

The amount of useless material lying above the beds it is desired to exploit is often a controlling factor in the successful quarrying of stone. At the present time it costs from 20 cents to 25 cents per cubic yard to remove such overlying material, except where expensive machinery is available. The ordinary small operator must therefore calculate whether the market value of his product is sufficiently high to stand this additional expense.

The geological and economic conditions which should control the actual locating of a quarry having been carefully considered, and the best possible site chosen, the method to be employed in actual quarrying must be decided on. The plan of operations will vary greatly with the nature of the stone, with its position, with the proposed scale of operation, and with various economic conditions. Granite is not quarried in the same way as marble;

heavily bedded stone requires different treatment from thin bedded examples; highly tilted strata cannot be attacked in the same way as horizontal beds, and well jointed stone requires different treatment from that in which joints are few or wanting.

A small operator, with a limited market, can not afford to install a plant which might be advisable for a larger quarry with a ready market for a greater output. In quarrying, as in most industrial operations, a larger plant, equipped with modern machinery, means a cheaper production, but it also means a larger production of a commodity for which no market at a distance can be found owing to the high rate of transportation. Of course, in the case of the finer stones, the ratio of the cost of transportation to the intrinsic value of the material becomes less, thereby permitting a longer haul and justifying the installation of a larger plant. The greater number of quarries in the country are producing the commoner grades of limestone on a small scale. It is useless to tell the owners of these quarries that their methods are wrong. It is certain that they quarry badly, but they do their work in the only way that can be made to *pay* under the conditions.

The proper method of quarrying varies, as already stated, with the nature of the stone and the conditions under which it occurs. There are, however, two primary principles that are of importance in all cases. The first of these is that the stone must be submitted to as little jarring and shock as possible; to this end, the use of explosives is to be kept down to a minimum. The effect of a blast is apparent in the shattering of the rock, but a less apparent result is the production of incipient cracks throughout the blocks. These cracks eventually assist the entrance of water into the stone whereby its life is materially shortened. Another bad effect of blasting is the weakening of the cementing material which binds the grains together; sandstones which have been quarried by blasting are known to resist the progress of decay for a shorter time than those obtained by other means. Blocks of stone procured by blasting are always more or less irregular and require subsequent shaping. A large amount of debris is also made, the cost for the removal of which has also to be reckoned with. When the beds are heavy and the parting planes tight, it may be an economic necessity to resort to blasting. In such cases the shattering explosives, such as dynamite, should be avoided and powder only used, preferably according to the following method. Along the line in which it is desired to part the rock, a series of holes is drilled almost to the bottom of the bed. The size and distance apart of the holes will, of course, vary with the distance from the free face, with the thickness of the bed, and with the character of the stone. A small amount of powder is used in each hole, and a space (6 inches to 1 foot or more) is left over the powder, above which the hole is tamped tight. A piece of crumpled paper shoved down to the right point will suffice to keep the desired space open provided that the tamping is very gently done for a short distance above the paper. The holes are then fired simultaneously by a battery. Surprisingly large blocks can be dislodged in this manner by the use of only a handful of powder in each hole.

The same reasons that render the use of explosives inadvisable should likewise deter quarrymen from the practice of hammering stone with heavy hammers, which develops incipient cracks and impairs the durability of the product.

The second general principle to be observed in quarrying building stone is the necessity of properly seasoning the output. Buckley remarks, "Men do not build houses out of green lumber, neither do they build them out of 'green' stone."

The rocks of the earth's crust always contain a greater or less amount of water; this is true not only of the stratified rocks but of the harder and more compact igneous rocks as well. The water thus included in stone is well known to quarrymen and is referred to as "quarry water." On removing the stone from its bed, it is necessary for this water to dry out or for the stone to "season." The drying out of the quarry water is apparently accompanied by a deposition, towards the surface of the block, of certain salts held in solution, whereby the stone is rendered less susceptible to the future absorption of water. It is very important that the stone should not be allowed to freeze during the period of seasoning, as the force exerted by the change of the water into ice is sufficient either to disrupt the stone or to greatly lessen its power of resistance. It is well understood in the slate industry that the stock must be split immediately after quarrying, and that it must, on no account, be allowed to freeze, as the result is ruinous. I have in mind a quarry in Ontario producing an excellent grade of limestone, the proprietor of which is well aware that the freezing of his product before seasoning is attended not only by injury, but by pronounced disintegration. Although proper precautions, in this respect, are much more important with some stones than with others, it may be regarded as a general principle that unseasoned stone is unfit for use. This warning is not without point, for I have seen perfectly green stone built into the walls of buildings of considerable architectural pretensions. Should the winter's frost overtake these structures before seasoning is complete, a really excellent stone will receive an undeserved bad name

In the case of certain stones, particularly sandstones, the process of seasoning adds greatly to the hardness. In such cases it is the practice to carve the stone before the quarry water has evaporated but not to place the product in the wall before the seasoning is complete.

"The season of year during which a stone was quarried, may, in certain cases be worthy of note. It is well known that many stones can be quarried with safety only during the summer season, but Grueber goes a step farther and states that while the best time for quarrying is during the summer, the freshly quarried material should not be allowed to lie in the sun and dry too quickly, as it is liable thereby to become shaky. This he regards as particularly likely to happen to sandstone. Stone quarried in winter, or during very wet seasons, is liable, according to this authority, to have but slight tenacity when dried, and to remain always particularly susceptible to the effects of moisture. Finally, he states, a stone is liable to disintegration if built immediately into a wall without seasoning. Stones for carved work are to be quarried in the spring, since such longest retain their quarry water, and this, if once lost, no subsequent wetting can restore."[1]

The actual removal of stone from the quarry can be effected in various ways. Perhaps the simplest example is in the case of stone so well bedded and jointed that the use of crowbar and wedge is all that is necessary. Much thin bedded limestone is quarried in this way, and even the harder stones such as gneiss, occasionally present exposures capable of being exploited in the same way. An example of such occurrence is to be seen in a gneiss quarry near Parry Sound which has been operated in this simple manner for three years.

Thin bedded stone, destitute of joints, may, in some cases, be cut into sections of convenient size by striking along the desired line of parting with chisel and maul. Flag stones are thus shaped and removed with the greatest facility in Cook's quarry near Wiarton.

The commonest method of breaking stone from beds of reasonable thickness is that known as "plug and feathers," which process is also largely used for the subsequent breaking of the blocks to the size required. The method (Plates XIX and XX) consists in drilling a number of holes along the line on which it is desired to split the stone. Into each hole is placed a pair of half-round pieces of iron with the convexities outwards. Between the irons (feathers) are introduced steel wedges which are driven down until they pinch. The pressure is gradually applied by striking along the line of the wedges, care being taken that no undue strain is exerted by any one wedge. The size, depth and distance apart of the holes depend on the nature of the rock, the thickness of the bed, the distance from the face, and the relation of the desired line of cleavage to the grain of the rock. Experience must determine these factors for any given stone, but the practice, in certain cases, will be indicated in the portion of this report devoted to a description of individual quarries. Almost incredibly heavy stone may be evenly broken in this manner; for instance, granite blocks four feet thick are sometimes parted by drilling the holes six inches apart and not more than three or four inches deep.[2]

In the case of certain stones which break very easily and in which the holes are therefore placed far apart, it is found convenient, in order to prevent irregular fracture, to give the proper direction to the cleavage by "grooving" the holes. This is done by driving down a tool which grooves the sides of the round holes in the direction of the desired line of parting. In the preparation of dimension stone from quarry blocks, experience has shown that the plug and feathers method may be used alone or that it may with advantage be combined with other devices. The most satisfactory plan must be worked out for each stone by itself.

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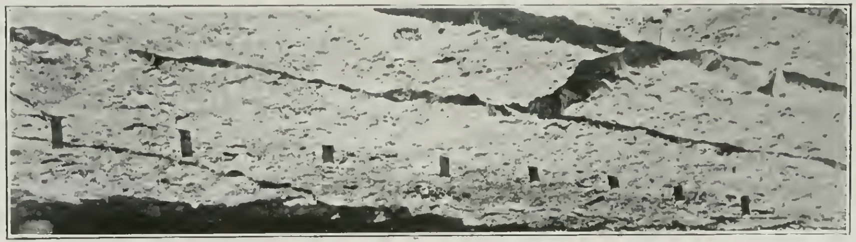
[1] Stones for Building and Decoration, Merrill, p. 456.

[2] An interesting account of the introduction of this method into America, and of more ancient means of accomplishing the same work, is given by Merrill in Stones for Building and Decoration, p. 391 et seq.

Plate XIX.

Drilling Plug Holes with Ball Drills, Longford Quarries.

Plate XX.



Plug and Feathers in position for splitting rock, Longford Quarries.

If the beds of stone are too heavy, or if the parting planes between the beds are too tight, the plug and feathers method cannot be applied with advantage to the actual quarrying of the rock. It is under such conditions that the quarryman is tempted to resort to the use of explosives. In the case of granite, modern science has not yet produced a method, of economic application, which is entirely independent of the power of explosives. All the softer kinds of stone can, however, be successfully and economically quarried by actually cutting the block from the solid rock. Whether it will always pay to employ these refined methods is open to question, but there is no doubt that in the case of high grade stone no other process is permissible. While it might be possible to carry on this cutting out process by hand labour,

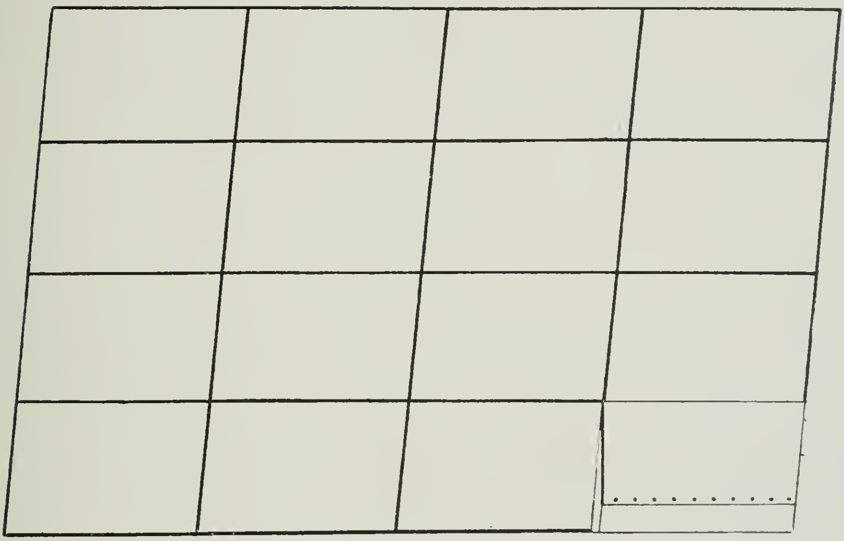


Fig. 5. Showing the floor of a quarry cut into rectangular blocks, the key block removed, and holes bored for raising the next block.

such an attempt could not possibly meet with financial success. The work is always done by the special power machinery, a description of which has been given in a previous chapter. These machines are of various types and are capable of cutting grooves (channels) of any desired length and to depths of ten feet or more. Further, they may be set up so as to cut vertically, horizontally, or at any desired angle. Just how the cutting operation shall be carried on depends on the character and position of the beds. To assume a general case, let us imagine the stone to be horizontal in position, free from either bedding or jointing, and to be of good quality to the surface. The method of procedure is to run a series of parallel vertical cuts the length of the desired opening. The distance between the cuts and their depth are made to correspond with the size of the blocks required. A second series of cuts is then made at right angles to the first set, whereby the stone is divided into a number of rectangular blocks of the required size. These blocks are still attached at their under side, and no means of access is yet afforded for their removal. To obtain this means of access it is necessary to remove one of the corner blocks, known as the "key block." This is sometimes done by shattering the block with powder, whereby the stone is destroyed. Another plan is to cut diagonally through the rectangular piece with a machine and to lift out the half thus set free. In some cases the block may be broken off by driving wedges into the channel on one side of it. The key block, once removed, a space is afforded in which to conduct operations for the freeing of the neighboring block. If the space is sufficient, a machine may be introduced and a horizontal channel made under the second block. This method is, however, seldom resorted to, a more common practice being to drill a series of horizontal holes under the block by a special drill known as a "gadder" (see p. 83), and raise the section by means of "shims and wedges," which are simply plug and feathers on a larger scale. These horizontal holes may be parallel to each other or they may spread out in a fan-like manner, according to the experience with the rock in question. (Plate XXII, also Fig. 5, page 97.)

The Quarrying and Dressing of Marble.

Although marble usually occurs in beds, the planes of bedding are very indistinct, so much so, that the various beds are recognized more by a change in the character of the stone than by any distinct line of parting. The layers may be in an almost horizontal position or they may be inclined at any angle up to the vertical. The method of quarrying will of necessity vary with the position of the beds; it seems advisable therefore to describe briefly the plan of operations in two extreme cases—one of steeply inclined and the other of horizontal beds.

As the quarries of the Vermont Marble Co., at West Rutland, Vermont, and those of the Missisquoi Marble Co., at Phillipsburg, Quebec, are operated on the two types of deposits in question, and as both these quarries represent the most modern practice, it is proposed to describe them as examples of the two types.

The quarries of the Vermont Marble Co., at West Rutland, are situated along a belt of marble which runs in a direction a little east of north. Near the surface, the beds dip eastward at an angle of about 15°. With depth, however, this dip rapidly increases until the beds are almost vertical in position. At a depth of about 200 feet, the "vein" again assumes a lower angle of inclination and with a dip of about 14° passes into the mountain to the eastward. In most cases the upper 50 or 75 feet are of little value on account of alteration by percolating water; through this portion an opening 40 or 50 feet square is made in the following way. The surface, after being divested of debris and soil, is at once attacked by channelling machines and the excavation carried down vertically 4 to 8 feet. The opening is then enlarged by directing the channels outwards on all four sides at an angle of about 25°

from the vertical. This is continued until the good marble is encountered, at which stage the excavation resembles a truncated pyramid and has the advantage of clean cut walls, thus obviating the necessity of future scaling. (See Fig. 6.)

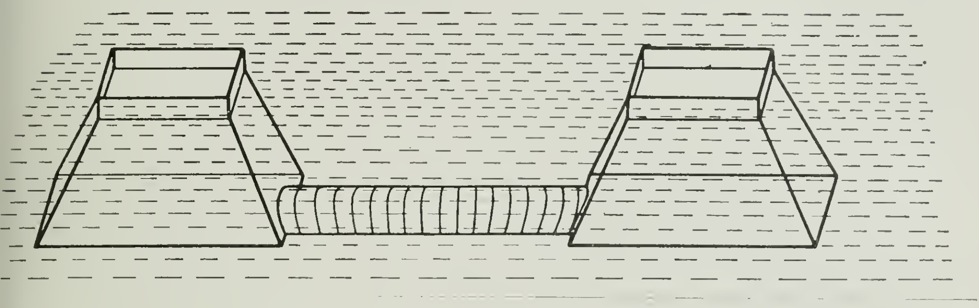


Fig. 6. Method of opening a quarry in the form of truncated pyramids connected by tunnel.

At the base of this opening, on the two sides facing the strike of the beds, tunnels are driven through the poorer upper material, by the careful use of mild explosives. These tunnels may extend along the strike for any desired distance and they are made of no greater size than will permit the introduction of a channelling machine. Along a line about 18 inches or 2 feet above the floor of the tunnel a channel is cut in the wall throughout its length. This cut is made about 6 or 8 feet deep and at such an angle that it will intersect the plane of the tunnel's floor at its termination. Another channel is then cut in the wall as nearly as possible in the plane of the floor. This cut will evidently intersect the former one at a low angle and consequently

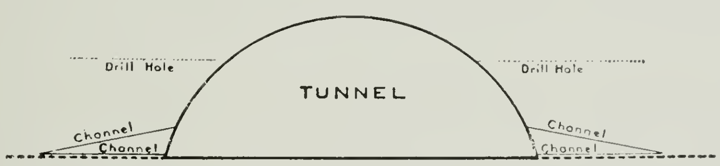


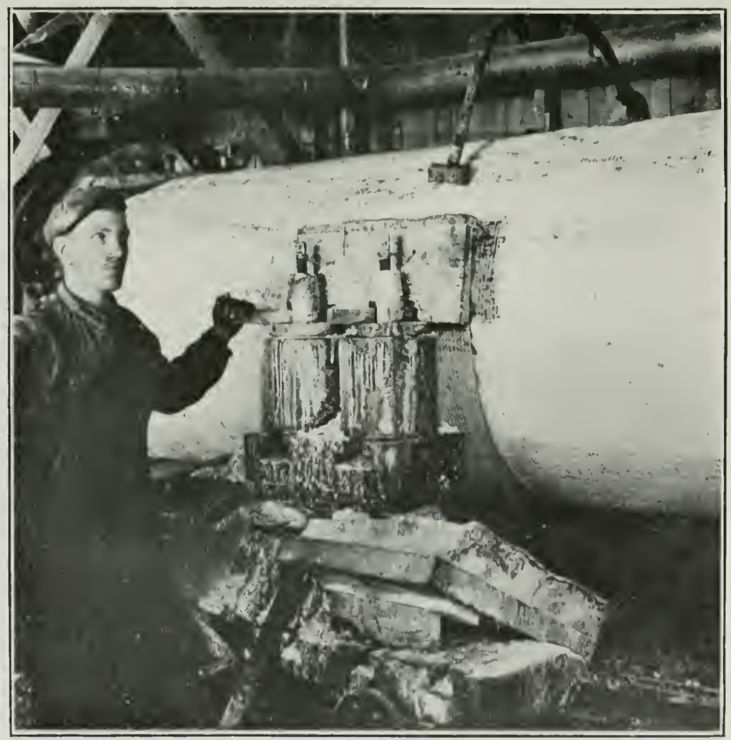
Fig. 7. Method of extending a tunnel laterally.

a long wedge shaped section is set free and is at once removed. Four or five feet above the gash thus made a line of drill holes is run in a horizontal plane, and by the use of mild explosives the intervening material is broken down. (See Fig. 7.)

By a repetition of this process the tunnel may be enlarged laterally for an indefinite distance. Whether the floor is left horizontal or is made to incline must be determined by the dip of the beds. If the beds are horizontal or vertical or inclined at a high angle, the floor is kept horizontal; if, however, the dip is moderate, the floor is made to coincide with it. All the material so far removed is either useless or of inferior quality. The care exercised in this introductory work is justified by the following facts; first, the underlying valuable marble is not injured by explosives; second, the walls are clean cut and a minimum of overburden has been removed; third, the material left between adjoining openings of the kind just described serve as pillars to support the hanging wall as the quarry is increased in depth; fourth, the small size of the openings to the surface permits of the entrance of less surface water than in the case of ordinary open quarries, and reduces the danger of injury to workmen by falling objects. For the removal of the valuable marble thus exposed, the channelling machine is first employed to cut the stone by lengthwise and crosswise trips into whatever size blocks may be desired. These cuts are usually made about 6 feet deep, but they sometimes extend to a depth of as much as 15 feet. The key block is removed by drilling a line of holes diagonally through it and removing the half thus set free. The space made available by the removal of the initial block of a course is sufficient to accommodate a gadder, whereby a line of holes 8 inches apart is drilled in the face of the next block. These holes are usually aligned on the plane of separation of different types of marble. "Raising the layer" is effected by driving wooden plugs into the holes and splitting the plugs by iron wedges. In this manner the quarry may be sunk vertically to any depth by the removal of successive courses. (Plates XXIII, and XXIV.) Having reached the depth at which the almost vertical beds again assume a more gentle inclination, side tunnels are run down the dip in the same manner as in the case of the original tunnel along the strike. In enlarging these tunnels laterally care must be taken to leave sufficient material between adjacent tunnels, and the same precaution must be observed in removing the valuable marble beneath. (Plate XXVI.) During the 80 years that these quarries have been in operation, various types of machine have been used. An account of the improvements introduced from time to time is without the province of this report, but a brief account of the apparatus now being installed may be of interest as illustrating the best modern practice on the other side of the line.

In the first place it is the intention of the company to electrify the whole quarrying plant as well as the mill machinery. Consequently both channellers and drills are to be actuated by electricity. After various trials the company has decided to use that type of drill and channeler which is actuated directly by air which is compressed individually for each machine by a small electrically driven compressor. At the time of my visit 15 machines of this kind were in operation (Gibson Electric-Air Channellers by the Ingersoll-Rand Co., Plate XIV), and the company intends to adopt this type throughout the quarries. The practical efficiency of these machines is about 160 square

Plate XXI.



Turning a 45-ton block of Marble, Proctor, Vt.

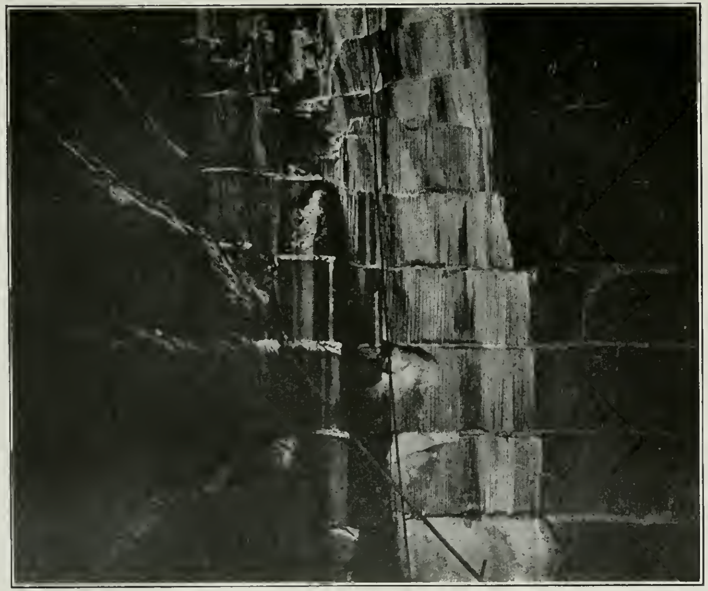
Plate XXII.

Raising a block of Marble by Shims and Wedges.

Plate XXIII.

Older part of one of the Quarries at West Rutland, Vt., showing the method of Quarrying on highly inclined beds and the work of the Diamond Boring Channeller.

Plate XXIV.



Older part of one of the Quarries at West Rutland, Vt., showing the method of Quarrying on highly inclined beds and the work of the Diamond Boring Channeller.

feet of channel in a day of 10 hours. They strike 290 blows a minute, cut $\frac{1}{4}$ inch deep, and travel forward $\frac{3}{8}$ inch between strokes. Ingersoll-Rand drills are employed for the most part, each drill being actuated by air from a small electrically driven compressor by the General Electric Co. Drills on quarry bars, whether used for vertical boring or for gadding, are similarly equipped.

The quarry blocks are raised by derricks and they may be loaded directly on flat cars for transportation to the various mills or to the stock yard. The yard at West Rutland is equipped with a crane which spans a railway track, the blocks being piled on both sides. About 10,000 blocks were piled in this yard at the time of my visit. A further idea of the magnitude of the operations may be gathered from the fact that the company uses 5 locomotives, 8 box cars and over 300 flat cars for transporting the stock from place to place. Travelling derricks are also employed for loading and piling. A favorite type is one made by the Industrial Works, Bay City, Mich., having a capacity of 5 tons at 12 feet radius, and $1\frac{1}{2}$ tons at 25 feet. (Plate XXV.)

An excellent water-power near Proctor furnishes energy for the various units of the complicated plants; a general idea of the development and distribution of this energy may be gathered from the following table:—

Central Station at Proctor:
- Three Turbines
L. C. Morris & Co., Philadelphia.
- Three General Electric Alt. Cur.
1,200 H.P. Generators.
Amp. 902; Speed 514; Volts, full load, 480.
- Transformers
480 to 11,000 volts.

Transformer Station at West Rutland

Nine Gen. Elec. Transformers:
Type W.O.; Form H;
Cycles 60.
Capacity 150 K'wtts.
Volts 10,000 to 3,300.

Mill

Motor Motor Motor
Operates on
3,300 volts
and
develops
200 H.P.

Twenty-four
gang saws.

Transformer
11,000 to 460 volts.

Gen. Elec. Co.
Induction Motor
Type I; Class 12-260-600.
Form K; Cycles 60; H.P. 360.
Volts 440; Amperes 438.

Gen. Elec. Co.
Constant Current
Generator
Form L; Amperes 962; Speed 600.
Type M.P.; Class 6-250-600.
Volts, no load 220;
full load 260.

Channellers and drills.

Other transformer Stations.

The blocks from the quarries are shipped to the trade in the rough state or they are cut into finished articles by the producers. It is the practice of the company to conduct this portion of their business in different mills according to the use that is to be made of the finished product. Interior, exterior, and monumental departments are recognized, but as the operations differ in detail only, it will suffice to review the general method of procedure. The marble is first cut to the desired size by means of gang saws, which are all of Patch manufacture and are equipped with the Frenier spiral feed. If it is desired to finish the sawn blocks or slabs with plane surfaces they go next to the rubbing beds whereby the surfaces are rendered quite flat. The final polishing is effected by treating the surface with abrasives of gradually increasing degrees of fineness. In conducting this operation by hand five substances are successively employed as follows:—

(1) Coarse sandstone from Ohio.
(2) Blue grit from Nova Scotia.
(3) Red grit from Nova Scotia.
(4) Pumice.
(5) Hone.

Hones are of different kinds, the commonest being the Scotch hone and the black hone. They are both fine grained shales. The final gloss is given by putty powder (oxide of zinc). Oxalic acid is also used if the marble is free from "flint," whereby the time required to raise the gloss with putty powder is much reduced. Oxalic acid cannot be employed with marble in which are any hard streaks, as the corrosion (burning) of the marble causes the harder material to stand out in relief, "raises the flint." While hand polishing must still be employed for all marble objects of complicated design, it is superceded by machines for plane work. The gritting machines (see page 89) do their work by means of carborundum powder of increasing degrees of fineness and are followed by a polishing machine using a felt buffer with putty powder.

The three machines, already referred to—gang saws, rubbing beds and polishing machines—may perhaps be regarded as essential, many other appliances are, however, installed in the mills of the company. The more important of these follow:—

Lathes.—For turning pillars, vases, etc. At the time of my visit 14 monoliths were being turned for the building of the Curtis Publishing Co., Philadelphia. The unfinished block weighed 45 tons, the columns being 30 feet 6 inches in length. (Plate XXI.)

Planers.—For surfacing, cutting mouldings on cornice stones, etc.

Reel machines.—For countersinking, etc.

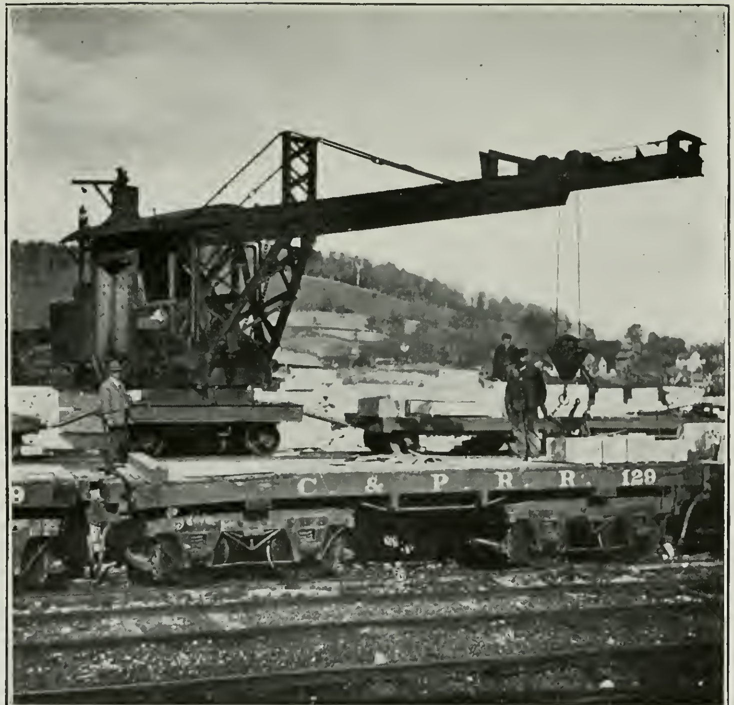
Carborundum wheel machines.—Used for much the same purposes as the planers which they threaten to displace.

Diamond saws (circular).

Pneumatic tools.—For dressing and carving.

Many appliances of a minor nature for cutting and squaring tile, for cutting oval holes in slabs, etc.

The company procures a very desirable, sharp sand near the Proctor mill; it is brought across the river valley by ærial cable.



Locomotive Crane loading Marble Blocks, West Rutland, Vt.

Plate XXVI.

Marble Pillars left to support roof in tunnelling, West Rutland, Vt.

The property of the Missisquoi Marble Co. is situated near the line of the Vermont Central Railway, at Phillipsburg, Que.

The belt of marble extends in a direction about north and south for a distance of three miles. The average width is about a mile so that a practically inexhaustible supply of material is available. The quarry was opened by the present owners after a careful and exhaustive inquiry into the method of procedure in the more important American quarries. We may therefore safely regard both system and plant as representing the best modern practice.

As the beds are practically horizontal, dipping only about 15° to the east, the actual quarrying consists simply in cutting the floor of successive courses into rectangular blocks by means of channelling machines in the manner already described. The quarrying plant consists of 7 Sullivan 6½ channellers, 2 Sullivan U.X. channellers, 1 quarry bar, and 5 air drills. The channellers are operated by superheated steam at 525° and are capable of cutting from 60 to 80 square feet in a day of ten hours. Plate XXVII shows a channeller at work in this quarry, and Plate XXVIII shows the same operation in the quarry of the North Lanark Marble and Granite Co. Plate XXX shows well the kind of work performed by these machines. The key block of a course is cut into halves by the channeller and the pieces broken from the bed by driving wedges into the channels. All the blocks are hoisted by means of a wire cable passed horizontally around the middle. No difficulty is experienced in introducing the cable into the channels around a block, so that a section, once freed from the bed, can be directly lifted without the additional labor of working it out from its original position in order to apply other kinds of grasping. Another advantage of this method of hoisting is that the block naturally turns on edge and it is therefore deposited on the car in the position in which the slabs are usually cut.

Except for these modifications no particular interest attaches to the actual quarrying of the marble as it is the same as that usually employed for all horizontally bedded stone of reasonable hardness. The subsequent handling of the quarry blocks is however effected by a plant which is in some ways quite unique, but which, on the whole, may be taken to represent the best modern practice.

Instead of using derricks to lift the blocks from the quarry the company has installed a crane which extends the full length of the opening (400 feet) and 40 feet beyond at each end. The width of the span is 100 feet, the same as the width of the quarry. The frame work of the crane is of steel and is borne on concrete pillars which are flush with the wall of the quarry. The frame is built in sections of 20 feet, so that, should it be required to extend the length of the opening, additional sections may easily be added. The crane is provided with two hoists, one capable of lifting 30 tons, and the other with a capacity of 5 tons. Electrical power is used to drive the machinery. The crane was designed and installed by the Dominion Bridge Co., of Lachine. By the use of this appliance a block can be picked up in any part of the quarry and placed either on a small car (gang truck) for transport to the mill or on railway cars for shipment. (Plate XXXI)

The mill buildings are erected close to the quarry; the superstructure is of steel and the foundations and piers of concrete. The two mills, each 345 feet by 45 feet, are placed in parallel position with a space of 60 feet between. This space is roofed and constitutes the working yard, Plate XXXII. An electric crane with a lifting capacity of 25 tons, commands the entire yard and is capable of travelling at a rate of 350 feet per minute. (Dominion Bridge Co.) Close to the face of each mill and extending the full length of the yard are tramways on which travel the "transfer cars." In the centre of the yard is a standard gauge track on which railway cars may be loaded with the finished product. The gang truck, bearing a block from the quarry, is brought on a tramway to the end of the mill yard where it passes on to a larger car known as a "transfer car." This car carries both truck and block along the face of the mill to the desired point opposite a saw. From the transfer car, the truck is then run, on rails provided for the purpose, directly under the saw, so that the cutting operation is performed on the same truck which received the block from the quarry. Eighteen Patch Merriman single pitman gang saws are installed. The length of the stroke is 18 inches and the saws are operated at the rate of from 90 to 110 strokes per minute. In cutting slabs it is customary to use 40 saws in a gang, under which conditions the efficiency is about 1 inch per hour. The hopper under the saw is constructed of concrete. Sand and water are fed to the machine by the Frenier Spiral Sand Feed and Standard Distributor, one of these pumps serving two saws. In addition to the gang saws, the mills are at present supplied with three rubbing beds, one planer, and one carborundum machine, all by the Patch Mfg. Co., as well as various pneumatic tools by Trow and Holden, Barre, Vt. The ground plan of quarry, yards and mills is shown in Fig. 8, and a general view of the plant in Plate XXIX.

Steam is generated by two Jenckes 100 horse-power boilers and by two 165 horse-power boilers made by John McDougall, of Montreal. The fuel used consists of two parts of bird's-eye anthracite and one of slack, consumed under forced draught. For developing power three engines are employed as below:—

One Jenckes Corliss, 100 horse-power compound engine.

One Bellis and Morcom, high speed compound engine.

One Bellis and Morcom, 420 brake horse-power compound engine.

The high speed engine is directly connected to a 12 K.W. generator, by the Allis-Chalmers-Bullock Co. Electrical energy is also produced from a 220 K.W. generator by the Lancashire Dynamo and Water Works.

The cranes, some of the saws, and the finishing and blacksmith shop machinery are operated by electricity. A complete lighting plant is also provided.

Compressed air is furnished by two compressors—a small one by the Canadian Rand Co., and a large one by the International Steam Pump Co.

A supply of clear water is obtained from a deep artesian well on the property.

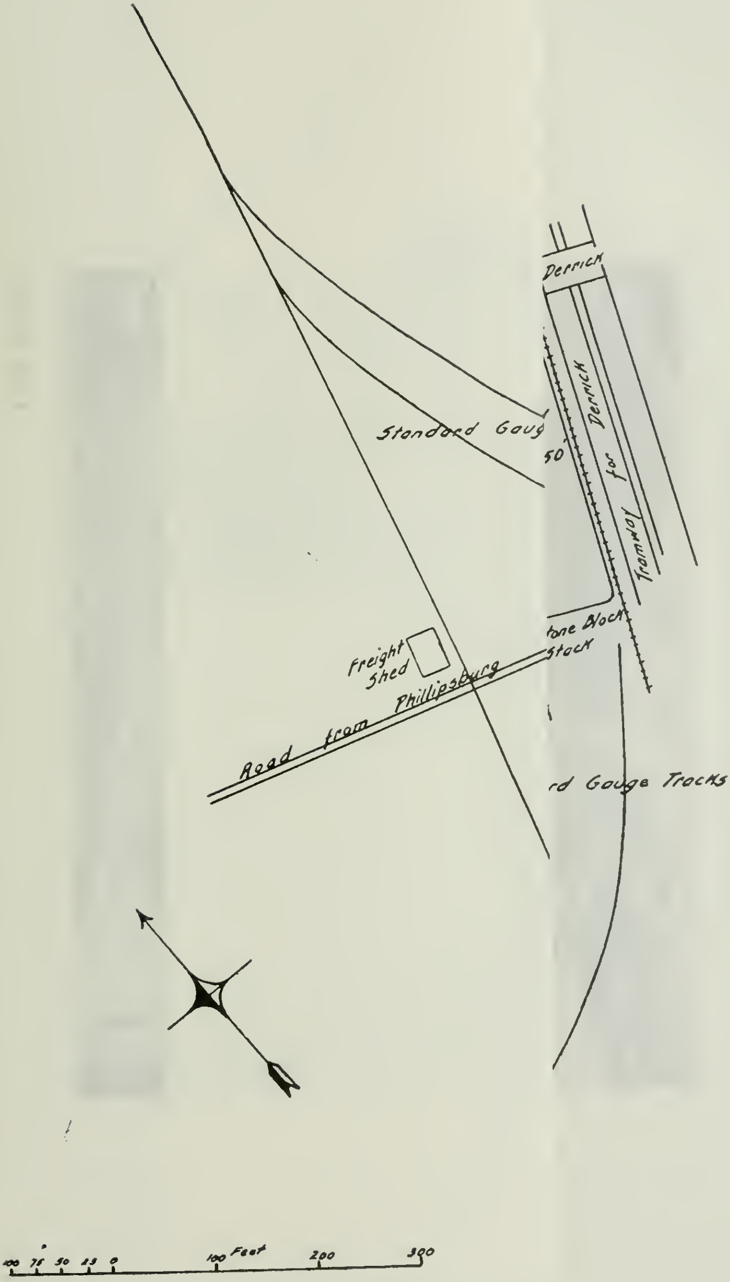


Fig. 8. Plan of the quarr.

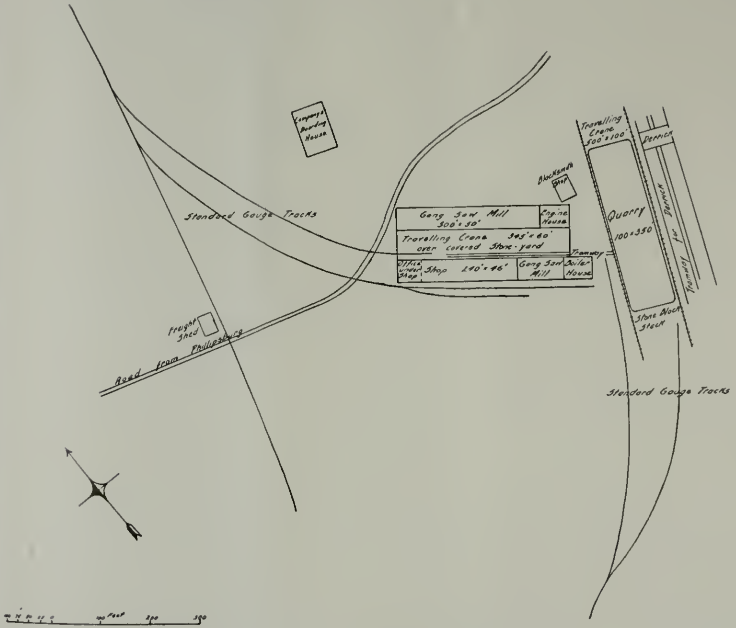
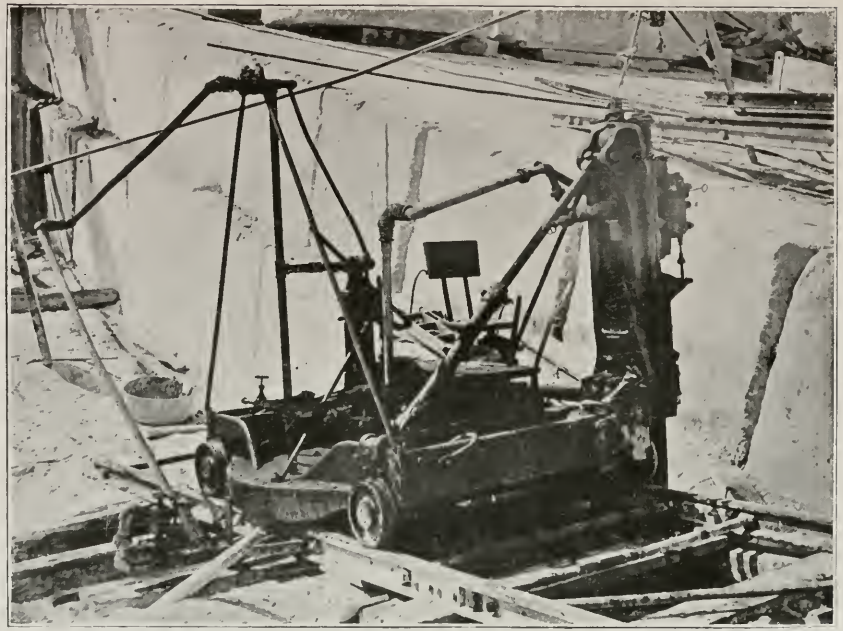


Fig. 8. Plan of the quarry, mills, and yards of the Missisquoi Marble Co., Phillipsburg, Que.

Plate XXVII.



Sullivan Channeller at work in Missisquoi Quarries.

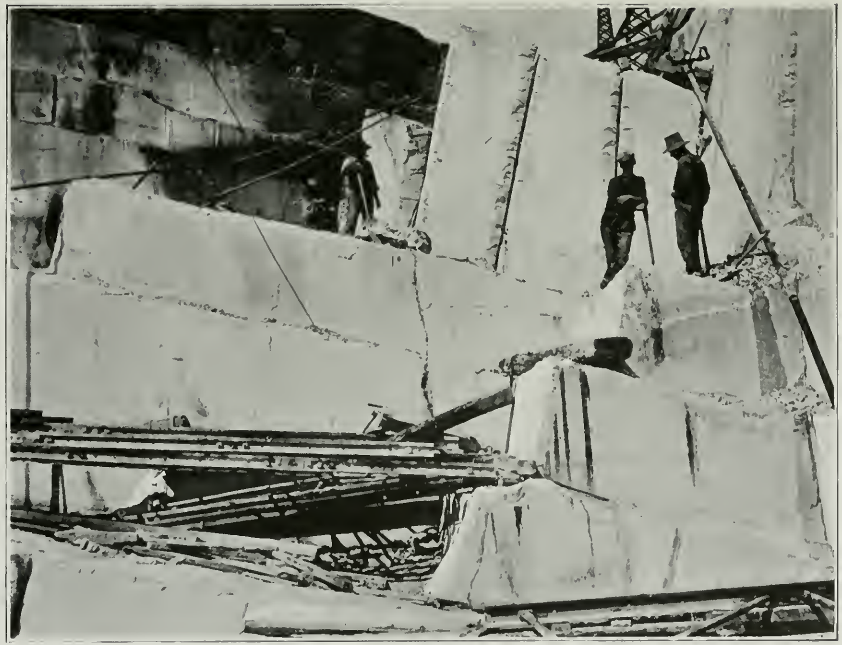
Plate XXVIII.

Sullivan Channeller at"work in North Lanark Quarry.

Plate XXIX.

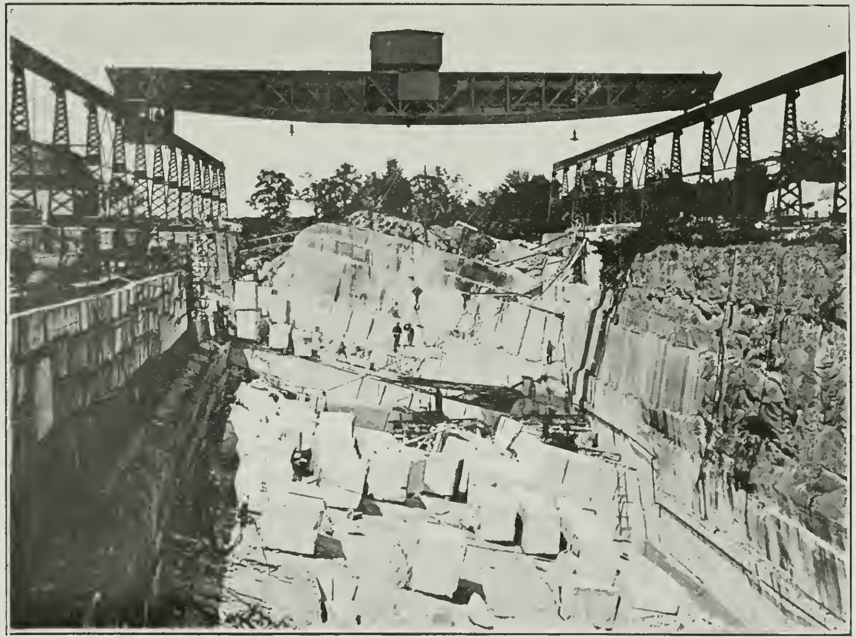
General View of the plant of the Missisquoi Marble Co., Phillipsburg, Que.

Plate XXX.



Work of the Channelling Machine, Missisquoi Marble Co., Phillipsburg, Que.

Plate XXXI.



Quarry and Electric Crane of the Missisquoi Marble Co., Phillipsburg, Que.

Plate XXXII.

Covered Yard with Mills on each side, Missisquoi Marble Co. Phillipsburg, Que.

Quarrying and Dressing of Granite.

Owing to the hardness of granite and the consequent high expense of working it, every physical property must be carefully considered and advantage taken of slight differences in structure which might be neglected in the case of softer stone.

Assuming that the quality of the stone is satisfactory, the degree of development of rift and grain must be carefully determined, for if these peculiarities of structure are feeble or absent, the quarrying can be carried on only at a greatly increased expense. In the granite area near Gananoque, Ont., it is found that the development of rift and grain varies greatly from place to place, in consequence of which, openings are constantly being abandoned for others where the stone can be parted with greater facility.

It is seldom that a mass of granite is continuous throughout; as already pointed out, the rock is usually traversed by vertical and horizontal partings. The vertical breaks (joints) are usually disposed in two directions at right angles to each other, and they may either facilitate the removal of the material or be developed to such an extent as to render impossible the making of dimension stone. The horizontal, or more usually slightly inclined partings (sheeting) are of the utmost importance. When these are absent undercutting has to be resorted to, whereby the cost of extraction is materially increased.

In former days, jointing planes were almost essential to economic quarrying, but at the present time, quarrymen assure me that, unless they are particularly evenly developed, they prefer to operate in rock where they are absent. If the rift is horizontal the major joints usually run with the grain, if the rift is vertical the major joints are coincident with it. A second series of joints usually less well developed run approximately at right angles to the major series.

In the quarrying of granite both blasting and channelling are resorted to. The former operation is performed by means of Lewis holes or Knox holes. A Lewis hole is made by drilling three or four parallel holes close together along the proposed line of fracture, broaching out the cores and firing with black powder. In the Knox system the holes are put down about eight inches apart and are grooved by a "rimmer" in the direction of the line of fracture. A small amount of powder is used in each hole and an air chamber, sometimes of two feet, left between the powder and the tamping. The holes are fired simultaneously by means of a battery.

Channels in granite are usually made by means of quarry bar and rock drill, whereby a series of holes is drilled as close together as possible along the proposed line of fracture. Most of the quarries at Barre, Vt., use a 2 inch + shaped bit and sink the holes from 3 to 6 feet at the rate of about five feet per hour. The cores are broached out by a rectangular faced bit $3\frac{1}{2}$ by $\frac{3}{4}$ inch. According to Dale, the practice in the thirty principal quarries in Maine is as follows:—"Vertical blast holes almost as deep as the thickness of the sheet are drilled by pneumatic or steam drills along a proposed line of fracture, under three sets of conditions. The block to be loosened must be:—

(a) Bounded laterally by two free ends (consisting either of two artificial channels or two joints or headings or dykes, or else by one of these and one channel) and bounded on the other by one quarried face and the desired line of fracture; or (b) bounded laterally by one channel and the proposed line of fracture and the other way by a heading or joint and a free face; or (c) not bounded laterally by any free end and the other way only by the working face. In this case after the fracture is made the two sides of the block must be cut either by blasting or splitting. In all these cases the boundaries of the block are the upper and lower surfaces of the sheets, and the lines of fracture must follow either the rift or the grain. Where the grain is weak it requires double the number of blast holes to effect a fracture along it than it does along the rift. Where there is no vertical rift or grain it is impracticable to use method c, and in such cases, even with two free ends, channelling is resorted to. Exceptionally, still another method is in use, which requires only one lateral joint-face and one working face (besides the sheet surfaces) the line of fracture forming the third side. But this method is regarded as hazardous by the more experienced men, for the fracture is apt to leave its direction of parallelism to the working face and swerve off diagonally to meet it. When the stone is delicate as in the Hallowell quarries, powder is used sparingly or not at all. In the latter case channelling is done in two directions at 90°, and the operation is completed by splitting with wedges in the third." [1] In each of these instances a working face is supposed to exist parallel to the grain or rift.

The following description by Merrill shows one way of opening up a working face. "At the Crotch Island quarries, on the coast of Maine, the sheets are freed at the ends by drilling two parallel rows of holes, the space between the rows being from 2 to 4 feet and that between the holes 8 inches. These holes are then charged, alternating a cartridge or dynamite with a plug of wood, for their full depth, and fired, one after another. This pulverizes the granite between the holes so that it can be removed with a shovel, and gives a free end to work from. Blocks of 100 to 1,000 tons are then separated from the main mass by means of blasts arranged according to the Knox system, and these in turn worked up into dimension stone by means of the plug and feathers." [2]

At the quarries near Barre, in Vermont, a working face along the grain is obtained by channelling along the grain and across the head. A section thus freed on three sides is separated by means of a series of Knox holes along the fourth side parallel to the grain. The block is then removed in sections by wedges across the grain. A free face once secured, blocks of considerable size can be freed by wedges alone along the grain, provided the ends are cut across by channels.

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[1] U. S. Geo. Sur., Bull. 313, pp. 69–71.
[2] Stones for Building and Decoration, G. P. Merrill, p. 388.

According to Watson, Laney and Merrill, the method of quarrying granite at Mount Airy, in North Carolina, is as follows:—"A hole about 3 inches in diameter is drilled perpendicular to the surface to a depth of the thickness of the stone desired, usually 5 to 7 feet, and then fired by a succession of light blasts, using in the first charge about a handful of blasting powder. The operation is begun by discharging about $\frac{1}{4}$ of a pound of dynamite in the bottom of the hole. This small charge of dynamite pulverizes the stone slightly at the bottom of the hole and forms a small chamber. The tamping is then cleaned out of the hole, and the hole is then recharged in the same manner, this time, however, using about a handful of powder. Recharging of the hole is continued with small charges of powder until a small seam has been started at the bottom of the hole, extending parallel with the surface. This is found out by using a small steel rod bent at the lower end and sharpened to a point, and passing it up and down the hole until the crack is located. After the crack has once been started, the use of light charges of powder is continued, increasing the charges gradually as the seam is found to extend in all directions from the lift hole, until a crevice extends a distance of 75 feet or more from the hole. The use of explosives is discontinued and a water-tight connexion is made to the hole by cutting off a piece of iron pipe of suitable length, which is fastened to the hole with melted sulphur. To this connexion is fastened an ordinary hand force-pump and water is pumped into the crevice already formed by the explosives. No difficulty is found in extending the crevice by continuous pumping of the water, until finally it covers an area as much as two acres in extent, and finds vent or relief by tearing out to the thin edges on the side of the hill."[1] The authors further state that by using compressed air at 70 or 80 lbs. pressure, instead of water, the operation is completed in a much shorter time. This method indicates a unique way of supplying in an artificial manner the necessary horizontal parting, which, owing to the absence of sheeting, is not present in the granites of Mount Airy. In this connexion it is interesting to note that artificial sheeting has long been produced in Southern India by building lines of fire which are gradually advanced over the surface of the rock, sometimes covering an area of 460 square feet. By this means a sheet about 5 inches in thickness is detached.

Quarrying and Dressing of Slate.

The following brief description of the method of quarrying and of the subsequent treatment of the quarry product is indicative of the practice in the Vermont-New York area.

The slates occur along a belt striking north and south for about 20 miles. The width of the belt is about $\frac{1}{4}$ mile but the quarries are by no means so wide, averaging from 100 to 200 feet. The dip is eastward at about 70° where observed, but a much less inclination is exhibited in parts of the belt. In opening a quarry, as the upper slate is usually worthless, a V shaped cut

[1] North Carolina Geol. Sur., Bull. No. 2, pp. 157–159.

is made along the strike by running a series of holes in line with the strike and at right angles to the dip. On encountering the good slate the V is continued downwards, largely at the expense of the stock, until a sufficient exposure is presented on the western or foot wall to give a working face. If the V is sufficiently deep a line of vertical holes is put down, sometimes as much as 20 feet from the margin of the V and the whole foot wall blown into the cut. A large amount of good stock is then ready for hoisting. This operation will have again produced a roughly horizontal floor. Another V is started on the eastern or hanging wall side and is followed by the removal of more good stock from the foot wall. These operations are repeated until a sufficient depth is attained to warrant an attack being made on the hanging wall. The removal of good stock from the eastern wall is effected by cutting vertical channels about 50 feet apart. Advantage is taken of the joints to make these channels with the least possible injury to the adjoining slate. The material between the channels is then blasted laterally into these cuts, but sufficient slate is left, as adjoining channels are enlarged, to form supports for the hanging wall. One and a quarter inch steel, and blasting powder are used.

It is obvious that these operations involve a considerable destruction of good slate. The disposal of this shattered material, as well as that of the large amount of worthless matter mingled with the good stock, requires a wide area for dumping. In order to provide for the easy removal and dumping of the waste the following method of hoisting is employed. A vertical pole "big stick," sometimes 240 feet high, is erected at a distance from the quarry usually about five times the length of the pole. From the top of this pole a $1\frac{1}{2}$ inch wire cable runs to the opposite brink of the quarry where it is securely anchored. On the cable travels a patent carriage which is able to hoist loads from any part of the quarry along the line of the cable.[1] The stock is landed near the shanties and the worthless material is dumped farther away, the long cable allowing ample room for this purpose. Such a hoisting plant with "big stick," cables, carriages, guys, and engines costs about $4,000 to install.

The quarry blocks "stock," are worked up into the roofing slates by gangs of three men each, consisting of block man, splitter, and trimmer. Each gang occupies a small individual shanty and they are therefore known as "shanty gangs." A block of stone, fresh from the quarry, is landed before the block man. This block may be 8 feet long by 4 feet wide and several inches thick. He first drills a small hole in the centre of the face of the slab and "rims" the hole in the direction of the grain of the slate which is usually the long diameter of the slab. By means of plug and feathers the slab is then broken into halves. Each half is cut into sections crosswise by notching one edge with a chisel and striking on the opposite edge with a beetle. The pieces, thus reduced to proper size, are placed on edge in a shady place to await the splitter. The edges are moistened and are kept

[1] The Jones Carriage, Poultney, Vt., is largely employed.

moist until split, which operation should be done as soon as possible after the blocks are prepared. The splitter using a thin chisel about 2 inches wide, and a light wooden mallet, works in a sitting position and splits the blocks into slates of the proper thickness. It is then the duty of the trimmer to dress the sheets to a rectangular shape of the largest possible size. This operation is effected by the trimming wheel, which consists of a single rotating blade like that of a lawn mower, operated by foot power. A guide provided with inch notches serves to give the necessary right angle and enables the workman to keep his sheets to standard size. In the green slates the ordinary sizes are 6 × 8 inches, 8 × 16 inches, 11 × 22 inches, 10 × 20 inches, and 14 × 24 inches. In the red slates smaller sizes are cut, *e.g.*, 4 × 8 inches.

At the present time a shanty gang makes from 4 to 8 squares a day, but as many as 18 squares are said to have been commonly made in a day when the quarries were first opened. This difference is locally attributed to a falling off in the quality of the stock. The average wages paid on the slate belt are indicated below:—

Foreman, $125 per month.

Pit boss, $90 per month.

Block man, 25 to 26 cents per hour.

Splitter, 25 to 26 cents per hour.

Trimmer, 21 to 23 cents per hour.

Laborer, 17 to 18 cents per hour.

Roofing slate is marketed by the "square," a square being the amount required to cover 100 square feet of roof, allowing three inches overlap. Three qualities are recognized, the price varying with the quality and with the number of sheets in the square.

About 80 per cent of the slate quarried in the United States is made into roofing slates. The other 20 per cent is known as "mill stock," because being deficient in cleavage, it is sent to the mills to be worked up into slabs for electrical work, wash tubs, etc. Special types of saws, planers, and other machines are used in slate mills, but as they are adaptations of machinery already described, no further account is warranted.

In slate quarrying there are certain prominent features, irrespective of the quality of the material, which the operator should bear well in mind:—

(1)—The large amount of waste, averaging 75 per cent.

(2)—The necessity of working up the stock as soon as it is quarried.

(3)—The fact that frost and heat are both destructive of stock.

(4)—The tendency for large sections of the hanging wall to fall in the winter.

(5)—The necessity of providing an ample dumping ground.

CHAPTER VIII.

Styles of Dressing Stone.

The walls of a building, exclusive of the trimmings, are usually laid up in one of three styles, although modifications and combinations of the three may be seen in the same structure.

Rubble work consists of stone of all shapes and sizes, laid up with little or no regularity; to the quarryman this kind of stone is known as *rubble.* If the wall is laid up in tiers or courses the stone is called *coursing* stone. The stones may or may not be cut to equal length so as to resemble brick work. The third type of masonry is known as "random coursing" in which the blocks are all rectangular and bedded, but as they may be of various sizes the tiers of ordinary coursing are not maintained. Many varieties of random coursing are recognized in which the differences consist chiefly in the degree of approximation to regular coursing. Stone for this kind of work is sometimes called "random coursing" but more frequently "shoddy." There seems to be some diversity of opinion among quarrymen as to the exact meaning of this latter term. Some operators regard as shoddy, roughly squared blocks which require more or less work on the part of the mason before being ready to lay. Others consider that the pieces must be all ready for the wall before deserving the name. Others again distinguish these two kinds as rough shoddy and cut shoddy respectively. The term "dimension stone" really applies to a stone cut to size, but it is also used to designate blocks of stone from which pieces of fixed dimensions can be cut. It is obvious that any stone of fixed size is a dimension stone in the strict sense of the word, but no quarryman or mason would think of pieces less than six or eight inches in thickness as dimension stone. The surface of the block is finished in different ways, the chief of which are the following:—

1. *Rock Face.*—This is the natural broken surface of the stone. If it is very rough a small amount of chiselling with a point is permissible. Frequently the margin is tooled.

2. *Pointed Face.*—The surface is rendered comparatively flat by means of the point. A tooled margin is often added as in the rock-face.

3. *Hammered Face.*—In this style of finish the surface is rendered plane by hammering with patent hammers of different kinds. Many degrees of fineness are produced according to the hammer used. By using the bush hammer so that the cuts lie approximately parallel a lined or streaked appearance is given to the surface. This method is often applied to granite.

4. *Ribbed or Tooth Chiselled.*—This finish may be given by using a wide flat toothed chisel but it is more commonly produced by machinery. It is usually employed with soft stones only and is a common finish, very popular at the present time in the case of Indiana limestone. Makers of artificial stone frequently use this style of finish.

5. *Sand Finished.*—This is a smooth but not polished surface, produced by rubbing with sand either on the rubbing bed or by hand. It is a common finish for exterior marble work.

6. *Iron Finished.*—The surface is similar to that of the sand finish; it is produced in the case of granite by using the scroll wheel and crushed steel instead of the rubbing bed and sand employed for marble and soft stone.

7. *Sawed Face.*—The surface is left as it comes from the saw; not commonly used.

8. *Polished.*—Requires no comment—see methods of polishing granite and marble.

Besides these methods of finishing, there are others differing in minor details. The *square drove* is a ribbed effect produced by using a broad flat chisel with a smooth edge. The ribs are not uniform and they lie across the direction of work and not parallel to it. It is suitable only for margins, etc., as the length of rib is the width of the chisel. To cover a broad surface with good square drove work is expensive. I find that this term is not in common use among our stone cutters, the expression "tooled margin" being far more common than "square drove margin." Special effects are produced by using the *toothed chisel* in two directions at right angles to each other and by directing the *point* along parallel lines instead of indiscriminately as in the ordinary point face. Many other types of finish are employed, but a consideration of such matters belongs to the architect and does not fall within the scope of a work of the present kind.

PART II.

SYSTEMATIC DESCRIPTION

OF THE

BUILDING AND ORNAMENTAL STONES OF ONTARIO.

INTRODUCTORY.

The first chapter is devoted to a brief account of the geology of Ontario in so far as the stone industry is concerned. The ensuing chapters deal with the different classes of stone in the following order:—

Chapter 2.—Sandstones,
Chapter 3.—Limestones,
Chapter 4.—Granites and Gneisses,
Chapter 5.—Crystalline Limestones and Marbles,
Chapter 6.—Miscellaneous Decorative Materials,
Chapter 7.—Slate.

Within the chapters the following system of classification is adopted:—

1. The various stones are considered according to the geological formation in which they occur.

2. The formations are divided into "areas." These areas have no particular significance except that they constitute convenient geographical subdivisions.

3. The individual quarries are, as far as possible, described under the name of the owner or operator, which is conspicuously printed at the head of the account.

4. The description of each property is given in the following way:—First, an account of the quarry proper, in which a number is given to those beds of stone which are selected for description. It was thought that confusion would be avoided by keeping the general account of the quarry separate from the description of the stone. The use of these numbers also facilitates the making of comparisons; Second, the detailed account of the stone; Third, a description of the plant, with economic observations and general remarks.

For the benefit of the general reader, who is not concerned with the detailed description of individual quarries, a short summary is given at the end of the account of each area, or, in some cases, at the end of the account of a formation. These summaries are printed under a conspicuous heading in which the word "summary" always appears. To these condensed accounts is appended a short bibliography of the area or formation in question.

It is to be distinctly understood that this report deals primarily with actual quarries and that little or no attempt is made to describe outcrops of rock which have not been actually exploited for the production of building stone. It is also to be understood that it is not the intention of this report to describe *all* the quarries in the province, but rather to give an account of the more important as typical examples of the different areas and formations.

CHAPTER I.

Outline of the Geology of Ontario.

The following brief account of the geology of Ontario is written with the sole object of indicating the extent and manner of formation of the rocks which are employed as building stone. Absolute accuracy is, in some cases, sacrificed for the sake of brevity.

It is doubtful if geologists have yet discovered any trace of the rocks which originally composed the crust of the earth; it has even been questioned whether or not there ever was a "crust." The earliest continent of which we have any knowledge consisted of a great and complex series of sediments and eruptive igneous rocks, all of which by the lapse of time and the stress of terrestrial movements have been more or less altered and rendered crystalline. Investigations as to the shape of this early continent have occupied the attention of many authors, but we are more concerned with the present geographical extent of the rocks than with the early configuration of the continent. As far as Lower Ontario is concerned, the area in which the ancient crystalline rocks may be found lies to the eastward of a line from near Kingston to the mouth of the Severn river on Georgian Bay and west of a line drawn in a zigzag fashion from a point on the St. Lawrence about 10 miles west of Brockville to the vicinity of Sharbot lake, thence to near Smiths Falls and thence to the Ottawa river near Arnprior. The area between these lines is characterized by the crystalline and metamorphic rocks of the ancient series. The period of time during which these rocks were formed, as well as the rocks themselves are designated by the term *Archæan.* The stretch of country itself will herein be referred to frequently as the *Archæan axis,* because it forms the centre around which the other rocks have been formed. The part of the province east of this axis will be referred to as the eastern region and that to the west as the western region. From the rocks of the Archæan axis are obtained *all* the granite, gneiss, crystalline limestone, marble, and slate, as well as the rarer decorative substances such as sodalite, serpentine, and the iridescent feldspars.

Whatever the original extent above the sea level and the consequent shore line of the Archæan rocks may have been, it is certain that the forces of nature wore down the original rocks and scattered the debris in a sea which gradually encroached on the land for a long period of time. The ocean thus advancing on the land, gradually spread out over the early crystalline rocks a new series of deposits derived from the decay of the older formations. The time of this advance is known as *Cambrian*, and the deposits made along the advancing shore line have been since consolidated into more or less compact sandstones which appear here and there as a fringe along the flanks of the Archæan axis. This "transgression" of the sea continued after Cambrian time with a similar deposition of sand during the earlier part of a period known as the *Beekmantown.* Whether the sandstones appearing along the flanks of the Archæan in Ontario belong to the Cambrian or to the Beekmantown division of time, or to both, is a questionable point, and of no particular interest for the purpose of this report, wherein they will be designated as *Potsdam-Beekmantown.* Of more importance is the fact that sandstones thus deposited in an advancing sea may be expected to exhibit diversity in character and irregularity in bedding. The deposits will be shallow and the beds lenticular, irregular, and discontinuous. Along the eastern flank of the Archæan axis, beds of sandstone exhibiting the above characteristics are seen from the vicinity of Brockville to Westport and along the Rideau lakes to Smiths Falls. Narrow fringes also extend farther north, and an important development occurs in the township of Nepean. From time to time quarries have been worked in this stone, more particularly near Lyn and Westport, in the vicinity of Perth and Smiths Falls, and in the township of Nepean.

On the western flank of the Archæan axis, very little sandstone is encountered, the only important development being near Kingston Mills. After the advance of the sea and the deposition of these shore-line sandstones, the rest of Beekmantown time was occupied by a retreat of the sea and a consequent enlargement of the continent. During the oceanic advance in both Cambrian and Beekmantown time, layers of limestone, with some sand, were being deposited in the deeper parts of the ocean while the fringe of sandstone was advancing on the land. During the retreat of the sea in later Beekmantown time the same thing continued, but the upper layers were successively brought to the surface as the sea receded. During this advance and retreat it is estimated that fully 5,000 feet of stone were formed. In Ontario there are no exposures of these deep sea Cambrian rocks, but the Beekmantown rocks appear in an area extending eastward from the sandstone fringe to a line running from near Ottawa to a point on the St. Lawrence about 20 miles east of Prescott. West of the Archæan axis similar rocks were doubtless made, but none are to be seen in Ontario as they have been covered by subsequent deposits. These later deposits also cover a part of the area described above as being composed of Beekmantown rock. Three general types of Beekmantown rock may be recognized: first, an extremely sandy limestone which fades imperceptibly downwards into the underlying true sandstones and is quarried near Smiths Falls, and also at Brockville and Prescott; second, a dark coloured limestone filled with characteristic cavities in which have formed crystals of pink and white calcite. This type is quarried for heavy construction, etc., more particularly in the vicinity of Brockville and Prescott; third, a crystalline dolomitic limestone of brownish colour which constitutes the finer building stone at Brockville and in the township of Augusta, and which is represented by a very dark brown and soft variety in the township of Beckwith near Carleton Place.

Following the Beekmantown oceanic retreat came a long period of time during which the sea again encroached on the continent, burying the older formations under the constantly accumulating sediments; to this period and to the rocks then formed the name *Chazy* is given. The advance of the waters was so great that in many places all of the earlier sedimentary deposits were covered and the waves of the sea beat once more on the old Archæan crystalline rocks. In consequence, Chazy deposits are found resting directly on the old crystalline floor, on the Cambrian rocks and on the Beekmantown series, according to the amount of the oceanic advance in the different areas. The Chazy rocks are chiefly fossiliferous limestones of dark colour and are, for the most part, superior to the Beekmantown stone and well adapted for heavy construction. With the limestones, however, are beds of shale which are of little or no value for building purposes.

Chazy rocks are now found in the form of an irregular ring extending along the eastern border of the Beekmantown stone in Dundas and Stormont, and stretching along the Ottawa and St. Lawrence rivers to a junction at the eastern limit of the province in the county of Glengarry. West of the Archæan axis only a small and irregular exposure of Chazy rock is seen, resting directly on the Archæan in the county of Frontenac. This absence of Chazy rocks west of the axis is not to be interpreted as a failure of deposition but as being due to a covering by deposits from a still further advance of the ocean. In all, 2,500 feet of Chazy rock are said to have been formed. It would appear that the transgression of the sea which is responsible for the formation of the Chazy rocks continued without interruption, at least in some part of the continent, for a relatively short period longer. During this extreme advance, several formations were successively formed, the *Lowville* (*Birdseye*), *Black River*, and *Trenton*. This advance was probably followed by a stationary period and a slow retreat during which part of the *Trenton*, the *Utica*, and the *Lorraine* (*Hudson River*) were deposited. The lower formations, the Lowville, Black River and Trenton are not easily separable except by means of fossil evidence, and they have not yet been accurately mapped, particularly in the western region.

Taking these three formations together, three different types of rock may be recognized as far as the building stone industry is concerned. 1st, a dark coloured type of rock, rather heavily bedded and usually presenting bituminous parting planes. Most of this rock is of Black River age, but some of it is Trenton. 2nd, a bluish type of stone composed largely of fossil fragments. This variety is quarried near Ottawa from the Trenton formation, but a similar stone occurs also in the Black River. 3rd, a compact very fine grained light coloured limestone, in some cases of lithographic character. It is quarried at Kingston, Napanee, Marmora, and Longford Mills more particularly. The rock is in part of Black River age, but some of it probably belongs to the lower part of the Trenton, and other parts to the Lowville.

In the eastern region a narrow ring of Black River rock lies inside the Chazy circle mentioned above; it also occurs on top of the Chazy rocks in the smaller areas of Carleton and Renfrew. On the western side of the Archæan axis an ill defined band of Lowville and Black River stone extends from the mouth of the Severn to the vicinity of Kingston.

In the eastern region, the Trenton formation fills in the centre of the ring formed by Chazy and Black River rocks and occupies a considerable part of the counties of Russell, Glengarry, Stormont, and Prescott. A small exposure also occurs in the centre of the smaller ring in Carleton. In the western region, the Trenton formation forms the shore of Lake Ontario from Kingston to Bowmanville and extends northward as a broad belt to Georgian Bay, where it forms the shore from the limit of the Lowville limestone to Collingwood.

The Utica formation forms the shore of Lake Ontario from Bowmanville to Whitby and extends northward as a belt of gradually decreasing width to the vicinity of Collingwood. The rock of this formation is a black, sometimes highly bituminous shale of no value as a building stone.

The next succeeding formation, known originally as the *Hudson River*, but of which so many local phases have been found that the name is no longer commonly employed, occupies the shore from Whitby to a point between Toronto and Port Credit. The belt rapidly decreases in width northward and comes out on Georgian Bay between Collingwood and Owen Sound; it also appears along the north shore of Manitoulin island. The rocks are largely shales which are quarried for brick making, and thin bedded argillaceous sandstones and limestones. The latter rocks were formerly quarried for flagstones, but little good building stone occurs in the formation and no quarry worthy of note is now in operation.

In the eastern region a small exposure of both Utica and Hudson River rocks is found south of Ottawa in the counties of Russell and Carleton.

It is thought by some authors that the long period of marine deposition was succeeded by an emergence of the land which took place during Lorraine (Hudson River) time and was manifested in the eastern part of the continent by profound changes in level. In Ontario it would appear that the rocks, just elevated out of the sea, were subjected to subærial decay and that a series of deposits were formed in shallow water or even on land. These deposits consist chiefly of red and greenish shales and coloured sandstones. The latter are irregular in form and of indistinct bedding, being intermingled with the shales in many places. A more distinct upper layer of sandstone of 10 or 12 feet in thickness constitutes one of the most important sources of building stone in Ontario. The stone is in part grey and in part brown, or the two colours may be intermingled producing the so called piebald stone. This formation, known as the *Medina*, overlies the Hudson River rocks and occurs as a narrow fringe along the base of the Niagara escarpment from Queenston Heights to Hamilton and thence to the vicinity of Owen Sound. The red shales are used extensively for brick making, and the sandstones are, or have been, quarried for building stone in a long line of quarries stretching from Merritton to Orangeville. The deposition of the Medina strata followed the close of the long period during which the Trenton, the Utica, and the Hudson River formations were made. It also represents the transition to the next succeeding age in which the marine conditions again prevailed and in which the *Silurian* strata were formed. In the Province of Ontario, four subdivisions of the Silurian rocks are recognized, the *Clinton*, the *Niagara*, the *Guelph*, and the *Salina*, in ascending order.[1]

[1] The Medina is usually regarded as the base of the Silurian series.

The Clinton beds are mostly thin limestones and shales; the former are quarried to some extent for the making of rubble and crushed stone. The formation appears above the Medina along the face of the Niagara escarpment from Queenston to Owen Sound; it also shows on some points on the east side of the Bruce peninsula and in Manitoulin island.

Succeeding the Clinton is the Niagara, which consists, in its lower part, chiefly of shale (Rochester shale). The upper layers are, however, of limestone from which much excellent building material is quarried. These hard upper layers form the brow of the Niagara escarpment, from Queenston to the Bruce peninsula. This escarpment, or more properly "cuesta," owes its presence to these hard Niagara layers, which have resisted the attacks of time and weather, while the softer rocks of the underlying formations have disappeared. The narrow exposures of the Rochester shales and of the Clinton and Medina rocks is due to their easy removal by the forces of nature as fast as the protecting Niagara limestone breaks down. The actual exposures of Medina sandstone are so narrow that the bulk of the stone quarried has been obtained either by quarrying beneath or by removing the overlying Clinton and Niagara rock. The south side of Manitoulin island shows Niagara rocks which also form the most of the Bruce peninsula. Thence the formation extends, stretching back from the brow of the cuesta as a belt 5 to 10 miles in width to Hamilton and Queenston. Many important quarries are situated on the Niagara limestones, more particularly at Wiarton, Owen Sound, Hamilton, Ancaster, Dundas, Thorold, and Queenston.

The Guelph formation tops the Niagara and occupies a lenticular area with a maximum width of about 15 miles and a length of 80 miles. The long diameter of this lens shaped area extends from the vicinity of Paris to Markdale. The rock is a yellowish dolomitic limestone and it is quarried for building and other purposes at Guelph, Galt, Hespeler, Fergus, and Elora.

At the close of the Guelph time the seas to the westward became very shallow, and in all probability partly enclosed, so that the water evaporated, leaving beds of salt and gypsum interstratified with bands of dolomite and dark coloured shales. This series of deposits is 200 to 300 feet thick, and is known as the *Salina* on account of the salt beds. The rocks of this series form a belt from 10 to 20 miles wide, stretching from the Niagara river to Lake Huron: the northern limit comes out on the Niagara river just above the falls and the southern near Fort Erie. On Lake Huron the northern boundary is near Chief's Point, but there is a southward bend of the formation so that it crops out along the shore as far as Goderich. Salt and gypsum are obtained from the Salina, and some of its layers are suitable for the manufacture of natural rock cement. The limestone bands are, in places, very fine grained and may have a value as lithographic material. Although quarried locally for building purposes, the stone is not a desirable one for important structures.

Following the Salina time, an oceanic invasion of the western area ushered in the Devonian age. The first evidence of this new invasion is seen in a narrow band of coarse and variable sandstone, the *Oriskany*. This rock occurs in exposures not over 25 feet thick, along the western limit of the Salina in Haldimand and Welland. While much of the stone is useless, a very fair quality for building purposes is obtained to the northward of Cayuga.

The next member of the Devonian series is the *Onondaga* (often referred to as the *Corniferous*), which consists largely of marine limestones and shows a thickness of from 150 to 200 feet. The rocks of this age form all that is left of the Western Ontario peninsula with the exception of a strip extending from Lake Erie to Lake Huron. This strip comes out of Lake Erie between Rondeau and a point 25 miles east; at its northern end it occupies the shore from the vicinity of Dashwood on Lake Huron to the mouth of the St. Clair river. Much excellent limestone for chemical purposes, for lime-making, and for building, is quarried from the Onondaga rocks. The quarries at Beechville and Amherstburg yield excellent material for chemical purposes and for lime making; those at St. Marys and at Amherstburg produce desirable building stone, and quarries near Port Colborne are largely worked for furnace flux and for the manufacture of Portland cement.

The strip of country above referred to as lying across the western peninsula from the foot of Lake Huron and the St. Clair river to Lake Erie east of Rondeau, is occupied by a higher Devonian formation, the *Hamilton*. The rocks are shales and limestones, and although the latter are used locally for building purposes, no good stone has been quarried from the formation. A small area of still higher Devonian rocks, the *Chemung* formation, overlies the Hamilton in the vicinity of Kettle point on Lake Huron.

It is questionable if the rocks west of the Hamilton area—those in Essex and Kent—should be classified with those to the east as of Onondaga age, but they are at least comparable, being of lower Devonian age. From recent investigations it would also appear that Silurian rocks again occur in the bed of the Detroit river near Amherstburg.

At a comparatively recent date in geological history, the northern part of the American continent, including the whole of the Province of Ontario, was covered with glaciers. These great masses of ice, sometimes thousands of feet thick, swept in a general southwesterly direction over the country, grinding down the surface and transporting blocks of stone and masses of clay from the north to the south. With the return of a milder climate the ice melted away leaving the boulder clay with the familiar "field stones" or "hard heads" scattered generously over the country. These loose stones are largely employed for building purposes, more particularly for foundations. In certain towns, of which Galt is a good example, the custom of using gneiss and granite hard heads for building is quite common.

CHAPTER II.

Sandstones of Southern Ontario.

The sandstones quarried in Ontario are obtained principally from three formations only—the Potsdam-Beekmantown, the Medina, and the Oriskany. Small quantities have also been obtained from the Chazy and they are likewise known to occur in the Trenton.

THE POTSDAM-BEEKMANTOWN SANDSTONE.

The advancing ocean which encroached on the old Archæan continent in early geological time caused a shore line deposit of sandstone to be formed. As this oceanic advance continued through both Potsdam (Upper Cambrian) and Beekmantown time, and as the sandstone rarely carries any distinctive fossils whereby its age may be determined, it is best to designate the stone by the double name as above.

This sandstone fringe was doubtless deposited as a continuous band along both sides of the original continent and should therefore appear along the line from Kingston to Matchedash bay, and from Brockville northward to the Ottawa river. The actual outcrops of the rock are always found adjoining the Archæan, but the disposition is by no means as simple as the above theoretical consideration would indicate. To the westward of the Archæan, the fringe of sandstone has been largely covered by later deposits, and, to the eastward, its outcrop is very irregular, owing to the uneven character of the old sea floor, its covering by later deposits and its removal by subsequent erosion.

The following geographical areas of Potsdam-Beekmantown sandstone may be recognized:—

South Frontenac area.
Brockville area.
Rideau area.
Smiths Falls-Perth area.
Mississippi area.
Nepean area.
Prescott area.

South Frontenac Area.

West of the Archæan axis, the principal outcrops of the formation are along the Rideau canal above Kingston Mills, in the vicinity of Dog lake, in isolated patches on Loughborough, Sydenham and Knowlton lakes, and westward to the Kingston and Pembroke railway near Hartington. The accompanying map shows the scattered character and comparatively small extent of the outcrops in this area. While small quarrying operations have been conducted at various points, the only important quarries are situated on the line of the Rideau canal above Kingston Mills. On the eastern side is the old Gildersleeve quarry and on the western shore Cuddy's quarry.

The Gildersleeve quarry, Wm. Gordon, owner, Cushendall, Lots 8, 9 and 10, Con. V., Pittsburgh, Frontenac county.

The actual quarry is on lot 8, and is opened in the side of a bluff facing the lake. The exposure is about 250 yards long and presents a vertical face of 25 feet. Irregular bedding is very conspicuous so that the description of a single section does not give an adequate conception of the quarry as a whole; thin bedded bands at one place are replaced by heavy stone cutting diagonally across them at another. However, a typical section is as follows, in ascending order:—

3 feet—Banded stone, white and pink with darker bands. Although thin bedded in part, the separation planes are tight so that material of 1 foot or more in thickness may be procured. Irregularly bedded with variable dip—65.

2 feet—Red stone, in places a solid 2 feet thick, in other parts separable into thin layers—66.

1 foot—Four thin red and white bands. In places a 7 inch white band—67.

3 feet 6 inches—Whitish stone passing upwards into salmon coloured and red.

10 to 15 feet to top—Mostly uniform red, thin and thick bedded. The most valuable stone—68.

This bluff of 25 feet represents the face of a knoll of about 5 acres extent which probably contains all the high grade stone on the property. A hard, flinty, white variety, very common throughout the formation, occurs at various places on the farms and has been quarried for rough work.

Although the value of the quarry is considerably reduced by the irregular bedding, the almost complete absence of joints counterbalances this objection and makes the obtaining of large blocks an easy matter. On the top of the knoll, above the red beds exposed on the face, the surface rock shows mostly banded stone in red, salmon, and white. It is not evident to what extent the heavy red beds underlie this banded stone—69.

The stone: No. 69.—This example was selected for complete examination and is therefore described first. The predominating colour is reddish, but bands of salmon and white occur throughout the formation. The red is much less brilliant than that of the red beds proper, and is shown in Plate LXXVII, No. 7. After treatment with carbonic acid the colour is not appreciably different.

Under the microscope it is seen that the constituent grains are practically all quartz, that these grains are well rounded and that they are cemented by a thin film of ferric oxide around each grain. The larger particles are about ½ mm. in diameter. The constituent grains have been pressed well together so as to deform each other in places. The pore space occurs as triangular interspaces where the film of iron oxide on neighboring grains has failed to fill the openings between the particles.

The physical properties of the stone are as follows:—

Specific gravity	2·67
Weight per cubic foot, lbs.	144·861
Pore space, per cent	12·408
Ratio of absorption, per cent	6·34
Permeability, cc. per square inch per hour	3·07
Coefficient of saturation	0·33
Crushing strength, lbs. per square inch	12778·
Crushing strength, after freezing, lbs. per square inch	17052·
Loss on freezing, per cent	0·081
Loss on treatment with carbonic acid, grams per square inch	0·0048
Transverse strength, lbs. per square inch	1162·
Chiselling factor	4·49

No. 68.—This stone is of good uniform brick red colour which is much brighter and cleaner than No. 69. Small yellow spots which seem to have resulted from the decomposition of iron pyrites are seen in places. The grain of the rock is similar to No. 69.

No. 66.—The mass of this stone is similar to No. 68, but it is banded with different tones of red having a purplish cast in places. The planes of stratification are more marked and are shown by whitish bands or streaks of hard clear quartz grains.

No. 65.—A much harder stone, showing marked irregular banding. The colour on the whole is like that of No. 69 but the colouring matter is irregularly distributed. The planes of stratification are strongly shown by lines of a blackish hue which really consist of almost colourless quartz grains. This is a less desirable stone than those described above.

No. 67.—A much lighter coloured stone, normally white but with irregular bands of reddish and grey.

The general durability of the stone as observed in different buildings shows that little discolouration by rusting results and that chisel marks are retained at least for 35 years. Most of the local buildings are made of the salmon-coloured, banded stone, with which the red variety is intermingled; this practice has not resulted in the best possible effect.

Some of the more important structures built from the quarry are the church at Cushendall; Dr. Gardiner's residence, Kingston; Laidlaw's store, Kingston; Post-office, Napanee. (Plate XXXIII.)

The shipping facilities are excellent as the stone can be loaded directly into scows on the Rideau canal.

The heavy white and flinty beds which occur on other parts of the property have been quarried in large blocks as much as 4 feet by 4 feet, and used in the waterworks at Kingston.

There is no present production.

J. Cuddy, Lot 9, Con. VI, Storrington, Frontenac county.

The stone in this quarry is very like that of the Gildersleeve property, but it is rather more evenly bedded. The extent is about the same—5 acres —and the shipping facilities similar. An example may be seen in the Public School, Picton, Ont.

Summary—South Frontenac Area.

There is, at present, no regular production of stone in this area. The only important development is on the Rideau canal above Kingston Mills. The stone is exposed on both sides of the canal and may be easily quarried and shipped. The material is a soft coarse grained, red, salmon-coloured and banded sandstone. The more westerly exposures in this area are hard and white, resembling the stone from the Rideau area.

Literature:—Geol. Sur. Can., Rep. 1852-3, p. 109-112.
" " " " 1863, pp. 97-100.
" " " " 1899, p. 78 I.
" " " " 1901, p. 175-176 A; p. 184 A.
" " " " 1902-3, p. 134 AA.
" " " Map Publication No. 626.

Brockville Area.

Sandstone occurs along the shore of the St. Lawrence from near Maitland upwards as far as Brockville, above which town the continuity of the formation is broken for four miles by granite. For six miles above the granite, sandstone again occupies the shore and extends farther westward inland. From this face on the river, the area extends northward to a point above Charleston lake in the township of Lansdowne. The whole of this triangular space is not occupied by sandstone, but is interruped by outcrops of the underlying Archæan rocks. The map shows the distribution of the sandstone in this area in a tentative way only, as no detailed map of the district has yet appeared.

The most important quarry is situated near Lyn, a few miles from Brockville.

Frank Bolin, Lyn, Lot 27, Con. II, Elizabethtown, Leeds county.

The quarry is situated on the southerly aspect of a hill which runs in a direction a little north of east and stands 60 or 70 feet above the neighbouring valley. The beds strike roughly with the hill and are remarkably thick—much thicker than is common throughout the formation. Despite the fact that fracturing is pronounced, the great thickness of the beds would favour the obtaining of large blocks of stone. The band is about 100 feet wide, and presents good stone for a distance of 200 yards. Beyond, the material is rougher, and passes into a conglomerate. The quarry is about 100 feet long by 50 feet wide and has been opened to a depth of 10 feet. The stone is uniform in character and of a greyish colour. The beds dip northward into the hill at an angle of 30°. The top of the hill is composed of hard flinty quartzite of the Archæan system.

The stone: No. 42.—This stone is a pure white sandstone, with but few brown spots; it almost exactly resembles the material from Wilson's quarry, at Perth, but is perhaps a little softer. (See description of No. 240, p. 131.) The stone has been largely used locally for building, and has been employed in the Parliament Buildings, Ottawa. In the rougher type of structure much unsightly brown is exhibited, but selected and dressed stone shows a fine, uniform grey appearance. The quarry is within a half mile of both the Grand Trunk and the Brockville and Westport railways.

There is no present production.

W. Stafford, Lyn, Lot 26, Con. II, Elizabethtown, Leeds county.

The stone on this property is essentially similar to that of the Bolin quarry. No present production.

Henry Armstrong, Landsowne, Lot 20, Con. II, Lansdowne, Leeds county.

On this property about three acres of sandstone are exposed presenting a thickness of about 14 feet. Very little work has been done, but the stone appears to be all soft and easily worked. The hard siliceous type seems to be entirely absent. In descending order the following beds are presented:—

14 inches—Whitish with brown stains in streaks and clouds.
12 inches—White with brown spots.
6 inches—Clear white—206.
8 inches—Clear white.
6 inches—White with occasional spots.

In some places the stone is two feet thick.

The stone: A white sandstone with a greenish cast, uniform in character and fine in grain; it resembles the stone from Bolin's quarry, at Lyn, but it is softer and may be distinguished by the somewhat greenish colour. This material is considerably softer than the stone from Wilson's quarry, at Perth, (240, p. 131) which has been selected for description in detail.

The best example of the use of this stone is seen in the Bennett block, in Gananoque. This building presents a uniform grey colour with no brown spots. The disappearance of the brown spots on weathering is noticeable in the case of many of the spotted rocks from this formation.

The quarry is about one mile by road from Lansdowne station on the Grand Trunk railway.

No present production.

Summary—Brockville Area.

The sandstone in this area occurs in narrow troughs in the underlying Archæan rocks. The deposits are thin and variable. The stone is mostly of a white colour but it is tinged with green in places. Much of the product is stained brown by the decomposition of pyrite. On the whole the stone is softer than the typical white sandstone from the Rideau and Smiths Falls areas.

Literature:—Geol. Sur. Can., Rep. 1851–2, pp. 64–65.
" " " " 1863, pp. 91–92.
" " " " 1900, pp. 134–137.

Rideau Area.

Sandstones are exposed along the greater part of the south shore of the Rideau lakes whence they extend south and east to meet the northern extremity of the Brockville area, with which the present area is practically continuous. As shown on the map, the northern part of the area is approximately correct, but, like the Brockville area, the eastern and southern extension awaits the publication of a detailed map.

Many small quarries are worked locally along the line of the Brockville and Westport railway between Delta and Westport, and along the shore of Rideau lake above Oliver's Ferry. The only important quarry now in operation is situated near Westport, an account of which follows:—

R. H. Young, Westport. Operated by Government for canal construction. Henry Howell, foreman, Westport.

At the quarry, only about one acre of valuable stone appears. This deposit consists of a single solid bed 3 feet 9 inches thick. The chief joints run northwest and average about 20 feet apart. A second series of joints cut the formation in a direction 25° east of north, but they are so few and so far apart as to be negligible. In consequence of this freedom from checks, blocks the entire thickness of the bed and of any desired dimensions can be obtained with facility (43). On the hill above the quarry a hard, white, siliceous type of sandstone occurs and a similar stone 6 to 8 inches thick, white in colour, but with hard siliceous bands (flint) underlies the workable material—44.

The stone: No. 43.—In colour this stone is a light reddish brown, mottled with light green and dotted with white. The general effect at a little distance is shown in Plate LXXVI, No. 9. On sawn or smoothed surfaces the small white spots stand out prominently. On treatment with carbonic acid the colour is not materially affected.

Plate XXXIII.

Potsdam-Beekmantown Sandstone, Wm. Gordon's Quarry. Post-office, Napanee, Ont.

Plate XXXIV.

Potsdam-Beekmantown Sandstone, Hughes' Quarry. Post-office, Smiths Falls, Ont.

Under the microscope the rock is seen to be composed of grains of quartz of very irregular size. The larger particles are as much as one mm. in diameter and are generally well rounded, the smaller grains are more angular and fill the interstices between the larger grains. The cementing material is carbonate of lime with a small amount of argillaceous matter. The pore spaces are scarcely perceptible under the microscope.

The physical properties of the stone are as follows:—

Specific gravity	2·656
Weight per cubic foot, lbs	152·103
Pore space, per cent	8·24
Ratio of absorption, per cent.	3·4
Coefficient of saturation	0·49
Permeability, c.c per square inch, per hour. .	12·75
Crushing strength, lbs. per square inch	11221·
Crushing strength after freezing, lbs. per square inch.	7569·
Loss on freezing, per cent.	0·094
Loss on treatment with carbonic acid, grams per square inch	0·018
Transverse strength, lbs. per square inch	619·
Chiselling factor	3·6

An analysis by Mr. Wait gives 0·20 per cent ferrous oxide and 0·34 per cent ferric oxide.

No. 44.—This stone is pure white except for the presence of occasional brown spots; it is comparatively fine in grain and except for the fact that it is a little softer closely resembles No. 240 from Wilson's quarry at Perth. (See page 131.)

Along the south side of Lower Rideau lake considerable stone is quarried in an irregular way; the property described below may be considered as representing the stone in this section.

R. Jacklin, Lombardy, Lot 26, Con. IV, S. Elmsley, Leeds county.

The overburden is light, both on this and on adjoining properties, so that an unlimited amount of stone can easily be obtained without stripping. In places the sandstone is capped by the lower beds of the Beekmantown limestone. Two types of the sandstone are recognized—a softer easily worked white variety which is, however, marred by brown spots, (233), and a hard flinty type, deeply pitted and full of cavernous spaces lined with black material (234). Very little work has been done and no regular quarry opened, the practice being to blast out the softer stone at various places over the property. These soft beds are from 10 to 12 inches thick, and appear to overlie the hard flinty type, but the occurrences are so irregular and so scattered that it is doubtful if there is any fixed relation between the hard and the soft types. There is undoubtedly a large supply of the soft stone available.

The stone: No. 233.—The stone is white with a very light greenish cast, and is spotted throughout with brown dots of ¼ inch diameter. The constituent grains are quartz, which are united by a very small amount of cement, which is not of a calcerous nature, but appears to be somewhat ferruginous in character. Under the microscope certain parts of the stone show that the constituent grains form a close mosaic without either cement or interspaces. The grains are more angular than in many of these stones and do not average more than one-fifth mm. in diameter.

The stone is occasionally marked by bright green clouds which appear to have originated from the decomposition of some mineral bearing copper. This stone is softer than the material of a similar character from Wilson's quarry at Perth, and could probably be worked with about the same facility as the stone from Kingston Mills which has a chiselling factor of 4·49.

No. 234.—This stone was originally of the same character as No. 233, but it has become harder and flinty in consequence of alterations. It is badly checked and broken, besides being marred by large cavities lined with a dark stain.

This brown spotted stone has been largely used in Smiths Falls and throughout the area. Owing to its porous nature it rapidly loses the white appearance and becomes grey through the soaking in of the dirt. By this means, and probably also by chemical changes, the brown spots become invisible and the stone presents a uniform grey appearance. Judging from buildings in Smiths Falls, it would appear that some of this stone is much more durable than other examples. Certain pieces, placed in position 30 years ago, are very badly decomposed and others of similar age have suffered little, except for the darkening in colour already referred to.

The stone from this and from adjoining properties could be loaded into boats on Rideau lake by a very short haul. There is no regular production.

Summary—Rideau Area.

The normal stone of this section is a hard, flinty, white variety marked by brown stains and checks; it is of little economic value. In some few places, however, the hard type gives place to a softer stone which is white in colour but is marred occasionally by brown spots. Extensive quarrying is not probable, because the soft stone is much interbanded with the hard type. Near Westport a greenish mottled variety is now being quarried for use in canal construction.

Literature:—Geol. Sur. Can., Rep. 1863, p. 92.
" " " " 1882-4, p. 2 MM. (Porosity, etc., given).
Rep. Royal Com. Min. Res., Ont., 1890, p. 80.
Geol. Sur. Can., Rep. 1901, p. 16 J.; Perth Sheet Map.
" " " Map, Publication No. 626.

Smiths Falls-Perth Area.

This belt extends from the neighborhood of Smiths Falls, along the northern side of Lower Rideau lake, through Perth and westward almost to the shore of Christie lake. The belt is from one to two miles broad and possesses a southern extension reaching down to Black lake.

Many quarries have been opened throughout the area and the stone has been largely employed in Smiths Falls and Perth. A considerable amount has been shipped to a distance, more particularly the purple-banded stone from near Perth, a description of which follows:—

James Hughes, MacCue, Ont., Lot 26, Con. VII, North Elmsley, Lanark county.

On this property the valuable stone occurs on a knoll overlooking a small lake and is exposed over an area of about 50 acres. In descending order the sequence of beds is as follows:—

12 to 18 inches—Purple-banded stone with three inch white top—229.
10 inches—Purple-banded stone—228.
4 inches—Soft, white stone with brown spots—230.

Beneath is a hard, flinty type of white sandstone with brown spots and checks and with a tendency to break in a direction inclined to the bedding. (231.) All the beds dip westward at a low angle and pass under a heavy overburden, beneath which it is possible that more of the good stone may be obtained. This purple stone is unique, and is described in detail below.

On the adjoining property of John Matthews, there is about an acre of white stone much like the soft white of this quarry. The overburden is from 0 to 4 feet.

The stone: No. 228.—The characteristic feature of the colour of this stone is the broad bands of purplish hue which vary from narrow lines to 8 or 10 inches in thickness. The colour of these bands is a much more distinct purple than that shown in Plate LXXVII, No. 5. Much of the intermediate material is of a yellow colour fading to white. This yellow tint is shown in Plate LXXVII, No. 8. A general idea of the stone may be obtained by imagining bands of a darker purple than No. 5 alternating with bands like No. 8, and fading into a yellowish white. On treatment with carbonic acid the colour is but slightly affected, but the stone loses somewhat in its brightness.

Under the microscope the stone presents a mosaic of small quartz grains, seldom more than $\frac{1}{4}$ mm. in diameter, closely apposed, and with a minimum of ferruginous and argillaceous cement. It is entirely to this cement that the rock owes its characteristic colour.

The physical properties of the stone are indicated below:—

Specific gravity	2·647
Weight per cubic foot, lbs.	150·383
Pore space, per cent	8·969

Ratio of absorption, per cent	3·72
Permeability, c.c. per square inch, per hour	1845·
Crushing strength, lbs., per square inch	15459·
Crushing strength after freezing, lbs. per square inch	11300·
Loss on freezing, per cent	0·0009
Loss on treatment with carbonic acid, grams per square inch	0·00386
Transverse strength, lbs. per square inch	417·
Chiselling factor	2·37

No. 229.—This stone is of a light yellow colour and closely resembles that shown in Plate LXXVII, No. 1. The grain of the rock is the same as the purple variety and it differs only in the absence of the iron constituent in the cement, whereby the colour is much lighter.

No. 230.—This stone is whiter but otherwise very similar to that from Jacklin's quarry already described (No. 233, page 128).

No. 231.—An indurated, flinty, white stone with checks and flaws lined with brown iron oxide; it has no economic value.

From this quarry some very large blocks of stone have been obtained—one 30 feet long, 2 feet wide and 18 inches thick is said to have been quarried. Unfortunately most of the good stone has been removed, and, unless prospecting down the hill reveals a further supply, the purple stone is practically exhausted. The practice in quarrying was to break the stone with wedges, very little powder having been employed. With the bedding, the stone breaks freely, and across the beds a good uniform break is obtained by lining and striking with a hammer. Much valuable stone was destroyed and the regular development of a quarry hindered by allowing contractors to quarry their own stone; in consequence of this, the exposure was picked over and no proper quarry ever opened. Contractors paid the owners $2 per cord for the privilege of operating. The following list indicates the prices obtained for the stone at the quarry:—

Sills, 40 cents per running foot.
Lintels, 40 to 50 cents per running foot.
Door sills, 60 cents per running foot.

The following list indicates some of the chief structures in which this stone may be observed:—

The Tay locks.
Post-office in Smiths Falls. (Plate XXXIV.)
Post-office, Almonte.
Post-office, Arnprior.
Mr. Code's residence, Perth. (Plate XXXV.)
C. P. R. station, Perth.
There is no output at present.

Westward from Perth, along the road between the first and second concessions of Bathurst, are several quarries in white sandstone.

Geo. S. Wilson, Allan's Mills, Ont., Lot 16, Con. I, Bathurst, Lanark county.

On this property about 40 acres of stone could be exposed by the removal of an average of 1 foot of overburden. The sequence of beds is not constant; in one place an upper 9 inch bed and a lower 8 inch bed have been quarried; beneath these is 1 foot of thin shaly material, and at the bottom, a fine white variety which has not been exploited. At another place, an upper 15 inch bed was observed, with thinner material below. Much of the stone is soft and white, (240), but the brown, spotted variety, similar to that in the Rideau area, overlies the good stone and is interstratified with it in places. Good evidence of the disappearance of the brown spots on weathering is shown in the quarry, for pieces which are perfectly white on the surface are found to be full of the spots when broken open. The practice has been to remove the upper beds only, but there is no doubt that good white stone can be obtained to a depth of 6 feet at least. There is a well developed system of joints striking northeast and a less important series running 20° east of south. The presence of these joints does not prevent the obtaining of blocks 4 feet by 6 feet in size.

The stone: No. 240.—The stone is white with a slight blue-grey cast and is shown in Plate LXXVII, No. 3. Occasional small brown spots are to be observed. Treatment with carbonic acid in water produces no effect whatever, but the stone imbibes dirt from the atmosphere and assumes a grey colour on long exposure.

The microscope shows an even mosaic of small quartz grains with scarcely any cementing material.

The physical properties are listed below:—

Specific gravity	2·631
Weight per cubic foot, pounds	156·007
Pore space, per cent	4·947
Ratio of absorption, per cent	1·98
Coefficient of saturation	0·32
Permeability, c.c. per square inch, per hour	1·75
Crushing strength, lbs. per square inch	31793·
Crushing strength, after freezing, lbs. per square inch	28912·
Loss on freezing, per cent	0·014
Loss on treatment with carbonic acid, grams per square inch	0·00181
Transverse strength, lbs. per square inch	1635·

Chiselling factor.—Inappreciable.

Mr. Wait describes the cement as "Silica and a trifling quantity of argillaceous matter," and gives the per cent of ferrous oxide as 0·27.

This stone is extremely strong, impermeable, and durable; it has a low porosity and is not greatly affected by frost. The colour is almost the same as the hard type of Nepean stone. In the chiselling test it shows a great hardness and rapidly grinds off the edge of the tool, but, as it breaks with ease, coursing stone is readily prepared. This stone passes insensibly into the spotted variety which is generally much softer. Although the chiselling factor of this and of the other related stones from the Potsdam-Beekmantown formations is low, it is not to be inferred that the stone cannot be chiselled. As already pointed out (see page 78) the fine edged chisel used in making the test so rapidly loses its edge by impact with the smooth surface of the slab employed that it has no chance to work into the stone and to break out chips in the manner of a narrower chisel driven by a mallet. The stone is certainly much softer than the hard, flinty type of material and is referred to as the "soft, white" variety in contrast to the flinty type. When the brown spots appear the stone seems to be still softer.

Stone was obtained from this quarry as far back as 1827; during the past six years about 2,000 cords have been quarried. Rough, hammer broken stone is sold at the quarry for $2.50 per cord, in the summer, and for $4 to $5 per cord, in the winter. The product is used largely in Perth where it may be observed in the Bank of Ottawa, Mr. Code's residence and mill, and in the Wampole building.

Ed. Trainer, Glentay, Ont., Lot 16, *Con. III, Bathurst, Lanark county.*

This quarry is operated in much the same manner as Wilson's but on a smaller scale. The stone is similar, but there is more of the spotted variety evident. The unspotted stone here has not the tendency to split diagonally observed in the Hughes quarry. The stone may be observed in the Municipal Poor House near Perth.

The following list indicates some of the smaller operators in this district. The stone is, in all cases, quite similar to Wilson's or Trainer's.

James Gibson, lot 17, con. I, Bathurst.
Wm. Hosie, lot 17, con. III, Bathurst.
J. Brady, lot 18, con. II, Bathurst.
Louis Bedour, lot 18, con. II, Bathurst.

Summary—Smiths Falls-Perth Area.

As in the Rideau area the common stone is hard and flinty. Two types of workable stone are quarried—a softer, but still hard white stone and a more readily cut, purple-banded variety. This latter stone is often referred to as the "Perth stone" and has been employed in public buildings at many places in eastern Ontario. The white variety is liable to have brown spots throughout but these largely disappear as the stone weathers. Great differences in hardness and durability exist as may be seen by an inspection of buildings in Smiths Falls, Perth, Almonte, etc. A good example of the use of both stones is seen in the residence of Mr. T. Code, in Perth, which has the walls of white stone and the "trimmings" of the purple variety. (Plate XXXV). That the white stone is capable of being dressed may be observed in the old post-office in Perth (Plate XXXVI).

Plate XXXV.

Potsdam-Beekmantown Sandstone. Residence of T. Code, Perth, Ont.

Plate XXXVI.

Potsdam-Beekmantown Sandstone. Post-office, Perth, Ont.

Literature:—Geol. Sur. Can., Rep. 1871–2, p. 128.
" " " " 1872–3, p. 165.
" " " " 1901, p. 16 J; p. 73 J; Perth Map Sheet, Publication No. 789.
Geol. Sur. Can., Map Publication No. 626.

Mississippi Area.

This area includes a small patch in Drummond and North Elmsley and a still smaller one in Montague. The main portion shows on the southeast and on the northwest corners of Mississippi lake and extends northward as a narrow belt, west of the Mississippi river, to lot 10 in con. XI of Pakenham. Although this stone has been quarried and used to a small extent in Carleton Place, Almonte, Pakenham and Lanark, I learned of no important quarry and none was visited.

Judging from the old buildings in Almonte, the sandstones west of that place are of white colour and sufficiently soft to be carved with some facility. The stone seen in Lanark village and said to have been quarried in the township of Drummond, is of a yellowish colour and has well withstood the attacks of the weather. There is probably no essential difference between these rocks and those of the Smiths Falls area.

Literature:—Geol. Sur. Can., Rep. 1863, p. 93.
" " " " 1901, p. 16 J.

Nepean Area.

The sandstones of this area are exposed chiefly in the southwest corner of Nepean Front and the south of March, thence they extend westerly as a narrow band to lot 12, concession XII of Fitzroy. There is also a small outcrop on lots 10 and 11, concession XI of Fitzroy, and a lens-shaped band stretching from lot 22, concession XII to lot 9, concession IX of Huntley. The only exposure of known economic importance is that in the township of Nepean and here the good stone seems to be restricted to about six lots as follows:—

C. Keefer, Rockcliffe Park, lot 6, con. I, Ottawa Front, Nepean township.

Howard Rock, Bells Corners, lot 5, con. I, Ottawa Front, Nepean township.

Mrs. John Beattie, Bells Corners, lot 4, con. I, Ottawa Front, Nepean township.

T. W. Tillson, Bells Corners, lot 6, con. II, Ottawa Front, Nepean township.

J. Davis, Bells Corners, lot 4, con. II, Ottawa Front, Nepean township.

R. Morrison, Bells Corners, lot 3, con. II, Ottawa Front, Nepean township.

Besides these occurrences, the literature contains references to other localities, particularly lot 35, concession IV, Nepean, and lots 26, 27, and 28, concessions V and VI, Nepean.

S. T. Kirby, of Ottawa, has a lease of the rocks on the Beattie and the Morrison properties, and the Foley Construction Co., of Ottawa, operates the quarry on the J. Davis property.

The haul from the quarries to the G. T. R. siding is about one mile and a quarter.

The Tillson quarry was selected for examination and must be considered typical of the area.

T. W. Tillson, Bells Corners, Lot 6, Con. II, Ottawa Front, Nepean, Carleton county.

The beds on this and on the adjoining properties are exposed on a gentle hill rising above the surrounding farm land. The dip is northward at a low angle. As in the case of nearly all quarries in the formation, the sequence of beds is different in different places so that no general statement can be given. A typical opening, however, shows the following series in descending order:

3 feet white, thin bedded stone of little value.
1 foot brownish and yellowish banded stone.
18 inches—Same.
9 inches—Same.
6 inches—Same.
8 inches—Same.
4 inches—Same.

Joints cut the beds north and south and east and west and are rather irregularly developed. Blocks can sometimes be obtained 4 to 6 feet long but never more than 2 feet wide. The joint planes are almost always covered with a brown skin of iron oxide; this skin must be split off, if it is desired to use the joint face for the exterior of a block in a building. Failure to do this has injured the appearance of certain buildings.

In another part of the quarry, at a lower level than the above opening, the beds have been worked to a depth of 6 feet in a white stone which occurs in layers about 18 inches thick. This stone is softer than the coloured type and is preferred by some builders—216.

Ten feet higher than either of the openings described and about 100 feet farther up the hill in a northwest direction, more of this white stone is encountered but it is poorly bedded, passes into the coloured variety, and is mixed with the hard flinty type. This stone is not so desirable for building purposes but it makes excellent paving blocks—217.

About 20 acres of stone are exposed on the property, of which not more than 3 acres have been quarried. There is undoubtedly a large amount of good material available.

The stone: No. 216.—Although commonly called the white Nepean stone, this example shows a distinctly grey colour represented in Plate LXXVI, No. 11. There is no appreciable change in colour on treatment with carbonic acid in water. The stone is composed of irregularly shaped quartz grains embedded in a calcareous cement of which there is a considerable quantity.

The physical characteristics are enumerated below:—

Specific gravity	2·631
Weight per cubic foot, lbs.	153·504
Pore space, per cent.	7·22
Ratio of absorption, per cent	2·93
Coefficient of saturation	0·21
Permeability, c.c. per sq. in. per hour.	4·87
Crushing strength, lbs. per square inch,	22032·
Crushing strength after freezing—not ascertained.	
Loss on freezing, per cent	0·023
Loss on treatment with carbonic acid, grams per square inch	0·064
Transverse strength, lbs. per square inch	1620·
Chiselling factor	0·25

Analysis: F. G. Wait, Mines Branch laboratory.

Cement.—Calcium carbonate and a trifling quantity of argillaceous matter.

Ferrous oxide, per cent	0·12
Ferric oxide, per cent.	0·25
Sulphur, per cent	0·002

No. 217.—This stone is white with a slight cast of green, while the almost similar stone from Wilson's quarry at Perth has a slightly pink cast. Treatment with carbonic acid destroys the green tone, and gives the rock a colour between Nos. 1 and 2 of Plate LXXVII.

The microscopical structure is identical with that of the Perth stone which it also resembles in its physical characteristics.

Specific gravity..	2·647
Weight per cubic foot, lbs	155·357
Pore space, per cent	5·958
Ratio of absorption, per cent	2·37
Coefficient of saturation	0·44
Permeability, c.c. per square inch, per hour	17·5
Crushing strength, lbs. per square inch	21627·
Crushing strength after freezing, lbs. per square inch.	19731·
Loss on freezing, per cent	0·041
Loss on treatment with carbonic acid, grams, per square inch.	0·00147
Transverse strength, lbs. per square inch	1835·
Chiselling factor—inappreciable.	

Analysis: F. G. Wait, Mines Branch laboratory.

Cement—Silica and a very little argillaceous matter.

Ferrous oxide, per cent.	0·3
Ferric oxide, per cent.	0·6
Sulphur, per cent.	0·04

No. 215.—This stone differs from the white Nepean only in the colour, which appears in yellow and brown bands and gives the stone a soft and mellow appearance in the wall. The physical constants were not determined but they are doubtless similar to those of Nos. 216 and 217 described above.

The stone is sold by the ton, $3 being the average price for the general run of the quarry, and $4.50 for dimension stone, f.o.b. G. T. R. siding. At the present time, most of the output is converted into paving blocks, the cost of producing which is $3\frac{1}{2}$ cents each, paid to the workman, and a small royalty to the owner of the property. Building stone is produced only when orders are received and in consequence it is difficult to ship selected stone on a paying basis.

Stone from this quarry was used in the construction of the new Museum, the Mint refinery, the Observatory at the Experimental Farm, and the addition to the Court House in Ottawa.

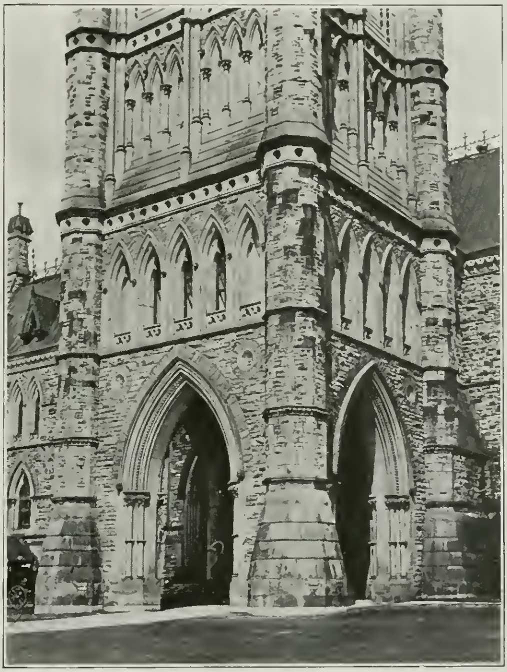
Summary—The Nepean Area.

The valuable stone is obtained from six lots in the southwest corner of Nepean Front. Three types of stone may be recognized—a white variety, a brown and yellow variety, and a hard flinty white kind. The beds are irregular in distribution but the whole deposit is thicker and gives greater promise of a continued output than most of the areas of the formation. The white stone retains its colour to perfection as may be seen in blocks exposed to the worst conditions by long exposure in the quarry. The coloured stone has a soft and pleasing effect and is preferred by some architects to the white variety. In earlier structures, as in the Parliament Buildings, in Ottawa, the stone was used without discrimination, the white and coloured being mingled with the hard flinty type. At the present time builders refuse the hard stone entirely and demand selected stone either of the white or coloured type. The material is said to chisel much more readily when freshly quarried and to harden on exposure. It is very likely that the harder bands observed throughout the Potsdam-Beekmantown sandstone areas may be due to a secondary hardening rather than to an original difference in the character of the stone. Most of the stone is now made into paving blocks for the city of Ottawa; building stone is being produced only when orders are received, which necessitates an additional cost in production in order to deliver selected stone. Systematic quarrying, with the acquisition of stocks of selected material, would do much to stimulate the use of this stone and to extend its application to a wider area.

Nepean stone has been largely used for building purposes, chiefly in Ottawa, where many business blocks and private residences are constructed of it. Of the public buildings the more important are the following: The

Nepean Sandstone. Parliament Buildings, Ottawa.

Plate XXXVIII.



Nepean Sandstone. Main Entrance, Parliament Buildings, Ottawa.

Parliament Buildings, (Plates XXXVII and XXXVIII), the new Museum, the refinery to the Mint, the Observatory at the Central Experimental Farm, the Archives building, and the recent addition to the Court House. Stone has also been recently shipped to Montreal for the construction of a large residence. For a detailed description of the stone *vide ante* under Tillson's quarry. Besides its use as a building material Nepean stone may find an application in the glass making industry.

Literature:—Geol. Sur. Can., Rep. 1863, p. 94; p. 813.
" " " " 1888–9, p. 125K.
" " " " 1897, p. 58A.
" " " " 1899, p. 34G; p. 47G; Map, City of Ottawa and vicinity, Publication No. 714.
" " " " 1901, p. 15 J; Perth Map Sheet, Publication No. 789.
" " " Ottawa and Cornwall Map Sheet, No. 120; Publication No. 903.
" " " " 1863–66, p. 283.

Prescott Area.

There is a large exposure of sandstone in Vaudreuil in Quebec which sends a tongue into Ontario occupying the south corner of East Hawkesbury as far as Ste. Anne de Prescott. Another small area which may be included here although it represents a different sedimentation is seen surrounding a peninsula of the great Archæan region to the north in the northern part of the township of Clarence. I am not aware that any extensive quarrying has ever been conducted on these exposures and in consequence they were not visited.

With regard to the character of the stone, Ells gives a section at Rigaud village, which may be taken to represent the Prescott area although outside the province: "The section comprises a thickness of 40 feet, which represents the upper portion of the formation and the transition beds to the Calciferous dolomites. In this, the lower 33 feet consists of interstratified beds of sandstone, sometimes calcareous but occasionally hard and vitreous with Scolithus markings. The upper 7 feet consist of reddish grey magnesian limestone of the type common to the Calciferous over large areas." Ells also states: "Further west on the north side of the Ottawa, between Papineauville and Montebello, a quarry is located in the Potsdam sandstone which has yielded a large amount of stone." It is reasonable to expect that the area in Alfred should be similarly productive.

Summary—Potsdam-Beekmantown Sandstone.

The stone is mostly hard, white and flinty with brown spots and checks; the workable varieties are the exception to the above rule. Four or five types of stone may be recognized as follows:—

1st. A coarse grained red, white, and salmon-coloured banded type, quarried at Kingston Mills.

Fig. 9. Sketch map of part of Eastern Ontario, showing the areas of Potsdam-Beekmantown Sandstone and the chief quarries.

2nd. A purple-banded type, procured near Perth.

3rd. A greenish red and white mottled stone now being quarried near Westport.

4th. The Nepean stone in hard white, soft white and yellow and brown banded varieties.

5th. White stone, sufficiently soft to work, is obtained at Lyn, Perth, etc. This stone varies in hardness and is often marred by brown spots.

On the whole the Potsdam-Beekmantown sandstones are hard and are not adapted to fine work. The three first mentioned types are the softest and most amenable to chiselling. Much of the stone makes excellent rubble and random coursing and for rock face work it is very desirable.

Literature:—Geol. Sur. Can., Rep. 1863, p. 91; p. 112.
" " " " 1899, p. 81 J; p. 136 J.

MEDINA SANDSTONE.

The sandstone band of the Medina formation has an average thickness of about 12 feet only: it represents a shore deposit at the opening of Silurian time. According to Grabau,[1] it is, partly at least, of terrestrial origin, and Wilson has suggested that it was originally wind blown sand. Practically all the exposures are characterized by features suggesting such an origin; most of the quarries exhibit irregular bedding, with lenses of one variety cutting diagonally across others. This irregularity has proved the greatest hindrance to the profitable extraction of the stone. Most of the beds are fine grained and present roughly three types, first, a brown to chocolate coloured variety, quarried chiefly at the Forks of the Credit; second, a white or grey variety obtained at Orangeville and from Milton northward to the Forks of the Credit, also at Hamilton; and third, a mottled variety in which blebs and bands of white occur in the brown base. This latter kind is obtained more particularly from Merritton to Grimsby. The formation occurs along the face of the Niagara cuesta from near Merritton to Hamilton. Between Hamilton and Milton the cuesta is much broken up and the exposures are few, but from the latter place northward to Cataract, outcrops are numerous. Above Cataract, the stone is hidden very largely but an important outcrop is known east of Orangeville and again near Shelburne. At no place is the exposure wide, as it appears only along the face of the "mountain" and has scarcely any lateral extent. The widest and most accessible places occur where the sandstone forms the top of a shoulder, on the mountain side. Much of the quarrying has been done by removing a heavy overburden or by actually mining into the side of the hill. Unfortunately, those places where the stone is most easily obtained yield a poorer product than where it is less accessible. It may almost be regarded as a rule that the heavier the overburden the better the stone. For instance the widest exposures lie north of Limehouse, but this region has never produced the fine quality of stone obtained under the overlying Niagara rocks at the Forks of the Credit.

For convenience of description the formation may be divided into the following areas:—

Niagara area.
Milton area.
Credit Valley area.
Orangeville area.

[1] Journal of Geology, 1909, p. 238.

Niagara Area.

The stone is to be seen in the gorge of the Niagara river, but the first economic outcrop is near Merritton. From this point as far as Hamilton numerous exposures are seen, particularly where the various streams have denuded the mountain side. Much of the stone in this area, more especially at the eastern end, is of the mottled type; but grey stone is obtained at various places and is practically the only kind seen at Hamilton. So many quarries have been opened and abandoned that to attempt a description of them all would be futile. The following properties which were actually visited must serve as examples of the area.

Niagara Central Railway, Merritton, Ont.

Close to the tracks of the Niagara Central railway north of Merritton and on the property of the Company is a cliff of about 20 feet in height extending for nearly half a mile. A typical section of this cliff shows in descending order the following beds:—

2 feet—Loose stone and soil.
5 feet—Mottled stone in beds ranging from three inches to one foot thick.
6 feet—Thin sandstone and shale—useless.
10 inches—Mottled stone.
6 inches—Mottled stone.
4 inches—Mottled stone.

In other parts of the cliff a different succession is shown with some grey beds. The mottled stone must, however, be considered characteristic of the quarry (89).

Much stone has been quarried here and used locally; some has also been shipped to Cleveland and other American cities. In from the face of the cliff, there is, for a considerable distance, no rise in the surface, so that a great amount of stone could be obtained with little more stripping than is indicated in the section above.

The stone: No. 89.—This rock is a fine grained reddish brown sandstone, with large irregular blebs of white scattered throughout the mass. The red part shows very distinct lamination and the whole rock is much indurated; it would be much harder to cut than the typical Medina sandstone, either brown or grey, from the Forks of the Credit. The white part is lighter than the ordinary grey sandstone of the formation but it has a tendency to turn yellow with the passage of time. Under the microscope the stone is seen to be made up of rounded or sub-angular quartz fragments with a considerable amount of cementing material in the form of minute flakes of hematite. The quartz particles average about one-sixth of a mm. in diameter.

There is very little production at present and neither statistics or prices could be learned with certainty. The Riordon paper mills, the old cotton mill and the Town Hall in Merritton are built of this stone, which may also be seen in the Packard Electric Light Co's. building, St. Catharines.

Robert Goodall, Rockway, Ont., Lot 10, Con. VII, Louth, Lincoln county.

On this property about 10 acres of stone are available which could be obtained by removing an average of 2 feet of stripping. The quarry consists of a crescentic opening which is about 150 feet across the face. While the exposed face presents the usual variations in the sequence of beds, this feature is not so marked as in some cases and fairly continuous beds are to be seen. The descending section is as follows:—

2 feet—Stripping.
18 inches—Shelly material.
8 inches—Mottled sandstone.
1 foot—Mottled sandstone.
2 inches—Shaly parting.
10 inches—Mottled stone.
14 inches—Mottled stone.
2 inches—Shale.
7 inches—Mottled stone.
2 feet—Mottled stone.
2 feet—Mottled stone, without reaching the underlying red shale—84.

The stone: No. 84.—The brown part of this stone is shown in Plate LXXVII, No. 4, which may be considered as the typical colour of the Medina brown stone, although many different shades are presented in many parts of the range. The white part occurs in blebs, varying from almost nothing to a foot in length and reaching, in some cases, a width of 6 inches. Most of the white parts are, however, not more than 6 inches in length. The stone is of fine, uniform grain without any distinct evidence of stratification; in this respect it is superior to the Merritton stone. While harder than the typical Medina sandstone, as obtained farther north, it could be more easily worked than the product of the quarry at Merritton. As in the case of this latter stone, the white parts of the present example turn yellow on weathering. Under the microscope the particles are seen to be finer than those of the Merritton stone; they are also more angular in outline and more closely set together with a much smaller quantity of cement. An analysis of the white portion was made in order to ascertain the cause of the yellow weathering. Mr. Wait found 0·32 per cent of ferrous oxide, 0·41 per cent of ferric oxide and a trace of sulphur. It would appear therefore that less than half of one per cent of ferrous oxide is sufficient to cause discolouration of white sandstone.

Throughout the quarry the blotching of the red stone with white is uniform, the bedding is reasonably flat, and the layers are sufficiently thick to produce good dimension stone. On the face, the thicker layers show a tendency to part along bedding planes to thinner material, but, a short distance in, the beds are tight and stone of 4 feet in thickness can be obtained. There is now no actual production and it is seven years since any work was done. Examples of the stone may be seen in the Roman Catholic church at

Niagara Falls, (Plate XXXIX), the paper mill at St. Catharines, and Solomon Grove's residence, Ontario St., St. Catharines.

When the stone is removed by contractors, they pay the owner $1 a cord royalty. The price is $2.50 per cord at the quarry and $6 per cord delivered in St. Catharines.

Wm. Biggar, Jordan, Lot 15, *Con. VI, Louth, Lincoln county.*

The quarry is situated where Sixteenmile creek cuts the escarpment. Stone has been quarried on both sides of a ravine which intersects the property. East of the hollow, the exposure is about 10 feet thick, presenting stone in beds of from 4 inches to 1 foot thick; it is all of the mottled variety and is covered by a heavy overburden. West of the ravine, about 20 feet are exposed, the top is white and thin bedded and the lower portion mottled, for the most part, but some bands of fine brown stone are to be seen. All the stone is irregular in bedding, with shaly partings and with considerable overburden. An average specimen is described below—83.

The stone: No. 83.—This example is much finer in grain than that from the two quarries previously described and is almost identical in this respect with the typical Medina from the Forks of the Credit. The brown part is slightly lighter than that shown in Plate LXXVII, No. 4, and the white blebs and streaks have the grey cast characteristic of the typical grey Medina shown in Plate LXXV, No. 9. This stone would doubtless be easier to carve than either of the samples already described.

Very little work has been done on the property; the product has been used locally only. Rough stone can be delivered at the railway for $5 per cord.

Daniel Thompson, Jordan, Lot 14, *Con. VI, Louth, Lincoln county.*

This property adjoins Biggar's, but the stone exposed seems to lie at a lower horizon and to be different in character. The outcrops are seen on both sides of a ravine 30 feet deep. Owing to a heavy talus on the slopes of the ravine, the thickness of the beds cannot be ascertained but it is certainly greater than is common on the Medina band. About 5 acres of stone are available without excessive stripping. This fact, together with the considerable thickness of the deposit, indicates a large supply. The beds are of lenticular shape and, in some places, are 2 feet thick and quite solid and compact throughout. All the stone is of the grey variety, but it is hard and is marred by fine brown spots throughout—82.

The stone: No. 82.—This is a more indurated stone, with particles larger than those in the stone of either the Goodall or Biggar quarry. The grains are about as large as in the Merritton stone but they are quite different in character, being set close together in a fine mosaic of closely appressed angular fragments. The brown dots referred to above are very small and are scattered

Plate XXXIX.

Medina Mottled Sandstone. Roman Catholic Church, Niagara Falls, Ont.

Plate XL.

Medina Mottled Sandstone. Tower of Church of England, St. Catharines, Ont.

throughout the rocks at intervals of about one-eighth of an inch; they appear to have arisen from the decomposition of some ferruginous mineral, the nature of which is uncertain. On weathering, these dots become still more perceptible and much darker in colour. Owing to the close set character of the grains the rock is hard—about equal to Goodall's—and could not be carved with facility.

Some of this stone was used in the construction of bridges on the Great Western line, but there has been little production since the time this road was built. Last summer 60 cords were quarried for use in basements of houses. The product can be delivered at the railway for $5 per cord.

The Grimsby quarries.

Brown, grey and mottled sandstones were formerly quarried near Grimsby, Ont. Here, the overburden is heavy and operations have been suspended, although a company was organized in 1890 to work the deposits. (See Bur. Mines, Ont., Rep. 1891, p. 97).

G. F. Webb, King St., Hamilton, Ont.

The quarry is situated on the mountain side at the head of Victoria St. The opening is about 200 feet long and has been worked back 50 feet. The present stripping is about 5 feet thick but it will increase as the quarry is enlarged. About 200 feet in from the present face the vertical cliff of the overlying limestones will make further operations impossible except by actual mining.

A section of the layers exposed is as follows:—

3–6 feet—Overburden.
2 feet—Thin shaly limestone.
14 inches—Limestone.
6 inches—Limestone.
4 inches—Limestone.
24 inches—Limestone in three 8 inch beds.
1 foot—Limestone, thin and shaly.
20 inches—Limestone.
30 inches—Sandstone.
10 inches—Sandstone.
1–2 feet—Sandstone, undulating and irregular, but in places 18 inches thick.
3–4 feet—Sandstone, fairly constant layer.

The stone is all grey and shows distinct banding (reedy), it so closely resembles the product from Mill's quarry that no specimen is described.

The main joints run parallel with the face of the mountain; they are far apart and do not interfere with the obtaining of large blocks of stone. There is no apparent jointing in the opposite direction. The practice is to quarry with ball drills and black powder and to break all the output into rubble; a great deal of good stone is thereby destroyed. Price, $4 to $4.50 per cord delivered at the work in the city.

Geo. Mills, Hamilton, Ont.

The quarry is situated on the mountain side, east of the head of Emerald St. The opening is 300 feet long and about 50 feet wide. The present overburden is 15 feet thick, but it will increase as operations are extended. The section exposed is as follows:—

15 feet—Loose material, stripping.

10 feet—Limestone. The upper part is thin bedded but the lower 18 inches (niggerhead) is solid. This bed becomes thicker to the westward and thinner to the eastward.

8 feet—Sandstone. The upper part is hard and flinty; the lower beds are of good grey stone and in places are 5 feet thick. Towards the west end the layers are thinner—118.

The stone: No. 118.—This stone is, in all respects, so similar to the product of the grey stone quarries at the Forks of the Credit that no description is necessary (see account of Nos. 321 and 53 from Georgetown and Orangeville, pp. 148 and 160).

The main joints run with the mountain and are fully 20 feet apart. Joints in the opposite direction are uncommon. Good blocks of stone 3 feet by 2 feet by 2 feet can readily be obtained. The property consists of 5 acres, on which there is much valuable sandstone. The heavy and increasing overburden adds largely to the cost of production. Some dimension stone was shipped from this quarry to Simcoe, but at the present time the whole product is broken into rubble. The equipment consists of one steam drill and one steam derrick. Four men are employed. Dimension stone is valued at 40 cents per cubic foot at the quarry.

Summary—Niagara Area.

The stone from Merritton to Hamilton shows a decreasing amount of the mottled variety with a corresponding increase in the quantity of grey. The Hamilton stone is all grey, while the Merritton and St. Catharines varieties are all mottled. At Grimsby both forms appear. The mottled stone is still available in quantity but the grey stone is covered by a heavy overburden. The effect of the mottled material is not displeasing but the white portions have a tendency to assume a dirty yellow colour. The Hamilton grey stone appears to be equal to any procured on the belt; it was formerly extensively used in Hamilton, but often in a very unsatisfactory manner, the practice being to split the stone parallel to the bedding and to use the sheets as a facing on limestone walls. With the exception of a little rubble, there is no present production throughout the district.

Literature:—Geol. Sur. Can., Rep. 1850–51, p. 14, et seq.
" " " " 1863, p. 310 et seq.
Rep. Bur. Mines, Ont., 1891, p. 97.

Milton Area.

Between Hamilton and Milton, the Niagara cuesta is lower and presents a more gradual ascent so that the outcrops of the sandstone are not common; towards Milton, however, the ridge again becomes conspicuous and numerous outcrops occur to the west and north of the town. The chief quarries are as below:—

James Timbers, Milton.

The quarry is situated two miles west of Milton directly behind the second brick yard on the line of the C. P. R., towards Campbellville. Here are large exposures of red shale which underlie the sandstone and which are extensively employed for brick making. The sandstone is about 12 feet thick in the quarry, which is 200 feet by 50 feet in size. The stripping is now about 3 feet, but it will increase as the quarry is worked back. Along the face of the hill the width of the sandstone belt before passing under the overlying limestone is from 100 to 300 feet. This represents the available stone, but the stripping would greatly increase before all this could be quarried. The stone is of the grey variety but is marked in parts by brown spots. The beds are extremely irregular, so much so that it is quite impossible to construct a section of any value. Westward from the main opening, a few other spots have been attacked, but the outcrop is soon cut off by the heavy talus from the Niagara limestone above—299.

The stone: No. 299.—This example is much coarser in grain than the ordinary stone from this area and is somewhat remarkable in the great number of the particles that show the crystalline facets of the original quartz crystals. Some of the brown spots are fine and evenly distributed, but others are about one-eighth of an inch in diameter and are scattered through the stone at intervals varying from one-quarter of an inch to one inch.

Rough sills are sold at 20 cents per running foot, and dimension stone at 40 cents per cubic foot, at the quarry.

Campbell Pollock, Milton.

This property adjoins Timbers' to the west. The stone is similar and has been little exploited.

D. Robertson and Co., Toronto.

The properties adjoin Pollock to the west. Quarries are opened on both sides of the ravine through which the railway ascends the cuesta. The stone occurs in heavier beds under a stripping of from 6 to 20 feet. In descending order are seen an 8 inch, a 2 foot, and a 3 foot bed. The bedding is still very irregular, and, while good grey stone may be obtained in places, much of the product is of the spotted type. The opening to the east of the railway is 600 feet long and has been worked back to a depth of 120 feet. The face is about 12 feet high. Ten to twelve men are employed.

Summary—Milton Area.

The exposures of sandstone in this area occur about half way up the mountain side to the west of Milton. From the east towards the west the following owners have operated to a greater or less extent; Wm. Wilson, James Timbers, D. Robertson and Co., and D. D. Christie. After a short interval an isolated quarry is found on lot 12, con. II, Esquesing, from which a small output has been obtained by Mr Crowshaw. Still farther north on lot 21, con. IV, Esquesing, a quarry is worked by John Farquar. In addition to these openings the stone is known to crop out to a considerable distance to the south of Wilson's farm. The stone is all of the grey type and is much marked by brown spots. The beds are very irregular in shape and the material varies greatly from bed to bed, being, in some cases, soft and grey, in others spotted, and in others of a hard whitish type.

Most of the present production is in the form of rubble, which goes to Toronto for foundations, etc. The best example of the stone is seen in a church, constructed in 1895 in Milton. This building shows the variable character of the stone, as many of the blocks are of inferior colour and general appearance. A great deal of diversity in texture is also to be noted. The Court House, built in 1863, shows the same variation in the stone with rock face finish. The dressed stone in the front is much more uniform, but the whole structure has weathered to a muddy colour; angles and chisel marks are, however, perfectly preserved. Although a great deal of fairly good stone for rough building is available in the area, the quality of the output does not seem to equal that of many other districts along the outcrop of the Medina band.[1]

Credit Valley Area.

Immediately to the north of Limehouse, the first station west of Georgetown on the Grand Trunk railway, low-lying outcrops of the sandstone are seen over a considerable area. To the northward the escarpment becomes more abrupt in character and an almost continuous exposure of the band is seen as far as the Forks of the Credit. Passing up the north branch the stone outcrops as far as Cataract; on the southern branch it is quarried for about a mile in the direction of Belfontain. Many quarries were visited along this line and a rather full description is given, although most of the operations have ceased.

W. W. Scott, Limehouse, Lot 22, Con. VI, Esquesing, Halton county.

This property was formerly largely worked and a siding from the G. T. R. was constructed to remove the stone. The product was used in railway work and for flagging. The outcrop can be traced across the 100 acre lot and on to lot 23, con. VI; it also appears on lot 23, con. VII, where it is largely exposed. The removal of the overburden has been largely effected by a small stream so that the rock is practically bare on the lots mentioned.

[1] Literature—(See Niagara area.)

The denuded belt is at least 100 yards wide. Much of the stone is thin bedded and suitable for flagging, in other places, it is thicker and adapted to building purposes. It is so long since the property was worked that no very definite information as to the position of the beds is obtainable. It would appear that the operations were conducted here and there as good stone presented itself and that a regular quarry was never opened. The stone, as is usually the case where it has been exposed, is of inferior quality and is much marred by spots and stained lines. Further, it is whitish yellow rather than grey, and lacks brilliancy; this difference in colour is doubtless due to exposure, as the stone in other respects closely resembles the typical grey Medina from the Forks of the Credit.

A. Appleyard, Limehouse, Ont., Lot 25, Con. VII, Esquesing, Halton county.

On this lot are exposed 5 acres of stone and the outcrop extends also into lot 24. The beds are much heavier than on the Scott property, as 18 inch, and 2 foot bands are common, and, in some places, stone 3 feet thick can be obtained. The total thickness of the formation is 9 feet, with all the beds dipping at a low angle to the north. The stone is not of the best quality, as brown spots and iron stains of different kinds are present in a large part of the outcrop. Some good grey stone was observed, but it seemed so mingled with poor material that its economic extraction would be difficult. Much stone was formerly quarried here and used for bridge building, the International bridge at Fort Erie being constructed largely from this quarry. For this purpose the stone is excellent as it can be obtained in large blocks and its wearing properties are good. For architectural purposes, the stone is not satisfactory on account of the iron staining. A building on the property shows the unfortunate appearance of the stone when used without selection and laid up in a very rough manner. Nevertheless some blocks are of fine grey appearance with the original chisel marks well preserved, and show that careful selection of the more desirable stone, together with good mason work, would alter the opinion above expressed as to the architectural fitness of at least some of the material. There is no present production, the long haul to Georgetown being a strong deterrent factor in the working of the property.

W. A. Irwin, Guelph, Ont., Lot 27, Con. IX, Esquesing, Halton county.

This property is located at a point where the escarpment becomes more pronounced; it seems to contain about 6 acres of stone. Much of this extent is quite bare, and the rest is covered by only a small amount of overburden. The stone is irregularly bedded but it is exceptionally thick in places; much of it is light brown in colour but presents, in places, a pinkish appearance. The unfortunate brown spots are again in evidence—301.

The stone: No. 301.—This specimen, which may be considered as representing the best product of the quarry, differs from the typical grey stone only in its colour which is light brown rather than grey; it much resembles

No. 13 of Plate LXXVI, but it has a slightly redder cast. The stratification planes are clearly seen as fine lines of a still darker brown.

Considerable work was done here some years ago but the property is now idle. The property of Mr. Wylie lying half a mile to the northward, on lot 28, con. X, presents much the same features as this quarry, and like it, is now out of commission.

Hugh Logan, Glen William, Lot 26, Con. VIII, Esquesing, Halton county.

This is one of the most extensive quarries now in operation on the Medina band. The workings extend across the lot and have been carried back 200 feet from the original face. The present stripping (soil) is light but it will materially increase as the quarry is extended through the 300 feet that remains before the main escarpment is reached. Beneath the capping of debris lie about 5 feet of thin shaly sandstone, from which only a little rubble is procured, then follows 10 feet of sandstone of which the upper 7 feet is excellent grey freestone. The lower 3 feet is harder and does not work easily. It is underlaid by a narrow band of "bastard" which is succeeded by the red shale. The good stone is all of the grey or white variety and in some places a single bed occupies the whole of the 7 feet. In other places several beds occur in the same distance. The stone is uniform in colour and texture and is well represented by specimen 321 described below.

The stone: No. 321.—This specimen has been selected as typical of the grey Medina sandstone, which is the finest building stone at present produced from the sedimentary rocks of Ontario. While minor variations, such as greater or less development of "reed," slight difference in hardness, colour and brilliancy are to be noted, the general character of the grey Medina may be inferred from the following description. The general colour of the stone is shown in Plate LXXV, No. 9; in places it is quite uniform, but fine horizontal lines representing the bedding planes may be observed in most of the stone, particularly after weathering for a short time. On treatment with carbonic acid in water, the colour is not materially affected.

Under the microscope the quartz grains have an average diameter of less than one-eighth of a mm., there is, however, a large number of very fine grains scattered between the larger ones. Considerable feldspar in a partly decomposed condition is present, as well as several other minerals in very small amount. The cement, which is largely of a calcareous character, is quite evident, but interstitial pores are not to be seen with distinctness, despite the high percentage of pore space. The physical characteristics of the stone are indicated below:

Specific gravity	2·66
Weight per cubic foot, lbs	146·01
Pore space, per cent	12·04
Ratio of absorption, per cent	5·16
Coefficient of saturation	0·53
Permeability, c.c. per square inch, per hour	143·4
Crushing strength, lbs. per square inch	21715·

Crushing strength after freezing—unsatisfactory test, probably about........	18000·
Loss on freezing, per cent...............	0·072
Loss on treatment with carbonic acid, grams per square inch....................	0·0131
Transverse strength, lbs. per square inch..	1614·
Chiselling factor......................	4·02

Analysis: F. G. Wait, Mines Branch laboratory.

Cement—Calcium carbonate with a small quantity of argillaceous matter.

Ferrous oxide, per cent.............. ...	0·41
Ferric oxide, per cent..................	0·14
Sulphur, per cent.....................	0·11

A considerable part of the grey sandstone used in Toronto has been obtained either from this or from the adjoining quarry and a large amount is yet available although it is probable that the cost of production will gradually increase owing to the greater amount of stripping that will be necessary. The stone is quarried by the use of black powder and is lifted by ordinary derricks. Twenty men are employed. The haul to the siding at Glen William is about a half mile. The prices f.o.b. Glen William are as follows:—

Rubble, $12 to $20 per 20 ton car according to quality.

Dimension stone, 45 cents per cubic foot.

Coursing stone, $1.50 per superficial yard.

Rough sills, 13 cents per running foot.

Dressed sills, 33 cents per running foot.

The Fleming quarries. Graham Bell, manager, Glen William.

This property adjoins the Logan quarry and it is, in practically all respects, similar. The opening is 600 feet long and it varies from 100 to 200 feet in width. The overburden is from 18 to 20 feet thick, and consists partly of soil and partly of thin beds of stone. At the south end, the soil is only 3 feet thick but at the north end it is much thicker; the thin rock is here, however, correspondingly less. A considerable part of these thin beds can be worked up for rubble as, in some places, 8 inch stock can be obtained. Beneath the thin material are 10 feet of heavy beds of variable thicknesses, but all capable of making dimension stone. Stone of any desired size can be obtained. At the bottom, overlying the shale, is a layer varying in thickness from a few inches up to 2 feet, of a hard variety which is used only for rubble as it is too hard to be chiselled with facility. For an account of the good stone see the description of No. 321. This fine grey stone constitutes the bulk of the output; it is, however, in some places banded with brown and in others it is streaked with pink which detracts from its value. The brown stone is occasionally of sufficient amount to be shipped as such.

Quarrying is carried on by the use of steam drills operated from portable boilers. Black powder is used as an explosive and much valuable stone is shattered in consequence. Four derricks are in place, which are operated, for the most part, by steam. The output is conveyed by gravity cars to the siding at Glen William. Twenty men are employed on the average. The prices are much the same as those quoted for Logan's quarry. The product is used largely in Toronto and was formerly employed to a considerable extent in Georgetown.

F. Rogers and Co., 1193 *Queen St. West, Toronto.*

This company owns 200 acres of land, situated north of Terra Cotta and separated by a short interval from the Fleming quarries to the south. In the past, considerable stone has been quarried by picking over the property and removing the good material; at the present time three distinct openings are being worked. The most southerly quarry has been the least opened up. It presents both grey and brown stone in an exposure 12 feet thick. The beds are rather thin, particularly the brown ones, and although a thickness of a foot is occasionally seen, the average output does not exceed 4 inches in thickness. The brown output is sold as selected rubble. A little good coursing stone in the grey variety is produced here, but the greater part of the output is more suitable for rubble. The stripping is light, and as the opening is several hundred yards from the vertical part of the escarpment, there is a large amount of stone still available at this point.

The second opening, north of the one described above, extends over 2 or 3 acres and is quarried to a depth of 3 feet only. The stone here is mostly grey, but it is discoloured and full of cracks. The bedding is indistinct and for the most part thin. Twelve inch stone was the thickest observed but the great bulk of the output is much thinner, averaging from 3 to 6 inches only. The product is used for foundations and is paid for at the rate of $14 a toise (162 cubic feet) after being laid in the wall.

The third opening, the most northerly on the south lot, is about 150 feet by 90 feet in extent. The upper 6 feet is thin bedded and of little value. Beneath these layers are several feet of creamy grey stone, ranging from 2 to 8 inches in thickness. In certain parts of the quarry brown bands are mixed with the grey, making the so-called piebald stone. This variety while similar to the mottled type of the Niagara area is not identical, for the white and brown are more or less interbedded instead of the white appearing as irregular blotches in the brown. Much of the grey stone shows very distinct bedding and in consequence splits easily along the planes of stratification and shows a very "reedy" effect on the severed edges.

On the north lot of this company a good deal of surface quarrying has been done in the past. An attempt was also made here to develop a more extended quarry and a cut was made for an inclined way to the railway. In this cut about 14 feet of very irregular, thin bedded, and poorly coloured stone is exposed.

No very fine stone is now being quarried on either lot but much rubble is being shipped and the face of the quarry is being cleaned up. It is hoped that as the systematic quarrying is carried farther towards the mountain that heavier beds of a better quality of stone will be revealed. This is a reasonable expectation in view of the fact that experience has shown that the quality of the stone and the thickness of the beds increases as the overburden becomes greater. The distance from the present workings to the point at which profitable extraction becomes impossible owing to the overlying Niagara limestone, is nearly a quarter of a mile.

Quarrying is effected by means of hand drilling and the use of powder. Much of the stone can, however, be removed by wedges and crowbars alone. The haul to the siding is about a quarter of a mile.

Selected grey rubble is sold in Toronto at from $2.25 to $2.75 per ton. The freight to Toronto is 65 cents per ton for selected and 55 cents per ton for common stone.

Examples from this quarry may be seen in the new residence at Victoria College, Toronto, and in a church on the east side of Yonge St., above the C. P. R. crossing.

Cyrus Townsend, Terra Cotta, Lot 30, Con. IV, Chinguacousy, Peel county.

This property adjoins Rogers on the north. The general character of the stone is the same and no work is now being done. Much of the commoner type of stone is seen, as well as some bands of the piebald type. The bedding is extremely irregular, but a considerable area is exposed over which stone has been quarried in a scattered fashion in the past.

Wm. Foster, Terra Cotta, Lot 31, Con. IV, Chinguacousy, Peel county.

The quarry extends nearly across the lot and has been opened up to a width of 100 feet or more. The face shows about 12 feet of stone, underneath which the red shales are apparent in places. The bedding is irregular as in all these quarries, but bands 3 feet thick run in some cases for 100 feet. The stone is of a fine grey colour with little or no admixture with the piebald type. Mr. Foster is able to ship excellent white coursing stone as well as a considerable quantity of dimension material. The irregular bedding causes much rubble to be incidentally produced, for which, however, there is a ready sale. Fifty-two pieces of stone, each 5 feet 3 inches square and 14 inches thick were produced from this quarry for use in the Custom House in Toronto. Examples of this product may also be seen in the John Abell factory and in the Central Prison in Toronto. Mr. Foster has furnished the following quotations, all f.o.b., Boston Mills siding:—

White dimension stone, 30 cents per cubic foot.
Undressed sills, 15 cents per running foot.
Squared random coursing stone, $2 per square yard.
Rubble, 60 cents per ton.
Selected white rubble, $1 per ton.

Four to six men are at present employed in the quarry.

Wm. Smeaton, Inglewood, Lot 1, Con. III, Caledon West, Peel county. The quarry is well up on the hillside and presents two openings, one on the brow of the shoulder which is comparable with the three properties previously described, and another close to the vertical part of the mountain where the sandstone is more or less covered by the overlying Niagara limestone. The first opening extends across the lot and has been worked to a depth of 10 feet. The stone is of the grey type and occurs in beds up to 1 foot thick. The bedding is much more regular than in the previously described quarries and there is practically no stripping. As in all exposures which are not well covered the stone is less desirable and is marketed as rubble only.

The main quarry is situated close in under the brow of the mountain proper, where the sandstone is covered by 20 feet of thin bedded limestone and 20 feet of soil. This opening is to be regarded as the most southerly of the group of quarries at the Forks of the Credit and as possessing a different character from the more shallow workings of the group centering around Terra Cotta. The quarry is 600 feet long, and about 100 feet wide. Under the heavy stripping, a solid grey band of 4 feet in thickness runs across the property. Beneath this band is a continuous brown stone layer, uniform in character and somewhat reedy in structure: the thickness is about 3 feet. Beneath the brown stone there is 7 feet of solid grey, without an apparent bedding plane along the whole face of the opening.

The main system of joints (backs) run northwest and southeast with an average interval of 40 feet. There are no joints in a direction at right angles to this. It is apparent therefore that stone of any desired size can be obtained. The brown stone is of a chocolate hue and it is much lighter than some of the stone formerly obtained at the Forks of the Credit.

The equipment on the property consists of two Rand drills, a 16 horse-power boiler and engine, a 6 inch pump, one horse-power derrick, and a loading derrick at Boston Mills siding. To this point there is a haul of three-quarters of a mile. When the quarry was in operation, the stone was removed by the Knox system of blasting, the holes being sunk with 2¼ inch steel at intervals of 8 feet almost to the bottom of the bed. About a handful of black powder was used in each hole. A space of a foot was left above the powder and the hole was then tamped hard. The line of holes was fired simultaneously by a battery. It is said that a channelling machine cannot be used as the stone is under strain and consequently would pinch the steel as soon as a cut of any considerable size was made. This strain acts in a northwest and southeast direction and not into the mountain.

It is to be regretted that the quarry is out of commission at present. With so much excellent stone available this inactivity can only be explained by the excessive cost of removing the overburden, which can only be effected by an expenditure of about 25 cents per cubic yard. Although the quarry is not now in operation and no stock is available for shipment the following list of prices may be of some value:—

Brown dimension stone, 75 cents per cubic foot, f.o.b. Boston Mills.

White dimension stone, 50 cents per cubic foot, f.o.b. Boston Mills.

Brown random coursing (shoddy), $1.75 to $2 per square yard, f.o.b. Boston Mills.

White random coursing (shoddy), $1.25 per square yard, f.o.b. Boston Mills.

North from the Smeaton property, the next three lots are owned by Messrs. Davidson, McGregor and Balmer. On the first two, little or no work has been done, on the last an opening 200 feet long has been carried back into the hill for a distance of 100 feet. The face now shows 8 feet of soil, 15 feet of thin limestone and 4 feet of brown sandstone. The quarry is full of water and little is to be seen.

James Pearson, Toronto.

This property consists of 550 acres, but it is not a continuous belt along the Medina outcrop. Extensive quarrying was at one time carried on and a siding from the Canadian Pacific railway connected with trams from the quarry. At the southeast end of the quarry a little stone was quarried a year ago. The face here presents the following section:—

10–25 feet—Soil, debris and thin bedded limestone.

18 inches—Grey stone, but variable.

3 feet—Grey stone.

5 feet—Brown stone, light in colour and not continuous or regular in bedding.

Grey stone of undetermined thickness to bottom.

Towards the west end of the property is a clean face, where much work has been done. The beds are much more regular and present the following sequence:—

10 feet—Soil.

15 feet—Thin bedded limestone.

16 inches—Limestone.

3 feet—Thin bedded sandstone and shale.

3 feet—Good grey stone, beneath which the rock is not visible.

Towards the northwest limit of the property is an opening connected by road with the siding, which shows heavy beds of grey stone 3 to 4 feet thick under 20 to 25 feet of stripping.

On this property, both brown and grey stone of good quality occur, but the latter is much in excess. The heavy stripping is no doubt responsible for the cessation of operations. The grey stone of the City Hall in Toronto was largely obtained from this quarry.

D. Robertson, Janes building, Toronto, part of Lot 8, Con. II, Caledon West, Peel county.

At this point the escarpment has become so steep that the shoulder occasioned by the harder layers of sandstone overlying the soft shales has a very limited width. In consequence, both in this quarry and in those to the west, open quarrying was carried on for a short time only before the overburden increased beyond the possibility of removal. Actual mining was then resorted to in order to obtain the stone from beneath the covering of 150 feet of Niagara limestone. As practically all operations have ceased in this once famous district, and as the conditions are very similar throughout, a description of the present property is indicative of all. An average section of the whole mountain side shows:—

150 feet—Niagara limestone, mostly thin bedded.
3–4 feet—Grey sandstone.
4–9 feet—Brown sandstone.
3–6 feet—Hard grey calcareous sandstone (bastard).
1 foot—Blue clay.
175 feet—Red clay to level of Credit river.

While this represents an average thickness of the grey and brown bands, a great amount of variation is possible, and, in some places, the two varieties are mingled together throughout the whole thickness of the sandstone layers. In the most prosperous days of the industry it was necessary to sort the product into brown, grey and piebald lots. The bedding is irregular, in places extremely so, but the thicker beds have occasionally a considerable extent.

The only operations now being conducted at the Forks of the Credit are carried on by three or four men who are getting out a little white rubble on this property. The opening is about 150 feet long and very shallow. The overlying limestone is 12 to 14 feet thick, and will rapidly increase if operations are extended. The accompanying sketch (Fig. 10) indicates the kind of stone and the peculiarities of the bedding.

To the west of this opening is the entrance to the mouth of one of the old tunnels, near which a section is as follows:—

30 feet—Limestone.
2 feet—Shale and grey rubble.
16 inches—Brown stone.
10 inches—Brown stone.
5 feet—Brown stone.
1 foot—Brown stone.

A comparison of these two sections is indicative of the manner in which the formation changes within a hundred yards.

The method of procedure in mining the stone was briefly as follows:—

A tunnel, 20 feet wide, and of sufficient height to accommodate the workmen, was driven by the use of explosives into the overlying limestone so that the floor of the tunnel coincided with the top of the sandstone. The good stone was then quarried out to the bottom of the bed throughout the extent of the tunnel. Twenty feet in from the mouth of the tunnel, drifts were run laterally from the main tunnel. These were usually made 30 feet wide and the good stone was removed as before. The 20 feet intervening between the drift and the face was left to support the roof. A dry wall was then constructed at the back of the drift and behind the wall another 30 foot strip

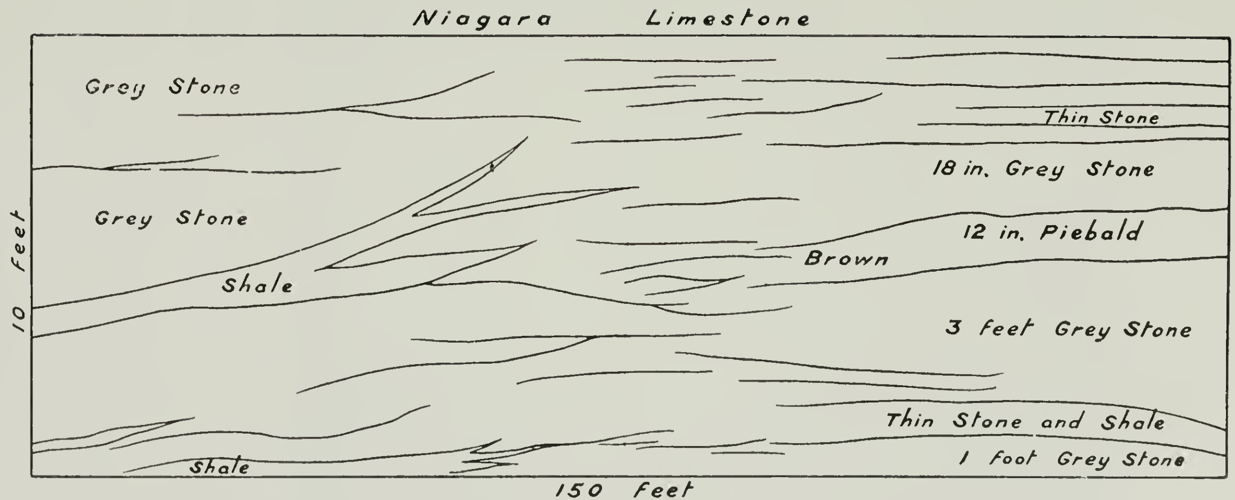


FIG. 10. Sketch illustrating the irregular bedding in the sandstone at the Forks of the Credit.

was taken out as before. In this manner the workings were carried back several hundred feet into the mountain. The main tunnels were placed at intervals of about 60 feet in the places where the observations were made, but I am not aware that any fixed interval was adopted throughout the region.

The Credit Valley Stone Co., Carroll and McKnight, Toronto.

This company has now acquired nearly all the property surrounding the Forks of the Credit. Their holdings abut the Robertson property and extend along the band in the direction of Belfontain. They also own the property in the angle between the Forks and up the Belfontain branch on the north side, as well as the old quarry in the angle between the Cataract fork and the main stream. This last location differs from the others in that there was no capping of limestone. The overburden was chiefly sand beneath which from 12 to 17 feet of sandstone occurred. The upper part—3 to 4 feet—was grey stone and the lower portion brown. Practically all the finer stone has been removed but much grey and piebald rubble could still be obtained. The cableway by which the stone was carried across the ravine to the railway may still be seen. From this quarry was obtained most of the stone used in the Parliament Buildings, in Toronto.

This company has installed a crushing plant of 100 tons per day capacity and are operating on the Niagara limestone at a point in the main escarpment directly opposite Credit Forks. By the removal of the limestone the sandstone beds will eventually be exposed and there is hope that the present demand for crushed stone may make possible the profitable removal of the heavy overburden and thereby give a new lease of life to the Credit Valley stone industry.

D. Robertson and Co., Toronto.

On the north branch of the Credit, at the cataract, which is about a mile below Cataract Junction on the C. P. R. about 10 or 12 feet of grey sandstone are exposed. A quarter of a mile lower, some small openings have been made on both sides of the ravine. The stone is grey and presents an upper 2 foot layer of thin material and a lower layer about 5 feet thick. The stone is rather reedy and not equal in quality to the better material at the forks. Very little output could be obtained without recourse to mining as the overlying Niagara limestone is very heavy in this section. Below the openings made at this point by this company and others, the valley widens out and no outcrops of rock are encountered until the vicinity of the forks is reached.

Summary—Credit Valley Area.

The outcrops of the Medina sandstone within this area occur as an almost continuous line from the vicinity of Limehouse to Cataract on the north branch of the Credit river and to near Belfontain on the south branch. The extent of the exposures is never great as the stone constitutes a lineal band along the face of the Niagara cuesta. The actual exposures may be considered as presenting three types, first, a region in which the sandstone is exposed

Plate XLI.

Medina Brown and Grey Sandstone. Municipal Buildings, Woodstock, Ont.

Medina Brown and Grey Sandstone. North Entrance, Municipal Buildings, Woodstock, Ont.

over the surface of comparatively flat country, where the Niagara cuesta is not apparent as an abrupt elevation: this type is seen immediately north of Limehouse, second, a region in which the cuesta presents a vertical face of 100 or more feet of Niagara limestone at the top, beneath which is a shoulder, sometimes a quarter of a mile wide, capped by the sandstone and covered with an increasing amount of soil and debris towards the vertical upper portion. Beneath the shoulder the mountain falls away more gradually and presents heavy beds of red clay. This type of occurrence is seen from near Glen William to a point above Inglewood. The third type shows the sandstone cropping out in the side of the mountain, the outcrop being marked by little or no projecting shoulder. To this type belong the exposures immediately around the Forks of the Credit.

Although somewhat thicker in places, the average of the sandstone is not more than 12 feet. The bedding is very irregular as a rule, but, in the more valuable quarries, some at least of the beds have a considerable extent.

The following varieties of stone are recognized:—

1.—Grey sandstone, hard, of varying texture and presenting brown spots.

2.—Grey sandstone, uniform in colour, fine in grain, and occurring in beds of sufficient thickness to make dimension stone. This is the well known "grey Medina," "white Medina," or "grey band" stone, so largely used in Toronto and elsewhere in the province. The best of this stone is uniform throughout but the most of it is somewhat reedy, *i.e.*, shows the planes of stratification. This constitutes the chief fault of the stone as it renders it somewhat harder to work and detracts from its appearance.

3.—Brown sandstone, of uniform colour in the same bed, but varying from chocolate colour to deep brown in different quarries. Like the grey stone, it is frequently reedy, but it is nevertheless the finest building stone produced in the province. The Parliament Buildings in Toronto are probably the best example of the stone, but it has been used very extensively in Toronto and elsewhere.

4.—Piebald stone, brown and white mixed. While this variety is not so desirable as the uniformly coloured stones, it does not present an unattractive appearance when used in limited quantity.

The hard and spotted type of stone is produced from the region north of Limehouse; it is more suitable for heavy construction and for flagging than for architectural purposes.

The second region, extending from Glen William to Inglewood, produces grey stone and a very limited amount of brown. It is found that the better stone always occurs under a considerable overburden. Where the stripping is light or absent, the stone approaches that of the first region in quality. Practically the total present production comes from this section, more particularly from the quarries of Logan, Bell, Rogers, and Foster.

The brown stone has nearly all been obtained from near the Forks of the Credit, where the steep character of the mountain side has rendered necessary the driving of tunnels into the formation in order to extract the stone. Both white and brown stone were formerly obtained here as well as considerable quantities of piebald. All the quarries have been abandoned and for the present at least Credit Valley brown stone is not to be obtained.

The excellence of both the brown and the grey stone is undoubted; the reasons for the discontinuance of quarrying must be sought in the economic conditions of the stone industry and in the physical difficulties of obtaining a further supply. The first reason, being of a general nature, need not be considered here, but the second, having reference to the available supply, will be briefly treated.

An unlimited quantity of the hard and inferior type of stone can be procured without difficulty, not only to the northward of Limehouse but in the region immediately to the north of Terra Cotta. Grey stone of good quality is still quarried between Glen William and Inglewood and can be procured at about the following prices, f.o.b., Glen William, Terra Cotta, or Boston Mills.

Common grey rubble, 60 cents per ton.

Selected grey rubble, $1 per ton.

Grey dimension stone, 30 cents to 50 cents per cubic foot.

Squared grey random coursing, $1.50 to $2 per square yard.

Rough sills, 13 cents to 15 cents per running foot.

It is apparent from these prices that grey stone can still be placed on the market at a reasonable figure. Although a large supply is possible in the future, it cannot be denied that the gradually increasing thickness of the overburden must of necessity add to the cost of production. Grey stone in considerable quantity can also be obtained from the old quarries along the Belfontain branch of the Credit river.

A little brown stone is still produced in Foster's quarry, but this property is south of the main brown stone area. Brown stone is also available on the properties of Smeaton, Davidson, McGregor, Balmer, Webb, and Pearson, in the region lying between Inglewood and the forks. On all these properties, however, the overburden is heavy, but the face is not cut by tunnels so that no reason exists why the same method of quarrying that was found satisfactory at the forks should not be employed here. While small amounts of brown stone could still be obtained in the old quarries at the Forks of the Credit, it is questionable, unless economic conditions change materially, if these quarries will ever be reopened on any considerable scale. The face is practically quarried back as far as possible and the old tunnels have broken down. To reopen these tunnels would require a large initial outlay, the return of which would be extremely doubtful. It is possible, however, that the demand for crushed stone will become so great that the whole of the overlying Niagara limestone may be made into a marketable product. In this event, beds of brown stone will be available for easy exploitation.

Plate XLIII.

The Niagara Cuesta at the Forks of the Credit.

Plate XLIV.

Medina Sandstone with overburden of Niagara Limestone, Forks of the Credit.

Northward from the old quarry, on the east side of the Cataract branch, the country does not seem to rise materially above the level of the sandstone; it is possible that prospecting in this direction might reveal beds of good stone under an amount of overburden capable of removal. Such exposures as appear towards Cataract, and also towards Belfontain, do not indicate, however, that the brown variety extends beyond the immediate vicinity of the forks.

A general view of the cuesta at Credit forks is shown in Plate XLIII; the heavy burden of limestone covering the good stone is shown in Plate XLIV.

Literature:—Geol. Sur. Can., Rep. 1850–51, p. 14 et seq.
" " " " 1863, p. 310 et seq.
" " " " 1863–66, p. 283.
Rep. Bur. Mines, Ont., 1891, pp. 98, 99.
Rep. Royal Com. Min. Res. Ont., 1890, p. 73, 74, 79.
Geol. Sur. Can., Rep. 1898, p. 171 A.

The Orangeville Area.

This area includes practically only two quarries, situated three miles northeast of Orangeville, but to these may be added a third which is located twelve miles further north near Shelburne. The stone is all of the grey variety and is now quarried only at the first of the locations described below.

Geo. Nicholson, Orangeville, Lot 6, *Con. I, Mono West, Dufferin county.*

The quarry is situated at a point where a small stream has denuded the thick layer of drift characteristic of this region and has eaten its way through the overlying limestone down to the sandstone layers. The quarry is about 200 feet wide and has been worked up the bed of the stream. Further extension in this direction is possible, but, laterally, the rapidly increasing amount of overburden renders quarrying more and more difficult. The sequence here exhibited is, in descending order, as below:—

10–12 feet—Boulder clay.
14 inches—Limestone.
6 inches—Limestone.
10 inches—Limestone.
10 inches—Limestone.
2 feet 4 inches—Heavy limestone bed.
3 feet 4 inches—Thin shaly sandstone and limestone.
1 foot 3 inches—Grey sandstone, somewhat fractured.
3 feet 3 inches—Grey sandstone.
5 feet 3 inches—Grey sandstone.
3 feet—Grey sandstone.
1 foot—Grey sandstone, rather reedy.

The sandstone beds are fairly level, but the subdivision given above is not constant throughout the quarry as the parting planes occur at different levels in different places. The quarry is remarkably free from joints in any direction. Most of the stone is rather reedy in character, showing a thin film of black material along the planes of stratification. The lower three foot bed is more uniform and free from this objectionable feature. The uniform stone (53) and the reedy stone (54) are described below.

The stone: No. 53.—In colour this stone is almost identical with that from Logan's quarry at Georgetown, which is shown in Plate LXXV, No. 9. Treatment with carbonic acid does not effect any distinct change in colour.

Under the microscope, the rock is seen to be composed chiefly of quartz grains which are not more than one-eighth of a mm. in diameter. In addition to the quartz there are a few grains of feldspar in a more or less decomposed condition. The quartz particles are mostly angular in outline and fitted close together, but the feldspar individuals are more rounded in outline. The cement, according to Wait, is carbonate of lime, with a little argillaceous matter; it is not present to any great extent. Interspaces of an extent comparable with three or four grains of quartz are present throughout the rock, which probably accounts for its high permeability as given below. A few grains of other minerals such as garnet and apatite are present. The physical characteristics are as follows:—

Specific gravity	2·655
Weight per cubic foot, lbs.	141·06
Pore space, per cent	14·87
Ratio of absorption, per cent	6·59
Coefficient of saturation	0·57
Permeability, c.c. per sq. in. per hour variable but always high	2130·
Crushing strength, lbs. per sq. in	12590·
Crushing strength after freezing, lbs. per sq. in.	10230·
Loss of weight on freezing, per cent	0·052
Loss of weight on treatment with carbonic acid, grams per sq. in	0·0192
Transverse strength, lbs. per sq. in	568·
Chiselling factor	4·

An analysis by F. G. Wait shows:—

Ferrous oxide, per cent	0·27
Ferric oxide, per cent.	0·41
Sulphur, per cent.	0·11

As this stone and the one from Logan's quarry are the only Medina stones examined in detail, it is interesting to compare the physical tests of the two types, particularly as, to the naked eye, or even under the hand lens, there is little difference to be observed. The microscopic examination of the two specimens shows that in the Logan stone the grains are unequal in size, with

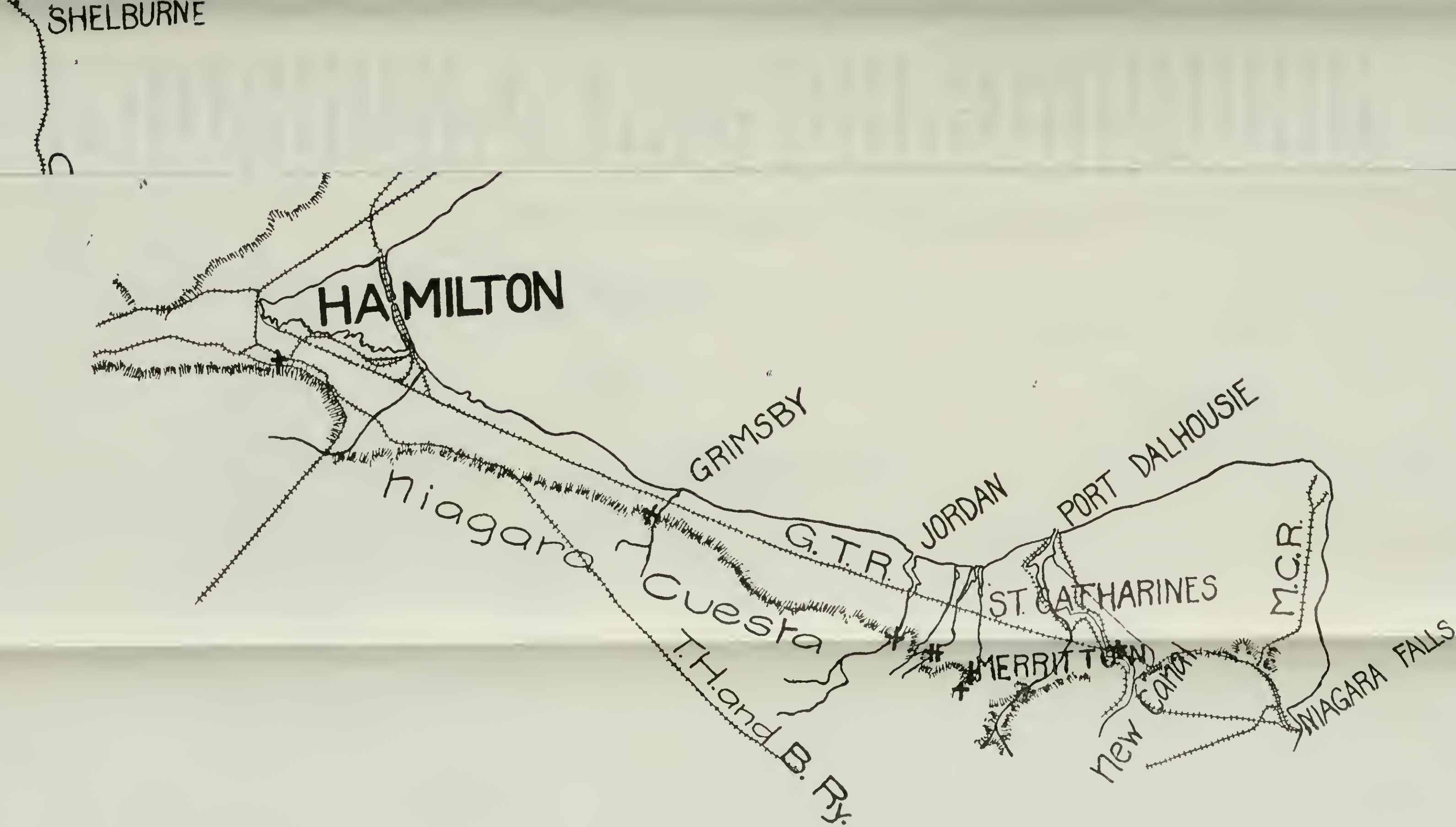


Fig. 11. Sketch map showing the Niagara cuesta and the chief quarries in the Medina sandstone.

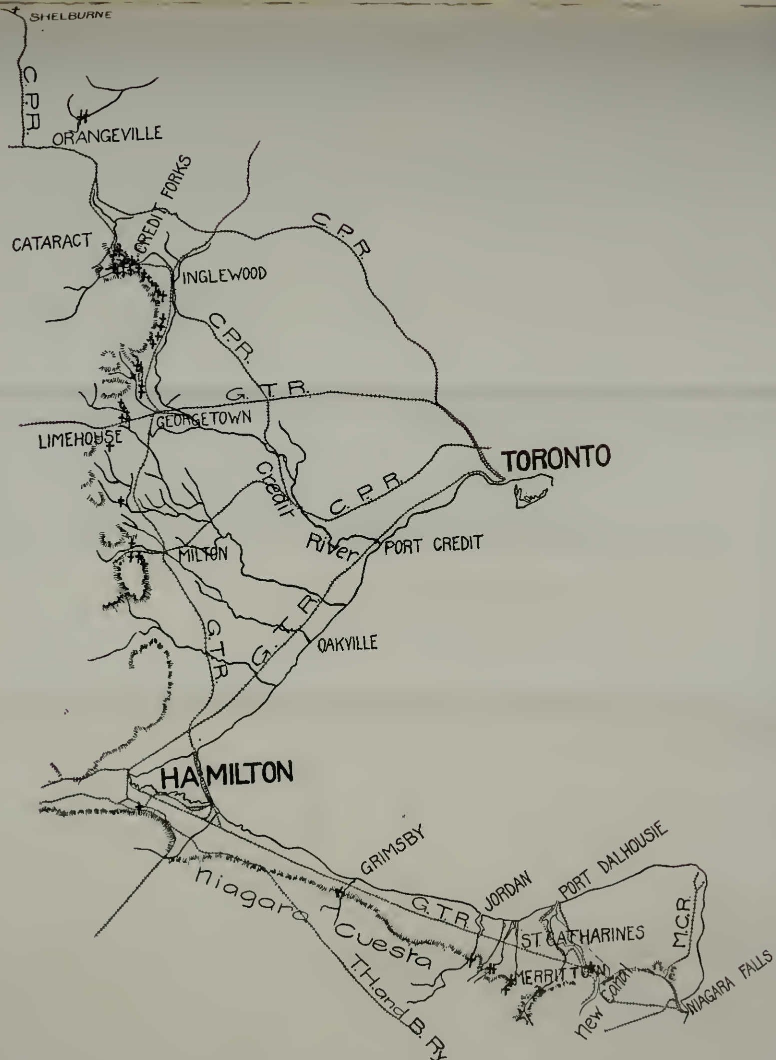


FIG. 11. Sketch map showing the Niagara cuesta and the chief quarries in the Medina sandstone.

a considerable amount of decomposing feldspar and consequently an appreciable amount of cement, while the Nicholson stone is cleaner, and provided with much less cement. On the other hand the Nicholson stone possesses large open spaces. These observations account quite clearly for the greater strength of the Logan stone and its greater weight per cubic foot. The presence of large interstitial spaces in the Nicholson stone and the lack of cement account for its much lower transverse strength and its extraordinarily high permeability. It will be observed also that the stone with the greater amount of cement loses more on freezing; this is probably due to the softening of the cement, which seems to be more essential to the holding together of the grains in the Logan stone than in the Nicholson variety. The difference in the coefficient of saturation probably represents correctly the relative durability of the two stones, for the Nicholson stone, having less argillaceous cement, would probably suffer less from the action of frost than the Logan stone.

Quarrying is effected by hand drilling and the use of black powder. A small gang saw operated by a gasoline engine is employed to saw the product into sills, etc. Two derricks are installed. Four men are engaged throughout the summer months. Laborers are paid $1.50, drillers $2, and cutters $4 per day. One team hauls to the railway at Orangeville 50 cubic feet per day. Mr. Nicholson has furnished the following prices, all f.o.b. Orangeville:

Rough dimension stone, 50 cents per cubic foot.

Sills, sawn top and bottom, rock face front, 35 cents per running foot.

Roughly squared coursing stone, $1.60 per superficial yard.

A business of about $1,000 a year is done.

The stone may be seen in the City Hall, Toronto, the new library at Fergus, and the post-office in Sarnia.

Owen Sound Stone Co., Lots 6 and 7, Con. I, Mono East, Dufferin county.

The exposures on this property occur under exactly the same conditions as in Nicholson's quarry, but the lateral extent is greater owing to a less amount of overburden. The quarry, now idle, has been opened for fully 600 feet along the northern side of the ravine and has been extended in that direction a considerable distance until the overburden is now about 20 feet. Owing to the present condition of the quarry it is difficult to state the sequence of beds but evidence of extremely irregular bedding is presented. About 14 feet of sandstone are exposed, which is roughly disposed in three beds. The two upper beds are of the same quality as Nicholson's but the lower bed appears to be hard and flinty. There is no present production but a large amount of stone has been obtained in the past. Much of the product was used in the City Hall, Toronto, and considerable amounts were employed in the same place for curbing.

The quarry near Shelburne represents the most northerly economic occurrence of the Medina sandstone. It has long been idle and was not visited.

Summary—Orangeville Area.

The outcrops occur three miles northeast of Orangeville where a small tributary of the Nottawasaga river has removed the heavy layer of boulder clay. Geo. Nicholson, Orangeville, is the only present producer, but a large amount of stone was formerly quarried by the Owen Sound Stone Co. All the stone is of the grey variety, rather dark and somewhat "dead" in appearance. It has been used in Toronto, Fergus, Sarnia, and other points. Nicholson can still produce stone without excessive cost by following up the bed of the stream which runs through his quarry.

Literature.—(See Credit Valley Area).

SANDSTONE OF THE CHAZY FORMATION.

A band of sandstone occurs in this formation and lies below the waterlime layer which is quarried for cement making in the vicinity of Ottawa. Outcrops of the sandstone occur in two widely separated areas, one near the village of Hawkesbury, and the other below Pembroke and on Allumette island.

The Hawkesbury Area.

J. C. Higginson, Hawkesbury, Prescott county.

The quarry is situated near the C.N.R. station and presents a face of 6 feet; the upper 3 feet is thin and shaly but the lower bed is in places fully 3 feet thick. All the product seems to have a tendency to break up owing to the lenticular parting planes. A well in the vicinity shows that the deposit is fully 50 feet thick—111.

The stone: No. 111.—In colour this stone is grey and of a darker cast than the ordinary grey Medina shown in Plate LXXV, No. 9; on weathering, it rapidly turns yellowish and shows a colour much like No. 10 of Plate LXXVII. The constituent mineral grains are fine and angular in shape; they consist for the greater part of quartz but considerable feldspar is present as well as an appreciable amount of argillaceous cement. The stone could be chiselled easily, but, judging from the effects of the weather on the material exposed in the quarry, it would not be a very durable material.

Whether the shattered condition of the material lying in the quarry is the result of the method of quarrying or whether it is due to a peculiarity of the beds, I am unable to say. The lower bed looks quite free from such flaws where it has not been disturbed. With a thickness of 50 feet it is reasonable to suppose that some good beds would be exposed by a careful examination. The present output is used locally as a road metal only. I am unable to learn whether this quarry is the one referred to in the report of the Geological Survey for 1863, in these words: "This sandstone, from the vicinity of Hawkesbury, was used in the construction of the locks of the Grenville canal."[1]

[1] Geol. Sur. Can., Rep. 1863, p. 814.

John Clarke, City View, Ottawa, Lot 32, Con. I, *Rideau front, Gloucester, Carleton county.*

A sandstone of very similar character to that at Hawkesbury occurs on the above lot and has been quarried to a small extent. The opening is about 25 feet by 50 feet, and it has been extended to a depth of 4 or 5 feet. The stone is irregularly bedded and badly fractured (221). The production has been very slight and operations have long since ceased.

The stone: No. 221.—In colour this stone is a little lighter than that shown in Plate LXXVII, No. 7. The fine angular constituent grains of quartz are cemented in an argillaceous cement which is present in considerable quantity. The stone is soft and could be easily cut, but, like the Hawkesbury rock, its weathering properties do not seem to be good.

The Pembroke Area.

On Morrison's island below Pembroke, on the south side, and at an elevation of 70 feet above the river, is a small abandoned quarry, showing 12 feet of limestone, with a maximum bed of 1 foot in thickness. A large amount of fissile red and blue shale lies below. In this shale, bands of sandstone become more pronounced as the water level is approached. On the shore a large amount of the sandstone is exposed—168.

On Becketts island more extensive quarrying has been attempted on the red variety of stone there exposed. A tramway was laid from the south side of the island to the quarry which was situated nearer to the north shore where the current it too swift for loading. The openings are full of water and overgrown with vegetation so that little information could be obtained. About 12 feet of stone is visible showing coarse and fine examples interstratified with shale. Most of the beds are thin but some pieces 10 inches in thickness are lying on the dump. A considerable quantity of this rock is available in different parts of the island. A selected sample of the best stone visible is described below as No. 169.

The stone: No. 168.—This is a rough, for the most part, thin bedded sandstone of a grey or white colour when weathered, but presenting on the fresh fracture a light purplish hue. The grains are all of quartz and are comparatively large in size. The amount of cement is so insignificant that the fresh stone is pulverulent, but it appears to harden very much on exposure. The irregularity of the bedding, the coarse and powdery nature of the stone and the lack of a clean uniform colour would prevent its use for purposes of finer construction.

No. 169.—This is a much finer stone than the grey variety and it has been examined in detail as representing the best type of Chazy sandstone occurring in the province. The colour is reddish with distinct bands representing the planes of stratification and is shown in Plate LXXVII, No. 6. On treatment with carbonic acid in water it assumes a slightly lighter appearance, but the difference is not at all marked. Under the microscope the stone shows very fine grains of quartz mingled with feldspar in a decomposed condition. The cement, which is present in some amount, appears to be argillaceous and ferruginous. Although the total pore space is high, it is not very clearly shown and must be of a very fine character.

The physical characteristics are as follows:—

Specific gravity	2·657
Weight per cubic foot, lbs	128·52
Pore space, per cent.	17·517
Ratio of absorption, per cent.	8·01
Coefficient of saturation	0·57
Permeability, c.c per square inch per hour..	2·25
Crushing strength, lbs. per square inch	9539·
Crushing strength after freezing, lbs. per square inch	10673·
Loss on freezing, per cent	0·253
Loss on treatment with carbonic acid, grams per square inch	0·0193
Transverse strength, lbs. per square inch	1124·
Chiselling factor	5·6

Analysis: F. G. Wait, Mines Branch laboratory.

Cement—Oxides of iron and a little argillaceous matter.

Ferrous oxide, per cent	0·68
Ferric oxide, per cent.	1·03
Sulphur	trace

The grey stone from these quarries may be seen in the Court House in Pembroke, while the post-office in the same place is the best example of the use of the brown stone. The latter building presents a mellow and pleasing appearance, but the stone is somewhat "dead" in appearance as contrasted with the freshly broken sample.

SANDSTONES OF THE ORISKANY FORMATION.

After the deposition of the Salina beds there was a considerable period of erosion during which masses of sand were distributed by the wind over the low, denuded country. The advancing sea rearranged these accumulations of sand to a greater or less extent and produced a series of beds known as the Oriskany formation. The series is seen near Waterloo on the Niagara river but the only area of any importance occurs in the townships of Oneida, North Cayuga, Walpole and Townsend, in Haldimand and Norfolk counties. The formation is not known farther west than Windham township; it does not exceed 20 feet in thickness and it is usually much thinner. Two economic areas are presented—one towards the western end of the line between Oneida and North Cayuga and the other in the township of Walpole.

The North Cayuga-Oneida Area.

The sandstone is here exposed in a belt about a mile long with a width of half a mile. The productive portion of this belt lies in its northeast corner.

Henry D. MacDonald, Clanbrassil, S.W. corner of Lot 47, Con. I, Oneida, Haldimand county.

The quarry is about ¾ acre in extent and presents a face of 12 feet. The stripping is very light; beneath, the following beds of sandstone appear in descending order:—

18 inches—Thin layers.

14 inches—Thin layers but thicker than above.

5–7 ft.—Sandstone.

3 feet 6 inches—Sandstone.

Sandstone continues below to a depth of 20 feet in all.

The beds are not broken by faults to any extent so that large blocks could be obtained from the lower layers. In places the stone is marred by the presence of petroleum which is said to largely disappear on weathering. Specimen 100 described below is one free from petroleum blotches, the other (101) contains a considerable amount of that substance. Besides the bituminous stains, yellow and brown spots and streaks appear in places.

The stone: No. 100.—The colour of this stone is grey with a brown cast and closely resembles that of the white "Nepean" shown in Plate LXXVI, No. 11. On weathering it tends to assume a lighter colour where exposed in a vertical wall, but where exposed in a horizontal position it becomes dark through the soaking in of dirt. The grains of quartz of which the stone is essentially composed are of variable size and of angular outline; they are cemented in a calcareous matrix. Compared with the better types of Medina stone, the grain of the present example is coarse, but it is somewhat finer than the majority of Potsdam-Beekmantown sandstones.

The physical properties are as follows:—

Specific gravity	2·657
Weight per cubic foot, lbs	154·95
Pore space, per cent.	6·55
Ratio of absorption, per cent.	2·64
Coefficient of saturation	0·28
Permeability, c.c. per square inch per hour	6·7
Crushing strength, lbs. per square inch	17949·
Crushing strength after freezing, not determined	
Loss on freezing, per cent.	0·034
Loss on treatment with carbonic acid, grams per square inch	0·071
Transverse strength, lbs. per square inch	2186·
Chiselling factor	0·22

Mr. F. G. Wait, chemist, Mines Branch laboratory, describes the cementing material as "Calcium carbonate with a little argillaceous matter," and gives the following figures for the deleterious materials:

Ferrous oxide, per cent.	0·2
Ferric oxide, per cent.	0·31
Sulphur, per cent.	0·03

It is very interesting to observe how closely this stone agrees with the white Nepean stone in all its characteristics. The two examples are so much alike in colour, and in all physical properties, that they could be used in the same work without any danger of variations becoming apparent.

No. 101.—This stone differs from No. 100 only in the presence of infiltered bands of petroleum whereby the colour is rendered darker and the brightness of the stone destroyed. The colour of these brownish bands is shown in Plate LXXVI, No. 3.

The residence of Mr. Walter Murray, built over 50 years ago of stone from this quarry, shows that its weather resisting properties are of a high order, as angles and chisel marks are perfectly preserved. The bituminous matter is not apparent but the general appearance is marred by the brown streaks referred to above. Another house in the vicinity, that of Mr. Thomas Murray, built 19 years ago, shows no sign of crumbling and no bitumen; the yellow and brown stains are, however, apparent and constitute the chief objection to the stone. The haul from the quarry to the railway at Anderson's siding is one and a quarter miles. The output is sold at $3 per cord in the quarry. About 150 cords per year are produced.

The stone may be seen in the following structures:—Presbyterian church at Clanbrassil, Presbyterian church at Cayuga, Methodist church at Balmoral, English church at Cayuga.

Oneida Lime Co., Buffalo, Gustave Benjamin, president, W. B. Anderson, manager, Lot 49, Con. I, Oneida, Haldimand county.

On this property are exposed about 15 feet of sandstone in beds of 2 feet 6 inches, 4 feet 2 inches, and 6 feet. The stone is soft and rapidly disintegrates. The decomposed material is screened and washed for use in steel moulds and acid hearth work; it is said to run 99 per cent in silica. The stone is too soft for building purposes, but harder material, more resembling that of MacDonald's quarry, occurs on other parts of the property, which is 54 acres in extent. The stone is grey in colour with many brown spots; it is coarser in grain than the MacDonald stone and has very little cement of any kind. It is pulverulent and extremely porous.

Summary—The North Cayuga-Oneida Sandstone Area.

The sandstones are exposed over an area of about a half square mile on the town line between North Cayuga and Oneida, in the county of Haldimand. The best stone occurs on lots 46 and 47 of con. I, of Oneida, and on the corresponding lots in North Cayuga across the road. Westward, the material is softer and brownish in colour and towards the south-east corner of the area it is hard and flinty.

Henry MacDonald's quarry already described is the only producer of building stone at present, but a considerable quantity has been quarried on adjoining lots as below:

East of MacDonald and on the same lot are Samuel Stannaman, 2 acres, and John Ward, 5 acres. Lot 46 shows good stone and is the property of John Thompson. Directly opposite the MacDonald quarry in North Cayuga, Thomas Murray holds 150 acres. East of Murray, Henry Aussem has a fair quality of stone, and south of Aussem, on the property of Jake McClung, the stone is more flinty in character. West of Thomas Murray the properties of Hugh MacDonald, J. T. Armstrong, and W. Hodgson, have been quarried to some extent, but the stone is softer and intermingled more with hard bands than in the openings towards the northeast corner of the strip.

Stone from these various quarries has been largely used locally for the construction of residences and for churches in the neighboring towns. Among the more important structures are churches in Clanbrassil, Cayuga, Balmoral and Caledonia. The Presbyterian church in the latter town has the lower portion built of stone which, I believe, was quarried on lot 46, con. I, of Oneida. The building was constructed in 1888 and shows no deterioration. The stone is bluish in colour; some pieces are uniform but others have the unfortunate yellow and brown stains. In the case of this stone, as with many others, the failure of builders to reject inferior material has resulted in the erection of structures the appearance of which is marred by the occasional occurrence of an unsightly, ironstained block. The stone from this area cannot be considered a high grade product but it is very durable, and, if a little discrimination were used in the selection of the portions used, very creditable structures would result.

Walpole Area.

The Oriskany sandstone crops out in isolated patches in Walpole, particularly towards the west side of the township on concession XIV.

Solomon W. Winger, Springvale, Lot 7, Con. XIV, Walpole, Haldimand county.

The sandstone is exposed near the centre of the lot and has been quarried to a depth of 5 feet over an area of about one-fourth of an acre. In descending order the beds exposed show an upper layer of 1 foot, followed by an 18 inch bed and a bed 2 or 3 feet thick. The upper layer shows hard concretions in a softer matrix, and all the beds are much stained with iron and marred by cavities caused by the solution of originally calcareous fossils.

The stone: No. 97.—This stone shows white bands composed of angular quartz grains with little or no cement, alternating with dirty brown irregular streaks in which the grains are more rounded and are cemented by a large amount of calcareous material carrying considerable iron. Hard, indurated bands traverse the rock at irregular intervals.

Summary—Walpole Sandstone Area.

The only important outcrops occur towards the west side of the township of Walpole in concessions XIII and XIV. The stone is of two types—a soft and a hard variety—which are so mingled together that selection is difficult in most cases. Much of the softer stone is too soft for building purposes and the harder type is too hard to chisel. A great deal of the stone

Fig. 12. Sketch map showing the location of the chief quarries in the Oriskany sandstone of Ontario.

is very badly iron stained and it is full of cavities owing to the solution of fossils. The product is suited only for the local construction of farm buildings and foundations. In these buildings it may be observed that all the soft stone is very dirty and stained; the hard bands only have preserved a white colour.

In addition to the quarry already described the following outcrops may be noted:—

Elias Shoap, Lot 9, Con. XIII.

Ten feet of sandstone are exposed under a limestone capping. The upper 5 feet are soft but the lower portion is very hard and flinty.

John J. Winger.

A small quarry towards the north of the west half of lot 6, con. XIV.

Alexander Winger.

A small quarry on the east half of the same lot.

Henry Howard.

A small quarry on the south side of lot 10, con. XIV.

Literature:—Geol. Sur. Can., Rep. 1863, pp. 359-361.
Rep. Royal Com., Min. Res. Ont., 1800, p. 46.
Bur. Mines, Ont., Rep. 1903, pp. 144-146.

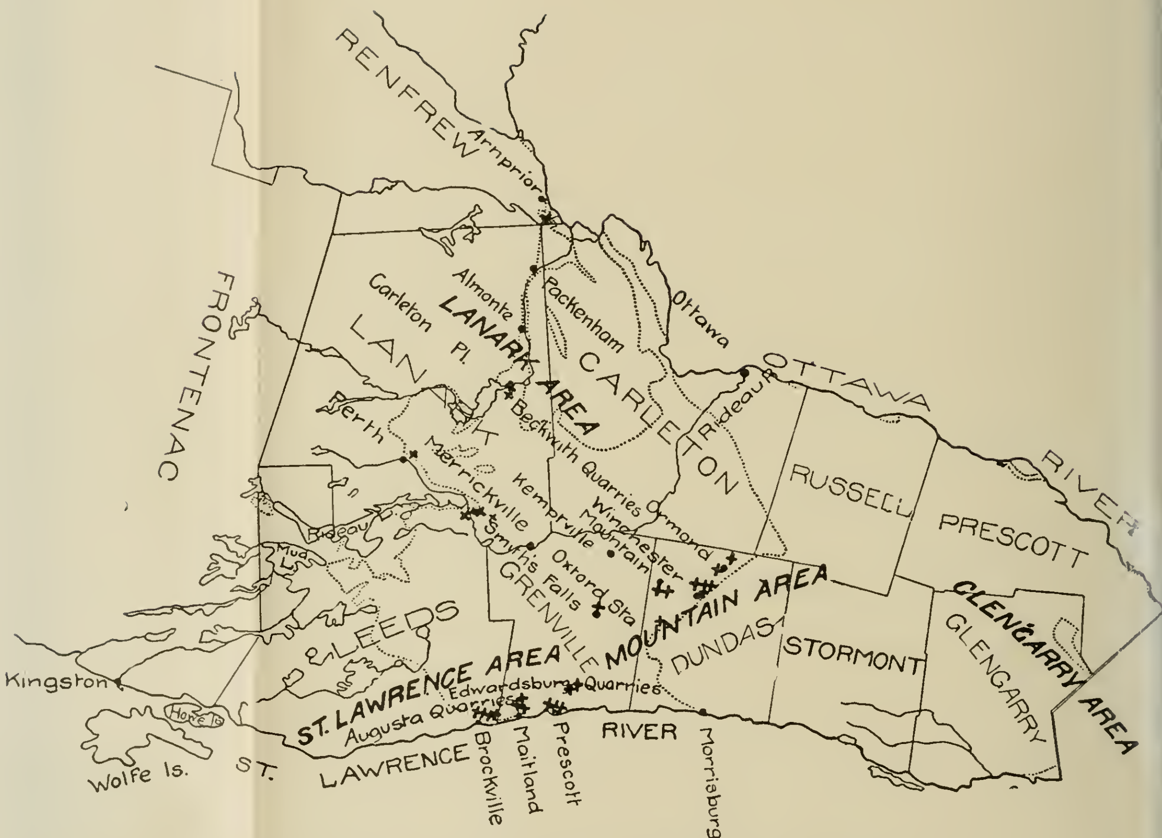


Fig. 13. Sketch map of part of Eastern Ontario showing the areas of the Beekmantown formation and the chief quarries.

CHAPTER III.

Limestones of Southern Ontario.

The province is rich in limestones of various kinds, some of them well adapted to building purposes, others particularly suited to heavy construction, and others which find a use in a great many ways outside the scope of this report. East of the Archæan axis, building stone is obtained from the Beekmantown, the Chazy, the Black River, and the Trenton formations. West of the axis the chief formations yielding good stone are the Black River, the Trenton, the Niagara, the Guelph, the Onondaga, and the Hamilton. The stone from each of these formations, while presenting many variations from place to place, is characterized by certain features which makes its recognition comparatively easy. In the summaries appended to the descriptions of the different areas will be found a general statement as to the character of the stone. Information with regard to the formation and classification of limestones will be found in the Introduction.

BEEKMANTOWN FORMATION.

This formation which consists chiefly of different types of dolomitic and sandy limestones covers a large area in Leeds, Grenville, Carleton, Lanark, and Dundas. A small patch occurs in Glengarry, another in Prescott, and a third in the vicinity of Pembroke. Besides these larger exposures, several small outcrops are known along the Ottawa valley. In places the formation is seen to gradate downwards into the underlying sandstones but it is always sharply defined against the younger formations which overlie it. The Beekmantown, formerly known as the Calciferous, is one of the great formations, having in its greatest development a thickness of 2,500 feet. In Ontario, its maximum thickness is probably not over 50 or 60 feet.

The quarries of this formation group themselves around certain centres, so that the formation may be conveniently divided into areas, although these areas may present no distinctive features. For economic purposes, therefore, it is proposed to treat the formation under the following subdivisions:—

The St. Lawrence Area.—Centreing around Brockville and Prescott.

The Mountain Area.—Centreing around Mountain in northeastern Dundas.

The Lanark Area.—Centreing around Smiths Falls, Carleton Place, Almonte, etc.

St. Lawrence Area.

The quarries included in this area occur in the southern parts of Leeds and Grenville. The output is used more particularly in Brockville and Prescott, but considerable amounts have been shipped to a distance, chiefly for purposes of heavy construction. So many quarries are known in this district that it is impossible to attempt a description of all of them.

A sufficient number were visited to obtain a clear idea of the character of the formation and the peculiarities of the stone. A description of these quarries follows:—

Dunham's quarry, Lot 1, Con. I, Elizabethtown, Leeds county.

The property is situated immediately to the south of the line of the Grand Trunk railway from which a spur formerly extended into the quarry. The opening is nearly a quarter of a mile long and from 50 to 100 feet wide. In places a depth of 40 feet has been attained. The stripping is insignificant. The following sequence of beds is well exposed:—

4 feet—Irregularly bedded, thin, whitish, and granular, weathering grey—45.

18 inches—Hard, splintery, in part solid but divided into layers in places —46.

2 feet—Hard, fine grey, not continuous but parting into beds of 6 and 8 inches—47.

1 foot 10 inches—Solid bed, stone like above but with scattered cavities holding pink and white calcite crystals—48.

1 foot 8 inches—Same.

10 inches—Same.

1 foot 9 inches—Same, but in part divisible into three beds.

2 feet—Same, but most of the layer is divisible into several beds.

10 inches—Darker and softer stone, no crystals—49.

8 inches—Like upper layers, with crystals—50.

10 inches—Same.

12 inches—Same.

3 feet 2 inches—A solid bed of similar stone.

There is a strong system of joints cutting the formation in a northwesterly direction. These major joints are from 6 to 8 feet apart. Cross joints are infrequent but very irregular, so that, while larger stone is obtainable there is a considerable amount of waste.

The stone: No. 45.—A hard fine grained, greyish limestone with many well rounded grains of quartz scattered throughout. In places the quartz grains become so numerous that the rock might be called a calcareous sandstone.

No. 46.—A hard, very fine grained, grey and brown mottled or streaked stone of fine crystalline character.

No. 47.—Hard, and fine in grain but with larger crystals scattered through the fine grained matrix; it is somewhat streaked in appearance and the crystalline grains are coarser than in No. 46.

No. 48.—This stone is somewhat like the last but it contains a great amount of sand scattered throughout the calcareous matrix or aggregated into bands. The bed is full of cavities filled with crystals of pink calcite.

No. 49.—A dark, grey, hard, fine grained and crystalline limestone with some fine quartz grains scattered throughout. More uniform in character than much of the stone and destitute of the large pink crystals.

No. 50.—This stone is a sandstone rather than a limestone and is composed of well-rounded grains of quartz of about one mm. diameter, imbedded in a crystalline calcareous matrix. The general colour of the rock is about that shown in Plate LXXV, No. 3. Glistening surfaces appear in places owing to the crystalline character of the calcareous matrix, which is not built up of fine crystals of calcite but of large crystals which are optically continuous for considerable distances; the cleavage faces of these large calcite individuals produce the glistening effect referred to. This peculiar appearance is met with to a greater degree in other rocks of this formation.

Some of the output has been used for architectural purposes, but the great bulk of it has gone into railway bridges, etc. There is no present production.

Mrs. Gillerain, Brockville.

This property is situated within the city of Brockville near the asylum. There is little stripping and the sequence of beds is as below:—

4–6 feet—Greyish limestone, very thin beds.

4 feet—Grey limestone with crystals as in Dunham's quarry, divided into thin beds, the thickest of which is 10 inches.

3 feet—Thin, shaly useless material, with sandy seams.

1 foot—Solid, dark crystalline limestone.

8 inches—Fine grained grey limestone.

10 inches—Dark crystalline limestone.

12 inches—Thin bedded, fine grained limestone.

8 inches—Dark crystalline.

8 inches—Lighter grey limestone.

1 foot—Dark, crystalline, sandy limestone—51.

Thin bedded, fine grained, grey stone.

The stone: No. 51.—This stone is practically identical with No. 50 described under Dunham's quarry above; in fact, the whole series here is in a general way similar to that described for the other quarry.

There is no regular production.

H. Dyer, Brockville.

One quarry is situated a half mile east of the asylum, south of the main road to Prescott. The beds exposed show layers of 4, 5, 6, and 7 inches for the most part, but stone 13 inches thick is obtainable in places. The output is used for building purposes and is cut into coursing stone, sills, etc., with rock face only, the stone being too hard for fine dressing —52.

The stone: No. 52.—This is a much better grade of stone than that from the quarries already described in this area, and it may be considered typical of the better type of Beekmantown stone from the lake front. The description given below should be compared with those of Nos. 264 and 254, which represent the better kinds of stone from the interior.

The colour is brownish grey and is represented in Plate LXXVI, No. 2. On weathering this stone becomes lighter in colour and assumes a mottled aspect with clouds of a rather dirty yellow tint.

The microscope shows the stone to be a fine grained crystalline aggregate in which the individuals are about ¼ mm. in diameter. The physical characteristics of the material are indicated below:—

Specific gravity	2·816
Weight, per cubic foot, lbs	173·75
Pore space, per cent	1·31
Ratio of absorption, per cent	0·472
Coefficient of saturation, apparently high, not satisfactorily determined.	
Permeability, c.c. per square inch, per hour	0·72
Crushing strength, lbs. per square inch	19050·
Crushing strength, after freezing, lbs. per square inch	24860·
Loss on freezing, per cent	0·017
Loss on treatment with carbonic acid, grams per square inch	0·017
Transverse strength, lbs. per square inch	2086·
Chiselling factor	3·00

The stone is a somewhat aluminous, magnesian limestone, the composition of which is indicated below, together with that of other stones of the same type from this locality.[1]

	1	2	3	4	5	6
Insoluble residue	....	....	....	....	19·52	....
Silica	4·80	8·76	7·00	3·68	....	6·28
Ferric oxide	1·00	·99	·57	1·22	1·01	·81
Alumina	3·32	3·84	0·79	0·80	0·81	1·05
Lime	30·10	28·31	29·20	30·94	25·92	35·00
Magnesia	15·49	15·39	17·96	17·46	15·36	12·26
Carbon dioxide	40·63	39·00	43·75	43·30	37·20	40·93
Water	....	....	0·88	....	....	....
Loss on ignition	3·97	1·35	....	....	0·22	....
Sulphur trioxide	0·75	0·47	0·41	0·46	0·86	0·62
Alkalies	0·85	0·90	....	....	....	....

1. Dyer's back quarry.
2. Asylum quarry.
3. Dyer and Sherwood's quarry.
4. A more carefully selected sample than 3 from the same quarry.
5. Murphy's quarry.
6. Easton's quarry.

I am inclined to believe that the remarkable increase in strength exhibited by this stone after being subjected to the freezing and thawing

[1] Bur. Mines, Ont., Rep. 1904, Pt. ii, p. 73.

test is an outcome of its chemical composition. Limestones with a content of from 3 to 5 per cent of alumina seem to exhibit this peculiar "anomaly" more than others.

North of this quarry and north of the railway in another opening showing beds 14 inches thick, of a lighter bluish colour.

At present there is small production.

James Perry, Brockville.

The quarry is close to Dyer's southern opening; stone similar.

Mr. Bradfield, Brockville.

The quarry is near Dyer's and Perry's. It presents a softer stone than the others, in beds of 5 and 6 inches. This stone is said to be more easily dressed than any other from the front and has been largely used for store fronts in Brockville. The walls of the Revere House are constructed from this stone. In general appearance it is very similar to No. 52 described below.

In the vicinity of Brockville are several other quarries, one on the asylum property, another near Dyer's back quarry, one at Murphy's corners, and another (Easton's) two miles northwest of Brockville on the Perth road. This latter quarry contains thick bedded, dark grey limestone. One bed has a thickness of 18 inches. The rock contains geodes of calcite.[1]

Within or close to Prescott are several quarries in Beekmantown limestone, the chief of which are Smith's, Buckly's, Barton's, Wood's, and Perkiss'. Typical of these quarries is Buckly's, a description of which follows:—

James Buckly, James St., Brockville.

The quarry is out of operation but the following sequence of beds may be observed:—

3 feet—Thin bedded.
8 inches—Dark limestone.
4 feet—Thin bedded material.
6 inches—Dark limestone.
3 inches—Dark limestone.
10 inches—Dark limestone with crystals of calcite—268.
1 foot—Softer, laminated stone.
10 to 12 inches—Hard grey stone—267.

The stone: No. 267.—This stone has a brownish grey colour and resembles Plate LXXV, No. 5. It is very hard and much finer in grain as well as more compact than most of the Beekmantown limestones.

No. 268.—This stone is exactly like No. 266 described under Plum's quarry below.

Mr. Buckly also holds a strip along the shore in which stone 12 to 14 inches thick is obtained; it may be seen in the buttresses of the Roman Catholic church in Brockville.

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[1] Rep. Bur. Mines, Ont., 1904, part ii, p. 72.

Plum's quarry.

This quarry, situated near the historic windmill east of Prescott, has been extensively worked in the past but the stone is now practically all removed to the limit of the road allowance. A 30 foot face is presented which shows both thick and thin layers of stone. Most of the stone is of the hard, dark coloured type, with numerous crystal inclusions, in beds ranging from 6 to 10 inches in thickness (266). The heaviest bed observed is 16 inches thick and is situated about 5 feet above the bottom of the opening—265.

The lighter coloured beds are more free from crystal inclusions than the darker ones. Small calcite veins running in a northwest direction cut the formation extensively.

The stone: No. 265.—This stone is somewhat like that from Dyer's quarry but it is finer and less uniform in grain; it is more strongly coherent and would be harder to cut. The colour is slightly darker and is of a grey rather than of a brownish-grey cast.

No. 266.—In colour this stone is exactly like that shown in Plate LXXV, No. 3. It is finely crystalline in character with numerous larger crystals of white calcite scattered throughout. Its appearance is marred by the white crystals and it would be hard to cut. This is a hard, dark and coarse stone, more adapted to heavy construction than to architectural purposes. There is no present production.

A group of quarries is situated on a ridge-like elevation on lots 23 to 26, con. III, Edwardsburg, Grenville county. The owners are: lot 26, E. H. Mills; lot 25, Harper Newman; lot 24, Wm. Delaney; lot 23, Hugh Scott. The quarries are all small and are worked from time to time only. The first of these is selected as an example.

E. H. Mills, Johnstown, Lot 26, Con. III, Edwardsburg, Grenville county.

The quarry is small and is not worked to any depth. There is an upper 8 inch bed, beneath which is a foot of thin material and a 10 inch, solid bed—264.

The stone: No. 264.—This stone may be considered typical of the better type of Beekmantown stone from the region inland from the St. Lawrence; it should be compared with No. 52, p. 173 and with No. 254, p. 180.

The colour is brown with a cast of yellow and is shown in Plate LXXV, No. 12. On weathering or on treatment with carbonic acid the colour becomes slightly lighter, but there is not a very pronounced effect. In structure the stone is very like that from Dyer's quarry, at Brockville, being of a fine grained and crystalline nature. Its physical features also, are of much the same character as the Dyer stone:—

Specific gravity	2·777
Weight per cubic foot, lbs.	168·598
Pore space, per cent.	2·73
Ratio of absorption, per cent.	1·01
Coefficient of saturation	·8
Permeability, c.c. per square inch, per hour	5·25
Crushing strength, lbs. per square inch	17547·
Crushing strength after freezing, lbs. per square inch	20183·
Loss on freezing, per cent.	0·305
Loss on treatment with carbonic acid, grams per inch	0·00537
Transverse strength, lbs. per square inch	2107·
Chiselling factor	3·85

The specific gravity of the Brockville stone is slightly higher, and its pore space slightly less, whereby its weight per cubic foot is increased; the crushing strength is greater, and, like this stone, it shows an increase in strength on freezing and thawing. It can scarcely be a mere coincidence that two stones so alike in chemical and physical properties should increase in strength on being subjected to this test.

The covering of soil is light and plenty of stone is available but the long haul would materially increase the cost of delivery in the centres of consumption.

A house on the property shows that the stone retains its colour well, that it is soft enough for bush hammering and that 29 years of exposure has caused no deterioration in the sharpness of angles. This stone is delivered in Prescott for from $4 to $5 per cord.

The Augusta stone.

A third group of quarries in the St. Lawrence area centres around a point in the third concession of Augusta directly north from Maitland village. The product of these quarries is known locally as "Augusta" and as "Maitland" stone, and is more prized than that obtained along the "front." The chief owners are Austin Fox, Adam Fox, Charles Stones, John Burns, P. Hunter, and Dawson Bros.

In all the quarries the upper 2 to 4 feet is thin and flaggy, but the lower portion shows heavy beds ranging from 15 inches to 3 feet in thickness. Owing to the presence of numerous irregular joints it is somewhat difficult to obtain large pieces without considerable waste; I am informed, however, that some special blocks have been raised which were 18 feet, by 4 feet 6 inches, by 2 feet 4 inches.

The stone from this section is of a brownish colour and has less tendency to turn grey on weathering than the stone along the river. Further, it presents fewer of the cavities with calcite crystals and it is much softer. As this stone may be dressed with greater ease than the local stone at Brockville and Prescott, it is largely used for the cut work in buildings in those towns.

Local contractors prefer it to the Trenton limestones from either Kingston or Ottawa.

Summary—The St. Lawrence Area.

The quarries of the St. Lawrence area may be grouped around certain centres, the chief of which are Brockville and Prescott on the river, and the third concession of Augusta and the third concession of Edwardsburg inland. Speaking generally the good limestone is interstratified with much thin bedded material partly of a calcareous and partly of an arenaceous character. In nearly all the exposures seen this intermingling of strata must of necessity increase the cost of production. The marketable stone varies from light to dark grey and brown, it is highly magnesian in character and it is frequently marred by the presence of cavities in which are crystals of white and pink calcite, of quartz and of barite, celestite, and gypsum. The stone from along the river is hard and is seldom employed except for heavy construction and rock face coursing stone; it usually assumes a yellow and dirty appearance on weathering. The material quarried inland is of a better colour and is more amenable to chiselling. The chemical and physical characters of the stone in general may be seen from the tables on pages 174 and 177.

In Brockville the local limestone may be observed in the Revere House, St. John's church, City Hall, Baptist church, Methodist church, Court House, First Presbyterian church, Roman Catholic church, the Church of England, and the Armouries. All these buildings show that the stone weathers a yellowish grey, rather dirty colour which is not attractive. On the other hand the stone seems to have well withstood the attacks of the weather as angles are still sharp and chisel marks quite fresh after the lapse of many years. The Augusta stone is employed for "trimmings," with the local stone for walls. This Augusta stone is darker, preserves its colour better, and shows very little chipping on hammered faces, being in this respect superior to most of the Trenton limestones.

In Prescott the Beekmantown stone may be seen in several of the churches and in the residence of Mr. D. Higgins. The local stone is dark in colour, but it preserves its tone better than the Brockville stone. It is a common practice to use the local product for rock face work and to trim with Maitland stone or with material brought from a distance.

As there is little or no regular production in the area, it is difficult to obtain prices, but in Brockville or Prescott rock face sills with hammered top and bottom may be obtained at 75 cents per running foot, and heavy base stone at $2. Untrimmed, 12 to 14 inch coursing stone is sold at the quarries for from 50 to 60 cents per running foot. Local stone is sold by the cord for $3 in Brockville and Prescott. Augusta and Edwardsburg stone is delivered at from $4 to $5.

Literature:—Geol. Sur. Can., Rep. 1863, p. 118, p. 619.
" " " " 1863–66, p. 236.
" " " " 1900, pp. 134–137 A.
Bur. Mines, Ont., Rep. 1904, pt. ii, p. 48, pp. 72–73.

Mountain Area.

In the vicinity of Mountain in northeastern Dundas are a number of small quarries in Beekmantown limestone. The output is small and the consumption local only. The stone appears to be thin and flaggy for the most part, and is, in places, characterized by the pink and white calcite crystals observed in the St. Lawrence area; it does not appear to be a very desirable building stone and only one quarry was visited. In describing the area, Dr. Ells states:—"The Calciferous (Beekmantown) limestones have a very considerable development on this sheet, and the soil overlying them is generally poor and thin or sandy. They are well exposed on lot 23, concession XII, Mountain. About two miles in a northeasterly direction from Van Camp's mill, Calciferous limestone occurs in thin beds and much disturbed, with characteristic vugs of pink and white calcite. This place has been opened as a quarry.

The formation is also well exposed in the neighborhood of South Mountain and all along westward of this place towards Kemptville and Merrickville."

Edward Robinson, Lot 21, Con. VII, Mountain, Dundas county.

Under a very light stripping two beds of stone are exposed and have been quarried over about three acres. The upper bed is 14 inches and the lower one 10 inches thick. A main series of joints cuts the formation at 50° east of north; a second series running north and south occurs with less frequency. The main joints are close together, seldom more than 2 feet apart, so that wide pieces of stone cannot be obtained, although pieces as much as 20 feet long have been quarried.

The stone: No. 72.—This example is a very hard, compact and exceedingly fine grained limestone of crystalline character. The colour is intermediate between that shown in Plate LXXV, Nos. 4 and 6. On weathering the stone assumes a yellowish hue; it is much too hard for work requiring chiselling.

The output is largely used in Winchester and may be seen in the residence of Alex. Rose, and of Dr. Mallock, also in Bishop's mills, at Inkerman. Mr. Robinson values his output at $3 per cord at the quarry and $5 a cord f.o.b. Winchester station. Similar stone is seen on the adjoining lots as below:—

Byron Watt, lot 20, con. VII, Mountain; Aaron Campbell, lot 20, con. VI, Mountain, also farther north is a quarry on the property of Felix Lamourie, lot 23, con. IX, Mountain.

Literature.—(See St. Lawrence Area.)
Geol. Sur. Can., Rep. 1896, p. 62A.

Lanark Area.

Towards the western border of the Beekmantown formation in the county of Lanark are a number of quarries from which stone is obtained for use in Pakenham, Almonte, Carleton Place, Smiths Falls and Perth. The material obtained in the township of Beckwith near Carleton Place and known as the

Beckwith stone is of a unique character and is shipped to considerable distances. The exposures of this stone occur over three lots only and there are only two operators.

F. McEwen, Carleton Place, Ont., East half Lot 9, Con. IX, Lot 11, Con. IX, Beckwith, Lanark county.

In the surrounding regions are numerous exposures of thin bedded limestones which are used for foundations and for road metal. On the lots in question there is a ridge with a general southwest trend which stands a little higher than the rest of the neighbourhood. The upper bed of this ridge is about 3 feet 6 inches thick and consists of a brown crystalline dolomitic limestone, described in detail below—254.

This upper bed is the only one quarried as the material lying beneath it is thin and shaly. Joints cross the formation 10° W. of S. and 5° N. of E., but they are not so close together as to prevent the obtaining of blocks 6 feet by 8 feet in size. The rock is very easily drilled and splits with remarkable facility; plug holes 3 inches deep and 8 inches apart suffice for the breaking of the layer throughout the entire thickness.

The stone: No. 254.—This is a type of Beekmantown stone not met with elsewhere in the formation, although it approaches the finer grades of Augusta and Brockville stone. (Compare No. 52, p. 173, and No. 264, p. 176). The colour is the darkest brown met with in any stone in the province and is shown on Plate LXXVI, No. 1. On weathering, the stone becomes still darker and assumes a minutely punctuate appearance; treatment with carbonic acid produces the same effect but not to such a marked degree. Microscopically the stone is composed of a mass of small crystals of dolomite averaging about $\frac{1}{4}$ mm. in diameter. Scattered larger crystals are seen throughout the finer grained base. Open interspaces are very apparent; these seem to ramify and to run irregularly through the stone.

The physical properties are as follows:—

Specific gravity	2·836
Weight per cubic foot, lbs.	151·38
Porosity, per cent	12·607
Ratio of absorption, per cent	5·09
Coefficient of saturation	0·3
Permeability, c.c. per square inch per hour	13·12
Crushing strength, lbs. per square inch	15588·
Crushing strength after freezing, lbs. per square inch.	13280·
Loss on freezing, per cent	0·081
Loss on treatment with carbonic acid, grams per square inch	0·01228
Transverse strength, lbs. per square inch	1130·
Chiselling factor	5·4

It will be observed that this stone has a higher specific gravity, a much greater porosity and permeability and that it is much more easily cut than the stones with which it has been compared. It is interesting to note the dolomitic character of the rock, as the following analysis by H. A. Leverin indicates:—

Insoluble matter	1·08
Ferrous oxide	·76
Ferric oxide and alumina	·56
Calcium carbonate	55·53
Magnesium carbonate	42·14
Sulphur	0·29

A five ton derrick is in position and the requisite tools are at hand to reopen the quarry on receipt of orders. The haul to the railway is about one-half mile.

Dressed sills are sold at 50 cents per running foot at the quarry and squared dimension stone at $1 per cubic foot.

Stone from this quarry has been shipped to Carleton Place, Pembroke, Renfrew, Arnprior, Almonte, Perth, Smiths Falls, and other places, where it has been largely used for trimmings on buildings constructed from local and more refractory stone. A large quantity of material is still available.

Daniel McNeilly, Carleton Place, Lot 12, Con. X, Beckwith, Lanark county.

On this lot a considerable area has been worked over. The stone is practically identical with McEwen's, but towards the eastern end it is somewhat darker in colour.

The stone: No. 255.—There is no essential difference between this stone and that described as No. 254 from McEwen's quarry.

Jas. McGillivray, Smiths Falls, Lot 3, Con. IV, S. Elmsley.

The quarry is situated about a half mile from Smiths Falls on the Lombardy road. The stone is thin bedded with an average of about 5 inches. The heaviest bed observed was 8 inches thick—232.

The stone: No. 232.—A fine grained crystalline limestone with crystals of white calcite of larger size scattered throughout. Well rounded grains of quartz of about ½ mm. in diameter are present but they are relatively small in amount compared with the fine crystalline calcite. The colour is browner than that of No. 235 which is described in detail under Coughlin's quarry. The present example has a colour comparable with that shown in Plate LXXV, No. 15.

The product is used for walls in Smiths Falls and is sold at the quarry for from $2.50 to $3 per cord.

D. Coughlin, Smiths Falls.

This quarry was not visited but it is probably situated on lot 26, concession V of Montague. The layers are said to average 6 or 8 inches in thickness, but some 10 inch stone has been obtained. Only the upper two feet are quarried.

The stone: No. 235.—This example has been selected as representing the hard sandy type of Beekmantown stone: the description here given applies with some modifications to much of the stone from the vicinity of Brockville and Prescott.

The colour is grey with a greenish cast and is shown in Plate LXXVII, No. 12. On weathering, the stone becomes slightly lighter and somewhat yellowish.

The rock is composed of rounded and subangular grains of bluish quartz cemented in a calcareous matrix; the more sandy examples like the present one would more properly be described as a sandstone, but, as the amount of sand and calcite varies greatly, we have all transitions from a sandy lime stone to a calcareous sandstone.

The physical characteristics are as follows:—

Specific gravity	2·73
Weight per cubic foot, lbs.	167·507
Pore space, per cent	1·633
Permeability, indeterminable.	
Coefficient of saturation	0·39
Crushing strength, lbs. per square inch	26858·
Crushing strength after freezing, lbs. per square inch	20505·
Loss on freezing, per cent	0·00
Loss on treatment with carbonic acid, grams per square inch	0·019
Transverse strength, lbs. per square inch	2968·
Chiselling factor	0.05

The outstanding features of this stone are its hardness, its compactness, and its high strength.

The large amount of sand present is indicated by the following analysis by H. A. Leverin:—

Insoluble matter	44·92
Ferrous oxide	·96
Ferric oxide and alumina	·10
Calcium carbonate	40·05
Magnesium carbonate	13·16
Sulphur	·053

It should be noted that the ferrous oxide runs rather high, in consequence of which the stone would turn yellow on exposure.

This stone doubtless represents passage beds from the Beekmantown limestone to the underlying sandstones. A good examples of the stone is seen in the Kingston warehouse, in Smiths Falls. The price is $4 per cord in Smiths Falls or $2.50 at the quarry.

A stone very similar to Coughlin's was formerly quarried by J. Moir at a point 3½ miles east of Smiths Falls. Small quarries have also been opened northward from Smiths Falls to Almonte. At Smiths Falls the soil is thin and small quarries were formerly opened on many properties within the town. Near Perth, also, thin bedded Beekmantown dolomites have been worked for road metal and for foundations.

Ells states that quarries were operated on lot 20, concession IX, Ramsay.

Summary—The Lanark Area.

The Beekmantown dolomites obtained for building purposes near Perth, and more particularly near Smiths Falls, represent lower beds in the series than those of the St. Lawrence and of the Mountain area. The stone of this area is characterized by its hard and sandy character and presents transitions to the underlying sandstones of the Potsdam-Beekmantown series. The typical stone is that of Coughlin's quarry near Smiths Falls, a detailed description of which is given on page 182. The cavities filled with white and pink calcite crystals so characteristic of the St. Lawrence area are not observed in the stone from this region.

In this area also occurs the Beckwith stone, which is of a very different character from any other rock of the formation; it is of a distinctly brown colour and weathers much darker. In structure it is granular-crystalline and somewhat porous so that weathered surfaces have a distinctly pitted aspect. This variety is soft, is very easily worked and has been largely employed for trimmings in buildings at a considerable distance. It is quarried near Carleton Place and may still be obtained in some quantity.

A large number of more important structures in Smiths Falls are of stone and show the effects of weathering on the Beekmantown arenaceous dolomites and the Potsdam-Beekmantown sandstones. The Roman Catholic church was built in 1860 of a sandy limestone quarried in the town. This stone is of finer grain than the typical example from Coughlin's quarry; it has stood the weather well and still presents a uniform grey colour. Some of the white sandstone used for trimming has stood fairly well, but other parts have badly effloresced and exfoliated. The posts are of the spotted sandstone and have turned dark grey by imbibed dirt; the spots are no longer perceptible. Except for the change in colour this stone has stood well. It has been a common practice to use the sandy limestone for walls and to trim with the white sandstone or the purple banded variety from Hughes' quarry. As observed in the church the limestone has, on the whole, stood the test of time better than the sandstone. The tendency of the sandstone to turn grey by the soaking in of dirt renders the colour of the two stones much the same after a few years of exposure. In some of the older buildings it was necessary to chip the stone in order to distinguish the one from the other. There is no doubt that the stone at present under review is very durable and of a fairly uniform colour. It is, however, hard to chisel and is seldom employed except for rock face work. The brown Beckwith stone is also seen in trimmings; it turns very dark in time and is too sombre a stone for the construction of a whole building.

Literature:—Geol. Sur. Can., Rep. 1863, pp. 116-118.
" " " " 1901, p. 73 J.; 15-17 J.
Bur. Mines, Ont., Rep. 1904, pt. ii, p. 70.

The Glengarry Area.

The Beekmantown formation is exposed over a considerable area in the township of Lochiel in Glengarry. I am, however, unaware of any important quarry and Ells mentions none in his report on the region. See Geol. Sur. Can., Rep. 1899, Pt. J.

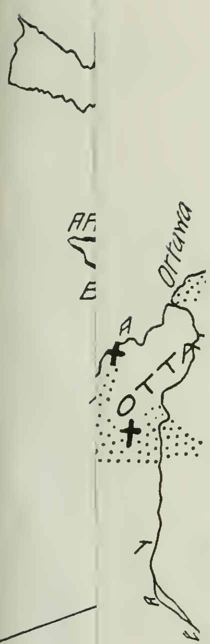
In the valley of the Ottawa river the Beekmantown formation occurs at intervals from Pembroke downwards. The proximity of more desirable stone to the centres of population has prevented the exploitation of the rather thin bedded Beekmantown dolomites. See Geol. Sur. Can., Rep. 1899, Pt. J.; Geol. Sur. Can., Rep. on Nipissing and Temiskaming Map Sheets, Sec. Ed. 1907, p. 116 (Publication No. 962); and Geol. Sur. Can., Rep. on N.W. Quarter-sheet, No. 122, of the Ontario and Quebec series, 1907. (Publication No. 977).

Summary—Beekmantown Formation.

The more important areas have already been reviewed (see pages 178 and 183). To sum up the whole formation, the following types of rock are recognized. First, a heavy dark coloured somewhat magnesian limestone with vugs of calcite, barite, and celestite. This is a rough stone suitable only for heavy construction—Prescott, Brockville, Winchester. Second, a crystalline limestone with variable amounts of sand—sometimes more properly to be called a sandstone—an extremely hard but durable stone—Brockville, Prescott, Smiths Falls. Third, a granular crystalline dolomite of brownish colour, softer than the other examples and a more desirable stone for building purposes—Brockville, Edwardsburg, Augusta, Beckwith.

LIMESTONES OF THE CHAZY FORMATION.

During the latter part of Beekmantown time the sea had gradually retreated from the continent leaving the Potsdam and Beekmantown deposits exposed to the eroding effect of the elements. Another great advance of the sea marks Chazyan time, in consequence of which Chazyan rocks as exposed in Canada are distinctly demarkated by a sharp line of separation from the underlying rocks. In Pennsylvania, where the maximum thickness is attained, the Chazy rocks are more than 2,500 feet thick. It is obvious that the advancing sea did not invade the Ontario region until late in the period and in consequence only the upper members of this great formation are seen in the province. The lower portion of the formation, about 150 feet thick, consists largely of shales and thin sandstones; the upper part, with about the same thickness, consists of limestones. Recent investigations tend to show that only the lower part is properly to be classed as Chazy, and that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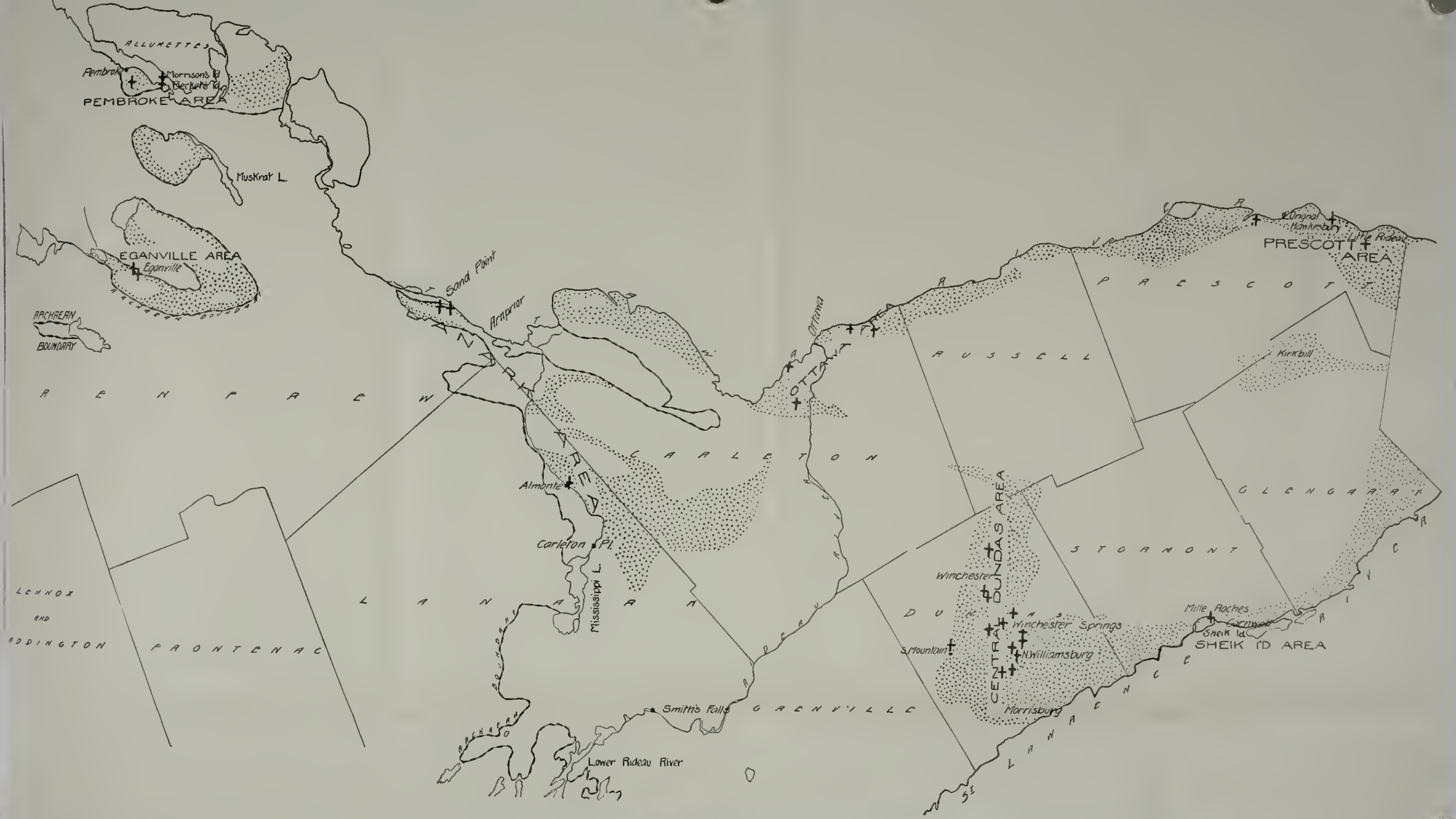

Fig. 14. Sketch map showing the areas and important quarries of the Chazy formation in Ontario.

the upper consists of two members, the lower of which is equivalent to the Pamelia formation of New York and the upper to the Lowville. In this report, however, it seems better to retain the older classification as it is more familiar to the general reader. With the lower part of the formation, as exposed in Ontario, we are not now concerned, as it consists of thin shales and limestones not adapted for building purposes. The upper limestone portion, however, contains some fine beds of stone adapted both to heavy construction and to architectural purposes. Like the Beekmantown, the rocks of this formation are confined largely to the region east of the Archæan axis. As the advancing sea found its way far up the Ottawa valley, rocks of this age are seen as far up as Pembroke, in outliers in Renfrew, Carleton, and Lanark, and along the Ottawa from Arnprior to the borders of the province. A large exposure occupies the greater portion of Dundas and sends a wing down the St. Lawrence valley almost to the eastern limit of the province. The distribution of quarries rather than that of the formation is indicated in the following division of areas:—

The Central Dundas area.
The Sheek Island area.
The Prescott area.
The Ottawa area.
The Lanark area.
The Eganville area.
The Pembroke area.

A glance at the map (Fig. 14) shows that this division is for purposes of description only and that it is not intended to show the geographical distribution of the rocks of this formation.

The Central Dundas Area.

Many small quarries have been opened in the vicinity of Winchester village and thence south through Winchester Springs to North Williamsburg. A few of these quarries are described below and this description is indicative of the character of all the workings.

Edward Baker, Winchester.

The quarry lies immediately to the south of the village near the Canadian Pacific Railway station. The excavation is not much more than 3 feet deep, but it extends over several acres. The upper portion is thin and shaly but the lower part is fairly solid, with, however, much irregular bedding and deformation. Stone of 1 foot in thickness can be obtained in certain parts of the opening.

The stone: No. 73.—The colour is practically identical with that shown in Plate LXXV, No. 3, being a dark grey. A distinctly banded structure is presented with lighter highly fossiliferous layers alternating with the dark grey. These lighter layers show scattered crystals of white calcite which also occurs to a less extent in the darker parts.

Stone from this quarry has been largely used in Winchester for building, and has also been made into lime.

W. Webb, East half Lot 35, Con. VIII, Williamsburg.

A dark stone (79) is quarried on this property from the upper layer only which yields a product from 8 inches to 1 foot in thickness.

The stone: No. 79.—This example is very dark in colour and resembles that shown in Plate LXXV, No. 1. The grain is very fine so that a crystalline structure can scarcely be made out under the microscope; in this respect it is finer than the stone from Marcotte's quarry at Mille Roches which it resembles in most respects. This latter stone has been selected as the type of this class; the general characteristics of the present example may be gained from the description of No. 136, p. 188. The weathering of this stone is likewise comparable with that of the Mille Roches stone, the altered colour of which is shown in Plate LXXVII, No. 14.

On several of the adjacent lots a similar stone has been quarried on a small scale, as on the property of O. Casselman, lot 36, con. VIII, Williamsburg, and on that of Wm. Robertson, west half lot 36, con. VIII, Williamsburg, and of M. Casselman, lot 3, con. I, Winchester.

Matthew B. Barclay, East half Lot 30, Con. VII, Williamsburg, Dundas county.

On this property two beds of different character are shown; the upper layer is as much as 20 inches thick in places, but it is not solid and it shows a strong lamination with a tendency to split along the bedding planes (75). The lower stone is lighter in colour, more compact, and about 18 inches thick—74.

The stone: No. 75.—A hard, dark grey, fine grained stone, practically identical with No. 79 from Webb's quarry.

No. 74.—A hard, fine grained, light grey stone, being of the same cast but somewhat lighter than Plate LXXV, No. 4. The stone much resembles the Beekmantown stone from Robinson's quarry described as No. 72 on page 179. As this material is markedly different from the typical Chazy stone above (75) it may belong to the Beekmantown formation. The stone weathers a dirty yellow.

Ed. Whittaker, N. Williamsburg, Lots 35 and 36, Con. VI, Williamsburg.

On this property several acres of stone are exposed. The upper layers only have been quarried. There are two distinct beds, one of 6 and the other of 8 inches in thickness—76.

The stone: No. 76.—This example is quite similar to the other typical Chazy stones from the region. It may be compared with Nos. 79 and 75, but it contains more scattered crystals of white calcite and small fossils and in that respect resembles No. 73 from Baker's quarry.

Wm. Farlinger, N. Williamsburg, Lots 31 and 32, Con. VII, Williamsburg, Dundas county.

This quarry is essentially similar to the ones already described.

Thomas McGregor, Cannamore, Lot 22, Con. XI, Winchester, Dundas county.

The quarry on this property has a light covering of soil beneath which are two beds each of about 10 inches in thickness. These beds are of a more solid character than most of the local Chazy stone, and present a dark blue rather than a dark greyish brown colour. Further, this blue colour is more persistent and the stone seems to wear better.

Summary—The Central Dundas Area.

Throughout this area, which consists of a belt through the townships of Winchester, Williamsburg, and Matilda, the soil is thin and exposures frequent. Many small quarries have been opened and stone has been obtained to a depth of a few feet only. The practice has been to remove the upper beds only, in some cases only one bed and in others the upper two beds. The stone is dark in colour but weathers lighter and shows a strong tendency to develop lines of parting along certain of the bedding planes. There is no really important quarry in the area, the stone being used locally for the most part, although some flagging obtained near Winchester Springs has been shipped to Cornwall.

Literature:—Geol. Sur. Can., Rep. 1863, pp. 123-135.
" " " " 1896, p. 62 A.
" " " " 1899, p. 136 A.
Bur. Mines, Ont., Rep. 1904, pt. ii, p. 40.

The Sheek Island Area.

C. Marcotte, Mille Roches.

There is only one quarry now in operation on Sheek island. It is situated at the northern end of the island opposite Mille Roches. The workings are situated at a low level so that they are flooded at seasons of high water. The upper bed, about a foot thick, is fine grained and soft; it is used for backing only—137.

Beneath this upper layer are about 4 inches of shale followed by the heavy valuable beds, from which solid stone 18 inches thick can be obtained—(136). Joints traverse the formation in a northwest and southeast direction; they are very evenly spaced being about 4 feet apart. Besides these major joints a series of less regularly developed partings cuts the main set at varying angles. The stone in these lower beds is seen to carry many fossils, and it likewise shows white calcite veinlets in some abundance.

The stone: No. 136.—This stone is very dark grey in colour and is shown in Plate LXXV, No. 1. On weathering it assumes the appearance seen in Plate LXXVII, No. 14. This alteration in colour is quite remarkable and shows that the stone while apparently homogeneous is made up of irregular layers of different composition. The highly fossiliferous character of the stone is much more apparent after weathering. On treatment with carbonic acid, the calcite forming the shells of the fossils is attacked more readily than the matrix, with the result that the original position of the shell is shown by thread-like depressions on the surface. The stone is very fine grained and compact and shows small crystals scattered throughout the general mass.

The physical properties follow:—

Specific gravity	2·738
Weight per cubic foot, lbs	170·349
Pore space, per cent	0·31
Ratio of absorption, per cent	0·115
Coefficient of saturation	0·26
Crushing strength, lbs. per square inch	21693·
Crushing strength after freezing, lbs. per square inch	29445·
Gain on freezing, per cent	0·008
Loss on treatment with carbonic acid, grams per square inch	0·1547
Transverse strength, lbs. per square inch	3423·
Chiselling factor	0·8

It will be observed that the stone is very compact, with a small pore space, and a high crushing and transverse strength. It appears to gain appreciably in strength under the freezing and thawing test and it was one of the very few examples that increased in weight at the same time; this increase is too slight to have any significance.

The above results may be taken as typical of these dark coloured Chazy stones, not only in the present locality but in the area around Winchester. The lack of uniformity in this rock is also shown by the following analysis by H. A. Leverin:—

Insoluble matter	14·76
Ferrous oxide	1·18
Ferric oxide and alumina	1·19
Calcium carbonate	76·98
Magnesium carbonate	6·50
Sulphur	·473

The high percentage of insoluble matter (clay) and of ferrous oxide should be noted.

Masons consider that this stone (136) is harder and more difficult to work than the Trenton limestone from the quarries north of Mille Roches, nevertheless there has been a large production in the past, the product being used for canal and bridge construction, as well as for ordinary building. A good example of the stone is seen in the newer part of the buildings of the St. Lawrence Paper Co., at Mille Roches.

No. 137.—When fresh, this stone has a pleasing grey colour like Plate LXXV, No. 4, and at first sight would appear to be a more valuable stone than the underlying dark material. Its weather resisting properties appear to be poor and it is used for the roughest purposes only.

There is a small present production. Mr. Marcotte is prepared to deliver rough stone at $8.50 per cord, f.o.b. Mille Roches.

Literature:—Geol. Sur. Can., Rep. 1896. p. 63A.
" " " " 1899, p. 134A.
Bur. Mines, Ont. Rep. 1904, pt. ii, p. 47.

The Prescott Area.

This area comprises a strip of country along the Ottawa river in the county of Prescott. The most important quarries lie east of Hawkesbury, but another section in the vicinity of L'Orignal has produced stone of a different type.

R. C. Ross, Little Rideau, Ont., West half Lots 27 *and* 28, *Con. I, East Hawkesbury, Prescott county.*

On this property the valuable stone forms a distinct knoll standing a few feet above the surrounding country. The formation dips about 10° to the southeast. Three main openings have been made along the strike of the formation on the northwest side of the knoll. The first or more easterly of these openings shows the following beds in descending order: 14 inch, 2 feet, 14 inch, 5 feet, 3 feet, 8 feet. The stone from all these beds is essentially the same and is described in detail below—109.

The main joints run 25° north of west and south of east; the minor series cuts the formation in a direction 55° east of north. Neither of these series of joints interferes with the obtaining of stone of any practical dimension that may be required. The opening is 200 feet by 200 feet and of a depth indicated in the section.

The second quarry follows the one described to the southwest, along the strike of the formation; it is only about 50 feet wide and displays essentially the same beds. The third opening is still farther to the southwest, and is about 300 feet long, but is not quarried as far into the hillside as in the first opening. The valuable stone is here thinner, probably not more than 10 feet thick; it is also somewhat coarser in texture.

From these three openings 160,000 to 170,000 cubic yards of stone have been obtained, the greater part of which has gone into the construction of locks, etc., on the Grenville and Carillon canal. The material has also been used for architectural purposes and may be seen in the following structures: St. Philip's church, Hawkesbury; Presbyterian church, Vankleek Hill; Roman Catholic church, Vankleek Hill.

The stone: No. 109.—The general colour of this stone is represented in Plate LXXVII, No. 10; it has, however, a speckled effect like that shown in No. 13, of the same plate. On weathering, or on treatment with carbonic acid, the colour becomes lighter and assumes a somewhat yellow cast with a speckled yellow appearance. This alteration is not very striking nor is the resulting effect displeasing.

The stone has a crystalline appearance due to its composition from broken parts of calcareous organisms, particularly the stems of sea-lilies.

The physical properties are as follows:—

Specific gravity	2·718
Weight per cubic foot, lbs	168·47
Pore space, per cent	0·68
Ratio of absorption, per cent	0·225
Coefficient of saturation	0·8
Crushing strength, lbs. per square inch	12890·
Crushing strength after freezing, lbs. per square inch	14479·
Loss on freezing, per cent	0·058
Loss on treatment with carbonic acid, grams per square inch	0·07226
Transverse strength, lbs. per square inch	2038·
Chiselling factor	4·6

Analysis: H. A. Leverin, Mines Branch laboratory:—

Insoluble matter, per cent	1·26
Ferrous oxide, per cent	.81
Ferric oxide and alumina, per cent	·50
Calcium carbonate, per cent	95·94
Magnesium carbonate, per cent	1·20
Sulphur, per cent	·034

This is a very fine stone, and although the quarries are now idle, the large amount—nearly 40 acres—which could be obtained by the removal of a very light stripping renders possible a future industry of some magnitude.

It is interesting to note that on another part of Mr. Ross' property a bluish limestone was formerly quarried on the exact locality of Dulac's famous defence against the Indians. This quarry is still capable of yielding excellent coursing stone in 5 and 9 inch beds.

D. D. Lanthier, L'Orignal.

This quarry as well as others in the vicinity is situated on a ridge of rock exposed in a east and west direction at an elevation of about 25 feet above the general level of the country. The beds are horizontal or with a very slight dip to the south. The overburden is slight and the shipping facilities excellent as the quarries are close to the line of the C. N. R. The jointing is strong and very regular in a southwest direction; the planes are from 18 inches to 5 feet apart. A second set of joints runs in a direction 20° west of south. The quarry is opened up for 200 feet along the ridge and is continuous with the excavation on the adjoining property. The following sequence of beds is exhibited:—

2 feet—In places solid but mostly splits into thinner material—184.
3 inches—Shaly parting.
1 foot—Solid stone.
18 inches—Solid stone—185.

Other beds of good stone, the thickness of which could not be ascertained in the present condition of the quarry, lie below.

The upper layers are filled with fossils and weather with a pronounced banding, *i.e.* the planes of bedding become perceptible. The lower stone is more uniform and shows scarcely any of this banded effect on weathering. This stone retains its dark colour well. Bush hammered work is lighter than the rock face and is clean, solid, and uniform in appearance.

There is no present production.

The stone: No. 184.—The stone is of a dark grey colour but with a brownish cast resembling Plate LXXV, No. 11. It very much resembles the other Chazy stones of the dark type, being fine in grain and dotted with small white crystals of calcite. On weathering, the colour does not seem to fade to the extent observed in some other localities.

No. 185.—This sample is lighter in colour, resembling Plate LXXV, No. 5; it is somewhat coarser in grain and is less filled with fossils than No. 184.

Literature: Geol. Sur. Can., Rep. 1863, p. 130; p. 816, p. 827.
" " " " 1899, pp. 85–87 J.; p. 136 J.
Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 98–99.

Ottawa Area.

In the vicinity of Ottawa the Chazy limestones are exposed to the west and south of the city and eastward along the north side of the Montreal road. The excellence of the Trenton limestones quarried near Ottawa has prevented extensive operations on the Chazy for purposes of construction, but stone of this age has been largely employed in the cement industry. The more important quarries are at the following points: lot 21, con. I, Ottawa front, Gloucester; lot 12, con. I, Ottawa front, Gloucester; lot 32, con. I, Rideau front, Gloucester; lot 34, con. I, Ottawa front, Nepean. These quarries are all small and unimportant with no present production; although some of them were visited it is unnecessary to describe them here.

For general information see particularly Dr. Ells' report on the City of Ottawa and vicinity with map. (Geol. Sur. Can., Rep. 1899, Pt. G.).

Lanark Area.

To the north of Almonte are several quarries in the Chazy limestone, the more important of which are the properties of O. Wright, Joseph Cullen, and J. K. Darling. The stone from these quarries is used locally only, and mostly for rock face work alone. It is a common practice to employ the local stone for walls and to trim with sandstone. As an example of the quarries of this area that of Wright is selected. This quarry lies about a half mile north of Almonte, and is probably the most important in the area.

O. Wright, Almonte.

The beds are quite horizontal in position and furnish stone from 6 to 14 inches in thickness. The layers are easily separable, present flat bedding planes and are readily broken into good coursing stone owing to the facility with which the material breaks across the planes of stratification. In quarrying it is the practice to exploit the upper 5 feet only and to fill in the excavation with debris as the face advances. All of this 5 feet is good stone with the exception of the upper foot, which consists of thin bedded material—256.

The stone: No. 256.—In colour this stone resembles the lighter type of Trenton or Black River rock; it presents the hue shown in Plate LXXV, No. 8. On weathering it turns very much lighter as may be seen in numerous buildings in the vicinity. The structure is very fine grained, but occasional larger crystals of calcite are present. While fairly hard the stone is much more easily dressed than the dark type of Chazy rock already described.

Local stone is delivered in Almonte for $4.25 per cord, and rough dimension stone at $7 per cord.

A good example of the local Chazy limestone is seen in the walls of the Sterling Bank, and in the Methodist parsonage at Almonte.

Northward from Almonte, similar stone is quarried at several places, particularly at Pakenham, where material 2 feet thick is procured.

Westward from Arnprior, stone which probably belongs to this formation is quarried at several points, of which the following quarries are typical.

Mrs. Andrew Bell, Braeside, owner; James Barnett, Braeside, operator.

The quarry is situated immediately to the east of the village and has been opened at several points on the top of the hill facing the river. The main working is about 300 feet by 100 feet in extent and presents the following succession of beds:—

1-3 feet—Soil.
18 inches—Loose thin bedded material.
5 inches—Solid bluish limestone.
1 foot—Thin bedded material.
5 inches—Solid bed.
5 inches—Solid bed.

3 inches—Seamy band.
8 inches—Solid bed.
11-18 inches—Solid bed—248.
3 feet—Black shale and soft shaly limestone.
2 feet—Contorted, thin bedded, friable stone.
1 foot—Solid bluish limestone.
15 inches—Solid bluish limestone.
The lower beds, as far as can be seen, consist of this same blue stone.

The stone: No. 248.—The colour is dark grey with a cast of brown and is similar to Plate LXXV, No. 11. The stone is hard and somewhat splintery; it is fine in grain but the uniformity is marred by bands of a more crystalline character, interbedded with the more compact material. This is a good solid building stone for ordinary purposes.

Miller gives the following analysis of stone from this quarry:—[1]

Silica	2·54
Ferric oxide	·92
Alumina	·74
Lime	50·80
Magnesia	2·15
Carbon dioxide	42·00
Loss	·15
Sulphur trioxide	·36

Although considerable stone has been obtained and a large area worked over, the operations are on a very small scale and are conducted without machinery of any kind. The large amount of useless material to be removed detracts from the value of the property. There is a small production from time to time.

Joseph O'Connor, Braeside.

This quarry lies a little to the east of Barnett's on the road from Braeside to Arnprior. The opening is of crescentic shape and is about 100 feet by 100 feet in extent. The following beds are exposed:—

10 inches—Friable top.
19 inches—Thin stone and shale.
9 inches—Solid fossiliferous bed.
18 inches—Black shale and thin beds.
18 inches—Corrugated layer, hard stone, breaks easily along the curved planes of bedding.
13 inches—Solid bed—249.
1 foot—Solid bed. Like 249.
18 inches—Solid bed. Like 249.
Joints cut the formation at 40 E. of N. and 25 N. of W.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 105.

The stone: No. 249.—A hard, fine grained, semi-crystalline, dark grey stone very closely resembling that described above as No. 248 from Barnett's quarry.

The product is used for foundations and rough work only. The property is worked intermittently only and the stone is disposed of at $4 per cord at the quarry or $7 per cord in the village.

Literature:—Geol. Sur. Can., Rep. 1863, p. 127.
" " " " 1894, p. 59 A.
" " " " 1901, p. 13 J.
" " " " 1907, p. 31.

The Eganville Area.

Stone has been quarried from both sides of the Bonnechere river, near Eganville. The more important quarries are on the south side in strata of Chazy age; those on the north appear to be of later age and probably represent transition beds to the Black River formation. From these latter beds better building stone is obtained than from the quarries on the south side, which are now operated for lime making only.

J. A. Jamieson, Renfrew.

The quarries are situated about a half mile east of Eganville on the south shore of the river. The beds dip at a low angle to the north and west. The whole section is not exhibited at any one point but is exposed in three shallow openings along a distance of 200 yards. In descending order the beds revealed are as follows:—

10 inches—Limestone.
3 inches—Limestone.
3 feet—Limestone, in places solid, in others breaks into layers.
3 inches—Limestone.
8 inches—Limestone.
1 foot—Limestone.
Unexposed interval.

1 foot—Hard, brownish black or dark grey limestone showing fine white calcite lines and calcareous fossils; becomes darker and bluer on exposure. Hard to chisel.

1 foot—Like above.
3 feet—Like above.
8 feet—Thin bedded bluish limestone, useless for building.
14 inches—Solid limestone bed of much lighter colour.
3 inches—Similar to above.
10 inches—Similar, but a little darker and very brittle.
4 feet—Thin bedded, useless, fine grained and splintery.

16 to 20 inches—Solid bed of the dark variety like the one foot bed above.

Mr. Jamieson converts all his product into lime, but there is a large amount of good heavy stone for structural purposes available. The material is, however, too hard and splintery for chiselled work.

Rev. P. H. Dowdall, Eganville.

Father Dowdall owns a quarry on the north side of the river near the village, where stone has also been obtained at several places along the bank. The following description refers to all these quarries in a general way.

The beds here are doubtless at a much higher horizon than in the Jamieson quarries as the formation dips in this direction. The stone is quite different, being of a more granular and less splintery character. In one of the most important of the openings the following sequence is shown:—

4 to 5 feet—Thin shaly.
14 inches—Greyish blue limestone.
6 inches—Thin bedded shale and limestone.
6 inches—Irregular limestone bed.
20 inches—Solid uniform limestone.
6-8 inches—Fossiliferous shaly parting.
3 feet—Limestone beds of variable thickness, grey and granular. This stone is interstratified with a fine grained, brittle variety; by itself it should make an excellent stone for dressing, but the blocks would have to be carefully selected to avoid admixture with the brittle material.

Material from these quarries has been used in the bridge at Eganville and in the erection of the church, where the effect of the atmosphere on this stone may be well observed. The grey granular stone from the quarries north of the river has been most generally used, but only for rock face work. It seems to turn blue on exposure and after a lapse of a greater period of time assumes a whitish colour. The eastern aspect of the building is still blue, but the northern face, exposed to greater vicissitudes of weather, has already become quite white.

Although this grey granular type of stone is of a rather superior quality, the difficulties of obtaining it in quantity free from flaws, and the necessity of removing a heavy overburden, render the possibilities of large quarry operations remote. In all these quarries, however, a large amount of rough stone for heavy construction is available.[1]

The Pembroke Area.

As may be seen by a glance at the map, there is a small area of Chazy limestone near Pembroke. Several quarries have been worked in this lime-

[1] The assemblage of fossils in the beds north of the river indicate Trenton rather than Chazy time.

stone to the south of the town. The property of Mr. Peter White has been selected for description, and must be considered typical of the area.

Peter White, Pembroke, owner; Barr and Markus, Pembroke, operators.

The quarry is situated about a mile south of the town of Pembroke. The excavation is 300 feet by 300 feet, and has been worked to a depth of 12 feet. The following sequence of beds in descending order is exposed:—

2 feet—Overburden.
3 feet—Thin bedded, 2 to 4 inch material.
4 inches—Limestone.
7 inches—Limestone—a good bed—170.
8 inches—Limestone—a good coursing bed.
7 inches—Limestone.
8 inches—Limestone.
9 inches—Limestone—a good coursing bed.
4 inches—Limestone.
3 inches—Limestone.
18 to 20 inches—Heavy coursing stone, dimension stone, bridge stone.

The stone: No. 170.—The colour of this stone, which may be considered typical of the quarry, is shown in Plate LXXVII, No. 9; it is of a distinctly greenish cast and rather more variable than shown in the plate. On weathering, or on treatment with carbonic acid, the stone assumes a mottled aspect, in part like Plate LXXVI, No. 11, and in part almost white. In structure the stone is exceedingly fine grained and shows distinctly its composition of substances of different chemical nature.

The physical properties are as follows:—

Specific gravity	2·776
Weight per cubic foot, lbs.	171·628
Pore space, per cent	0·936
Ratio of absorption, per cent	0·340
Permeability—not determined	
Coefficient of saturation—not determined	
Crushing strength, lbs. per square inch	22706·
Crushing strength after freezing, lbs. per square inch	24500·
Loss on freezing, per cent	0·028
Loss on treatment with carbonic acid, grams per square inch	0·112
Transverse strength, lbs. per square inch	2441·
Chiselling factor	5·2

This stone is compact, fine grained and easily chiselled; it has a strong tendency to split along the stratification and to chip out under the chisel. The colour and weathering qualities are not of high character, although the strength appears to increase under the freezing test.

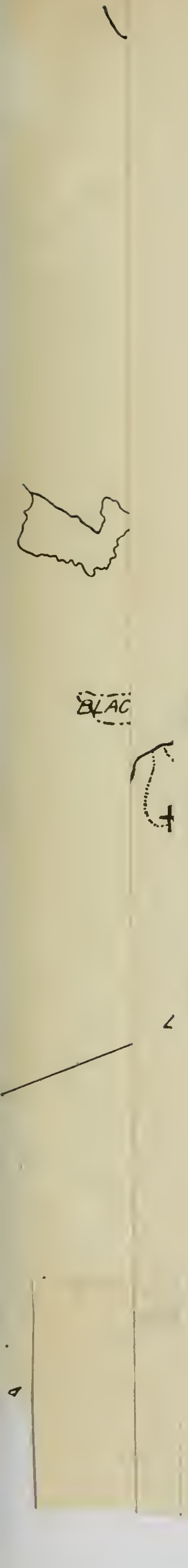

Fig. 15. Sketch map of Eastern Ontario showing the areas of Black River and Trenton limestone and the location of the chief quarries east of the Archæan axis.

The following analysis indicates the chemical character of the stone:—[1]

Carbonate of lime	83·96
Carbonate of magnesia	9·29
Carbonate of iron	0·69
Insoluble	6·06

The stone from all the beds is very much alike; it all turns blue after a short exposure to the weather and then gradually assumes a white colour. It is all fine grained and compact but shows horizontal banding which becomes more pronounced on weathering. It is not too hard for chiselling and is an excellent stone for rock face work and for purposes of heavy construction. The stone may be seen in many buildings in Pembroke, *e.g.*, James Oxford's residence, Munroe Block (base), General Hospital, Convent, churches.

Four to six men are now employed in the quarries. Black powder is used to break down the face and plug and feathers to prepare the stone for shipment. The stone is sold at from $11 to $12 per toise, delivered in Pembroke. The material from the bottom heavy bed is valued at $1.25 per cubic yard, f.o.b. Pembroke. Crushed stone is sold in Pembroke at $2.30 per cubic yard.

Summary—The Chazy Formation.

The general distribution of the rocks of this age has already been indicated and need not be repeated. For general purposes, however, it may be considered that four rather distinct types of stone are produced from as many different centres.

First. A hard, heavy and very dark coloured stone in thick beds from Sheek island. This stone weathers lighter, is very hard to chisel and is adapted to rock face work, and purposes of heavy construction. (No. 136, page 188).

Second. A lighter coloured grey stone resembling Trenton rock, quarried at Almonte.

Third. A fine encrinal limestone of light blue-grey colour occurring in heavy beds in East Hawkesbury. This is a high grade stone, easy to chisel, of excellent appearance, and suitable to either heavy construction or architectural work. (No. 109, page 190).

Fourth. Very fine grained, dark coloured stone from Pembroke. This variety is soft, but it has a muddy aspect on weathering. It has been used for building and for bridge work. (No. 170, page 196).

THE LIMESTONES OF THE BLACK RIVER FORMATION.

Overlying the Chazy limestones and shales are a series of beds which represent later stages in the deposition of the same marine invasion responsible for the Chazy formation. Authors differ somewhat as to the proper position of certain of these beds in a systematic classification, but usually three members are recognized—(1) the Lowville or Birdseye; (2) the

[1] Geol. Sur. Can., Rep. 1876–77, p. 486.

Black River; and (3) the Trenton. These formations may be collectively called the Trenton group, although certain authors use the term Trentonian to include not only these but still later rocks known as the Utica and the Lorraine (Hudson River). With regard to the lowest member, the Lowville, it is questionable if it should not be included in the Chazy; for the purposes of the present report it may be disregarded. The Black River formation consists of dark and heavily bedded limestones usually of quite limited thickness and geographical extent, and of lighter coloured compact stones of lithographic character.[1] This latter variety apparently fades up into the basal Trenton, so that, in many cases, it is quite impossible to ascribe a quarry to either formation with certainty. Typical Trenton rock is lighter in colour and more thinly bedded than the heavy type of Black River stone, but, as stated above, it may contain some of the light lithographic stone. In this report the word "Trenton" is occasionally applied, not only to the Trenton proper, but to the whole group of formations in a collective sense.

The quarries of the Black River formation may be conveniently grouped under the following geographical areas:—

1. The Stormont-Glengarry.—This area forms a circular belt, interrupted on its northern side, from 2 to 5 miles wide, lying within the ring of Chazy rock in the counties of Stormont and Glengarry. Quarry centres are Embrun' Cambridge, Dunbar, Mille Roches, and Glen Robertson.

2. The Ottawa River.—This area consists of a series of interrupted strips stretching from Ottawa to the eastern border of the province. The exposures occur along the Ottawa valley a few miles inland from the river. The chief quarries are near Ottawa but several others of importance occur at various places farther east.

3. The Carleton.—This area lies in the western part of the county of Carleton; it is about 25 miles long by 8 miles wide. The centre of this area is occupied, however, by Trenton rocks. There are no important quarries.

4. The Dirleton.—This area is a small patch near Dirleton Place, near the Ottawa river in the northwest part of Carleton.

5. The McNab.—A small area in the western corner of Renfrew, in the township of McNab.

6. The Renfrew.—This area may be made to include several isolated outcrops in the centre of the county of Renfrew; there are no very important quarries.

7. The Western.—This area, which is probably in part to be ascribed to the Lowville, forms the shore of Lake Ontario from the Archæan border to Bath. Thence it extends north in a narrow belt to Georgian bay. Important quarries have been opened at many places on this belt.

The Stormont-Glengarry Area.

The distribution of the rocks of this area has already been mentioned. The quarrying industry centres around (1) Embrun and Cambridge in Russell, (2) Dunbar in Dundas, (3) Mille Roches in Stormont, and (4) Glen Robertson in Glengarry.

[1] Some of the light coloured lithographic stones included with the Black River may be either of Trenton or Lowville age.

The Embrun–Cambridge section.—Several quarries have been opened near Embrun on the same kind of stone. The more important are those of Laplante, Bruyère, and Carrière; the first of these will serve as an example.

Louis Ménard, Embrun, owner; A. Laplante, Embrun, operator.

The quarry is close to the village on the south side and has been opened up to a length of 150 feet, and a width of 100 feet. The excavation is not more than 5 feet deep, but, owing to a dip of 10° in a northeasterly direction, the following section is exposed:—

2 feet—Soil.

2 feet 10 inches—Limestone beds 6 to 8 inches thick. In places these beds are sufficiently "tight" to yield stone of almost the entire thickness of the layer.

1 foot 8 inches—Solid limestone bed.

1 foot—Solid limestone bed.

1 foot—Several thin beds.

14 inches—Solid bed.

All the bedding planes are irregular, so that the product requires dressing for use as coursing stone. Joints cross the formation at intervals of from 4 to 8 feet, in a direction 10° N. of W. All the beds are much alike in the quality of the stone—77.

The stone: No. 77.—The colour is a dark blue-grey resembling that shown in Plate LXXV, No. 6. On weathering it becomes much lighter, like nearly all these dark stones. The structure is fine grained and even, with only occasional crystals of a larger size.

The physical properties follow:—

Specific gravity	2·714
Weight per cubic foot, lbs.	168·363
Pore space, per cent	0·6
Ratio of absorption, per cent	0·222
Crushing strength, lbs. per square inch	17975·
Crushing strength after freezing, lbs. per square inch	15480·
Chiselling factor, (this factor is too high owing to lateral chipping.)	7·45

There is no plant on the property and no regular production. A very fine church in Embrun exhibits the character of the stone.

Fallon Bros., Cornwall.

The quarry belonging to this firm is near Cambridge and close to the line of the Ottawa and Cornwall railway. The excavation is 300 feet by 100 feet, and has been opened to a depth of 15 feet. There is very little overburden and practically no waste in the form of thin bedded useless material. The beds show the following thickness in descending order: 14 inch, 6 inch, 18 inch, 20 inch, 8 inch, 8 inch, 2 feet, 3 feet or more. Two series of joints, N.E. and N.W., cut the formation almost at right angles and greatly facilitate the extraction of large blocks. The bedding planes are irregular so that the stone requires "bedding" for use as coursing material. This wavy bedding is also seen throughout the layer and shows itself more plainly on weathering. This is one of the chief faults of the Black River stone. The product has a somewhat splintery fracture and is inclined to "chip out" on dressing. The specimens described below are typical of all the beds; they were obtained from the thick lower layer—78, 80.

The stone: No. 78.—The colour is similar to that of Plate LXXV, No. 14. Except for this brownish tint the stone is very similar in all respects to that described above from Menard's quarry. (No. 77.)

No. 80.—A very dark heavy stone like the above; it is comparatively fine in grain and somewhat irregular in fracture. Cavities full of white calcite are sparingly present throughout the rock.

This is essentially a heavy stone quarry, the product being suitable for the construction of bridges, etc., rather than for architectural purposes. Examples may be seen in the copings of the canal from the bridge in Cornwall to the coal sheds, in Lindsay's store, Ottawa, and in monument bases throughout the district. The quarry is out of commission, but it is stated that stone can be loaded on the cars for from $2.50 to $3 per cord.

The Dunbar section.—Several quarries in the Black River limestone centre about Dunbar in Dundas county. The product of these quarries is used locally and in the villages within a radius of 10 or 15 miles. The stone is dark blue in colour but weathers whiter. Being more easily dressed it is employed for trimmings in buildings of which the walls are constructed of Beekmantown or Chazy stone.

The Mille Roches section.—North of the village of Mille Roches lie a number of abandoned quarries from which immense quantities of stone were obtained in the palmy days of canal construction. The following list indicates the location and the present owners of the more important properties: Miss Maud Copeland, W. half lots 26 and 27, con. II, Cornwall; John Manson. E. half lot 25, con. II, Cornwall; E. Thompson, N.E. quarter lot 25; Philip Thompson, lot 22; and John Henderson, lot 21, in the same concession.

A number of these quarries were visited, but as they are all filled with water no very definite information could be obtained. The openings are all in low land and there is a heavy overburden so that a reopening on a large scale would involve considerable expense. The beds are very heavy and are capable of producing stone of any dimension required. In what is known as the Davis quarry on Wellington Manson's property, the top bed is 3 feet thick. Beneath this is a solid bed from 8 to 9 feet thick, and a third layer of 6 feet at the bottom. The quality of the stone is much the same throughout all the beds of the different quarries.

The stone: No. 135.—This specimen from the Davis (Manson) quarry is typical of the stone from all these old quarries. The colour is very dark and rivals that of the Chazy stone from Sheek island; it is shown in Plate LXXV, No. 3. On treatment with carbonic acid the effect produced is very similar to that of the Kingston stone shown in Plate LXXVII, fig. 15; but very fine lines of the original colour may be seen in places. The grain of the stone is fine and numerous small fossils are scattered through the rock.

The physical properties are as follows:—

Specific gravity	2·716
Weight per cubic foot, lbs	169·335
Pore space, per cent	0·099
Ratio of absorption, per cent	0·037
Coefficient of saturation	0·53
Crushing strength, lbs. per square inch	22356·
Crushing strength after freezing, lbs. per square inch	14548·
(This result seems abnormally low; it was not verified by a duplicate).	
Loss on freezing, per cent	0·0204
Loss on treatment with carbonic acid, grams per square inch	0·163
Transverse strength, lbs. per square inch	3069·
Chiselling factor	3·15

With this stone, and with the similar stone from Kingston, it was peculiarly difficult to obtain constant results. In making the crushing tests it was found impossible to make the first crack and the final collapse appear at the same time. The same feature was observed in the chiselling test; several much higher results than the one given were obtained as well as a few lower ones. It would seem that the stone is not of homogeneous composition. Stone from these quarries has been largely used in canal construction; it can be obtained in blocks of any desired size and can be dressed with reasonable facility. Exposed to the weather it turns much lighter in colour and gradually exhibits wavy disintegration along the planes of bedding. This unfortunate feature, so common to these heavy bedded stones, is much more perceptible in some blocks than in others. At present there is no regular production, but a little stone for local use is occasionally obtained. In Mille Roches, rock face, squared coursing or dimension stone is valued at $1.50 per cubic foot.

Glen Robertson section.—In the immediate vicinity of Glen Robertson are three quarries as below:—

Mrs. Browning, lot 3, con. II, Lochiel; Mrs. A. C. McDonald, lot 6, con. II, Lochiel; Mrs. A. McDonald, lot 7, con. II, Lochiel.

About 8 miles northwest from the village a small quarry has been opened on the property of Mrs. I. McPhie, lot 28, con. V, Lochiel. Several other small openings have been made on the Black River belt in this vicinity.

Mrs. A. C. McDonald, Glen Robertson, Lot 6, Con. II, Lochiel, Glengarry county.

The quarry extends to the neighbouring lot and has been worked on both properties by the same operators. Rock is exposed over a wide area with little more than 3 feet of stripping. There are two beds worked, each of about 3 feet in thickness. Joints cut the rock 20° E. of S. and 20° S. of E., but these partings are sufficiently far apart to permit the extraction of large stone.

The material splits easily along the planes of stratification, but the parting is wavy and irregular and shows bituminous matter on the dividing surfaces. On weathering, the rock becomes a lighter colour and the wavy stratification lines become pronounced.

A spur connected this property with the G.T.R. at one time but there has been no production for 10 years—106.

The stone: No. 106.—This stone is very dark grey in colour and exactly resembles the material from the quarries north of Mille Roches which is represented in Plate LXXV, No. 2. In other respects also it is like the Mille Roches stone but it has considerably more veinlets of white calcite and lenticular blebs of the same material scattered throughout. The physical properties are doubtless much the same. (See No. 135, page 201).

Mrs. Browning, Glen Robertson.

The quarry is south of the village and close to the railway; it has been opened to a depth of 6 feet over a space of 250 feet by 100 feet. The overburden is slight or absent. The beds are not continuous or well defined but in some parts of the quarry an upper bed 2 feet 5 inches thick is underlaid by another of 3 or 4 feet in thickness. This latter bed is, however, shaly and thin bedded at the top, whereby it loses 10 inches in thickness. The tendency to split along the bedding planes is pronounced throughout the quarry; while this feature facilitates the obtaining of stone of reasonable thickness for ordinary building, it detracts from the wearing power of heavier material for bridge building, etc.

The major joints strike 10° N. of E. but other irregular partings are present.

The stone is similar to that from the McDonald property, and, like it, shows the wavy bituminous parting planes. There has been no production for many years. The Coteau bridge is the only important structure built from this quarry.

Mrs. McPhie, Lochiel, Lot 27, Con. V, Lochiel, Glengarry county.

This is a small quarry of about 50 feet by 20 feet. There is a heavy overburden of from 6 to 8 feet, of soil. The hole is full of water but it was probably 5 feet deep. The thickest stone seen is 14 inches. The stone shows much less of the wavy bituminous parting than the other quarries in the district, but it presents a banded appearance owing to the alternate arrangement of fossiliferous and non-fossiliferous layers. The formation dips 10° to the south and is irregularly jointed at 60° E. of N. and 10° S. of E. (107). This stone resembles certain phases of both Trenton and Chazy rocks rather than the typical Black River of this area.

The stone: No. 107.—This material differs from any other Black River stone examined and approaches very closely the structure and appearance of the Chazy material from Ross' quarry, at Hawkesbury. As the boundaries of the formations have not been very definitely determined, the stone may well belong to the Chazy series or to the transition beds between the two.

The colour is slightly bluer than that of the Hawkesbury stone and is shown in Plate LXXV, No. 6. (Compare Plate LXXVII, No. 10). On weathering, or on treatment with carbonic acid, the stone turns somewhat yellowish and presents a mottled aspect, the general effect of which resembles Plate LXXVII, No. 8.

The rock is made up of broken fragments of small calcareous fossils and is essentially an encrinal limestone. On weathering, the fossil nature of the rock is very perceptible.

The physical characters are as follows:—

Specific gravity	2·726
Weight per cubic foot, lbs	168·633
Pore space, per cent	0·88
Ratio of absorption, per cent	0·328
Coefficient of saturation	0·85
Crushing strength, lbs. per square inch	19532·
Crushing strength after freezing, lbs. per square inch	17651·
Loss of weight on freezing, per cent	0·067
Loss on treatment with carbonic acid, grams per square inch	0·102
Transverse strength, lbs. per square inch	2290·
Chiselling factor (although this figure is the result of several determinations which agree fairly well, it seems much too low, judging from the appearance of the stone)	1·3

This stone was used in the Roman Catholic church, at Alexandria, and some was quarried for the Reformatory in the same place. This material was never used and is now lying in the quarry; it shows that chisel marks, etc., have been perfectly preserved since 1896, but that the light bluish grey colour has altered to a rather dirty grey tint.

Summary—The Stormont-Glengarry Area.

The typical stone throughout this area is a very dark, heavily bedded limestone with wavy partings marked by bituminous matter. On weathering, these wavy lines become more pronounced. The stone is better adapted to works of a heavy nature than to ordinary building as it is rather hard to chisel and requires "bedding" for use as sills, etc. The physical characteristics may be inferred from the account of No. 135, p. 201, and No. 77, p. 199. A somewhat different type from Lochiel is described in detail as No. 107, p. 203. The more important quarries are at Mille Roches, Glen Robertson, Cambridge, and Embrun.

Literature:—Geol. Sur. Can., Rep. 1863, p. 172, p. 816.
" " " " 1896, p. 63 A.
" " " " 1899, p. 136 A.
Bur. Mines, Ont., Rep. 1904, Pt. ii, p. 46: p. 110.

The Ottawa River Area.

The narrow belts of Black River rock which are exposed at many points along the Ottawa valley from Ottawa to the eastern border of the province have been exploited for building stone, more particularly in the vicinity of Ottawa, near Rockland, at L'Orignal, and farther east.

The most easterly quarry of any importance is in the township of East Hawkesbury on the River à la Graisse. This quarry was not visited but it is thus described by Ells: "Another Black River quarry is seen on the River à la Graisse in the southeastern portion of Hawkesbury East, where they (the beds) have a dip to the southwest at an angle of about ten degrees." [1]

F. Beauchamp, Clarence Creek.

The quarry is situated close to the village and has been exploited largely for local construction.

The opening is not extensive but it shows the following sequence:—

8-10 inches—Thin material.
10 inches—Limestone bed.
3 feet—Thin bedded stone.
8 inches—Limestone bed.
1 foot—Thin material.
8 inches—Limestone bed.
16 inches—Solid bed.
12 inches—Solid bed—178.

These two lower beds are the most prized. The stone is lighter in colour and more granular than most Black River samples and is also freer from bituminous partings. The value of the quarry is reduced by the presence of the heavy overburden of thin, useless material.

The stone: No. 178.—The colour is similar to Plate LXXV, No. 6, but the stone shows spots and bands of a darker colour. The bulk of the rock is made up of fairly coarse calcite crystals in which are imbedded a few fossils. In

[1] Geol. Sur. Can., Rep. 1899, p. 135A.

places the fossils are more numerous and give the rocks a banded appearance. This is a good solid and easily worked stone and is very well suited for rubble and coursing stone. The church, the priest's residence, and many stores and foundations in Clarence Creek are constructed of this stone. After 15 years exposure the stone assumes a pleasing light brownish grey colour. There is no regular production. Stone is valued at $4 per cord in the village.

Alexander Stewart, Ottawa.

The quarry is situated southwest of Rockland, in the township of Clarence, it has been opened along the face of a bold bluff facing the Ottawa river. The lower beds are of Black River age but the upper portion belongs to the Trenton. The whole side of the escarpment has been quarried for a distance of 300 feet, and the workings have been carried 100 feet into the hill. Both heavy stone for the construction of bridges, and thinner material adapted to architectural work, are easily obtained. An approximate section shows, in descending order, beds of the following thickness:—2 feet, 3 feet, 1 foot, 18 inches, 1 foot, 2 feet, 18 inches, 10 inches, 10 inches, 16 inches, 3 feet, 2 feet, 1 foot, 1 foot, 18 inches, 3 feet, 2 feet, 1 foot, 1 foot, 18 inches, 14 inches, 3 feet, 1 foot, 1 foot, 1 foot, 10 inches, 18 inches, and some lower beds now invisible. These beds are separated at times by shaly partings of several inches in thickness. All the layers are not equally good; some are harder and whiter, some are filled with cavities or with crystals of calcite, and some have the bedding planes so pronounced that they are liable to split into thinner material. The lower beds and some of the upper bands as well have the wavy bituminous partings well developed. Most of the stone is of a dense, non-crystalline type, but some granular crystalline bands are developed which resemble closely the stone from Clarence Creek. The chief variation in the stone consists in the degree to which shaly parting is developed. The specimen described below (186) is a fair average; some are more shaly and others more compact.

The stone: No. 186.—The colour is similar to that of Plate LXXV, No. 3, being a dark grey, but little lighter than the stone from Mille Roches; it weathers much lighter on exposure. The grain is very fine but occasional crystals of calcite appear. It can be worked with reasonable facility, but like the other fine grained stones of this formation, it possesses a conchoidal fracture which creates a tendency to chip out under the chisel. The physical properties are, in all probability, similar to those of No. 135, described on page 201. The specimen, which is 8 inches thick, is bounded by a bituminous parting on both sides and another occurs 2 inches from one side.

A siding connects the quarry with the Grand Trunk railway. Four somewhat dismantled derricks are in position and a quantity of quarrying apparatus is on the ground. Operations have been suspended.

Government quarry, Lot 22, Junction Gore, Gloucester, Carleton county.

A quarry from which was obtained a quantity of heavy stone for canal construction occurs on both sides of the road, east of the locks at the Hogsback on the Rideau river. The beds dip 10° to the southeast and present the following layers:—16 inches, 3 feet (divisible into two beds in part), 1 foot (increasing to 3 feet, north of the road), 16 inches, 1 foot. The beds are not regular, but the above figures serve to indicate the size of the stone obtainable. Main joints cross the formation at 20° E. of S. The stone is dark in colour and has the usual bituminous partings. It is not certain that the formation belongs to the Black River. Dr. Ells' map indicates it as Trenton, but the aspect of the stone is decidedly similar to the typical Black River material. There is no present production.

P. J. Ryan has an old quarry north of this in similar stone.

Richard Clark, owner; Foster and Irwin, operators, Ottawa.

The quarry is situated on the Merivale road about a mile north of City View, probably on lot 33 of Ottawa front, Nepean township. The stone is thin bedded and shows the following succession in descending order:—10, 6, 14, 15, 18, 24, 8, 2, 15, 3, 36, (thin bedded) 12, 12, 10 inches. The product is crushed for road metal and none is now used for building purposes —220.

The stone: No. 220—This is a rather hard and exceedingly fine grained stone, resembling Plate LXXV, No. 3. There is a tendency to split irregularly and to present sharp points and angles on the broken surface. The stone is very similar to that from Stewart's quarry, at Rockland.

Summary—The Ottawa River Area.

There are few important quarries in this area and none now being worked for building stone. The stone is mostly of dark colour and semi-crystalline character; it is more suited to heavy construction than to architectural work. There are a few quarries east of Ottawa and north of the Montreal road. Farther east, at Rockland, is a large quarry now abandoned and a smaller one at Clarence Creek.

Literature:—Geol. Sur. Can., Rep. 1899, pp. 26–28G.; pp. 85–87J.

The Dirleton Area.

This area is about four miles long by a mile wide and occurs in the township of Torbolton in the northwestern part of Carleton. Some important quarries were formerly operated here near the shore of Buckham bay on the Ottawa river. The district was not visited. Concerning these quarries Dr. Ells says: "Large quarries are located at several points, notably on Black River outcrops south of the entrance of Buckham bay, on the Ottawa river in the township of Torbolton."[1]

[1] Geol. Sur. Can., Rep. R. W. Ells, p. 44, Publication No. 977, 1907.

The McNab Area.

Ells states: "These rocks (Black River) form the crest of a ridge extending south for over a mile from the river, and on the south flank, which drops somewhat abruptly to the clay flat inland, are several quarries from which also fossils peculiar to the formation have been obtained." [1]

It is probable also that the Sand Point quarries should be included here, although they may be in part of Chazy age.

John Brennan, Arnprior, near Sand Point, township of McNab, Renfrew county.

Mr. Brennan owns two quarries near Sand Point; the first is situated behind the station and the other a quarter of a mile to the east. The first quarry has been opened for 250 feet along the face of a bluff 20 feet high; it presents the following succession:—

20 feet—Overburden.
6 inches—Solid bed,
16 inches—Fairly solid but with one parting in places.
3 inches—Shale.
20 inches—Solid bed.
4 inches—Shale.
8 inches—Solid bed.
10 inches—Solid bed.
3 feet 8 inches—Beds 6 to 8 inches thick.
14 inches—Solid bed.
2 feet 10 inches—Beds 6 to 8 inches thick.
1 foot 8 inches—Fairly solid but with planes of separation in part.
3 feet—Beds 6 to 8 inches thick.

The formation is well jointed at right angles, 40° S. of W. and 35° W. of N. The latter series of joints forms the face of the quarry. The beds dip slightly into the hill, *i.e.* southeast. In the eastern quarry the stone is similar to that of the western quarry described above. The excavation is about 100 feet long and shows the same jointing as the western quarry. The succession of beds is as follows:—

15 feet—Overburden.
4 feet 6 inches—Thin bedded, hard, whitish, maximum 8 inches—244.
15 inches—Solid stone, greyish when fresh but weathers easily and assumes a dirty brown colour—245.
10 inches—Solid bed.
9 inches—Broken and thin.
15 inches—Solid bed—246.
6 inches—Fossiliferous aud cherty, dark in colour—247.
1 foot—Solid bed, like 246.
15 inches—Solid bed, like 246.
11 inches—Blue stone, like 247.
2 feet 8 inches—Beds of varying thickness, like 246.

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[1] Geol. Sur. Can., Pub. 977, 1907 p. 23.

There are in these quarries four types of stone, the hard white upper beds, the softer grey material, the hard blue, and the average whitish stone, the latter being the most desirable material. All the beds are easily worked, the product being cut to desired size by lining with the chisel and striking with the sledge. Plug and feathers are not required to break the stone.

The stone: No. 246.—As this example was selected for detailed examination, it is first described; the other types will be compared with this as a standard.

The colour of the fresh stone is dark brownish grey and it is represented in Plate LXXV, No. 11. On weathering, or on treatment with carbonic acid, the stone assumes the colour shown in Plate LXXVII, No. 10. The grain is exceedingly fine and a distinct lamination in different shades of brown is apparent.

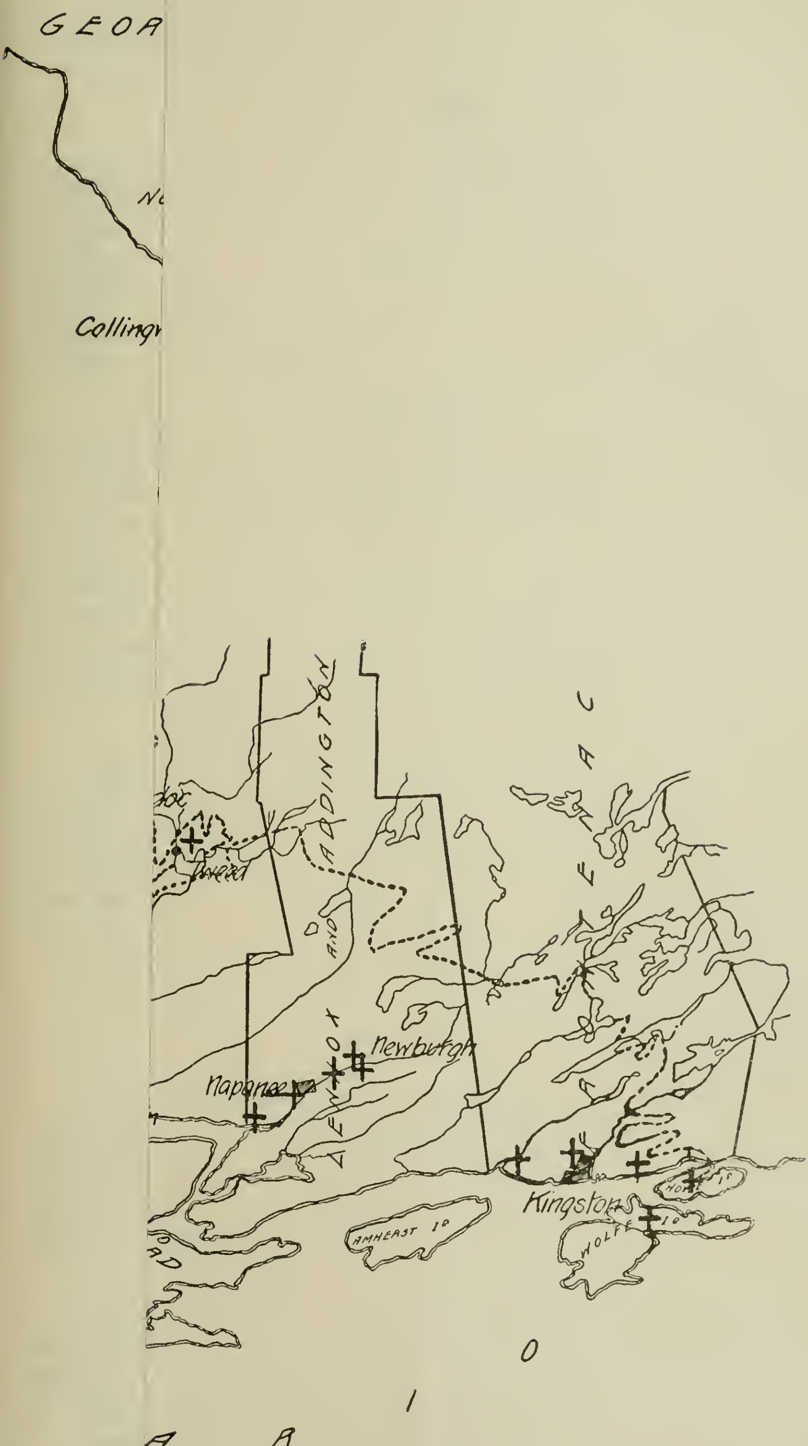
The physical characteristics are as follows:—

Specific gravity	2·79
Weight per cubic foot, lbs	171·216
Pore space, per cent	1·67
Ratio of absorption, per cent	0·608
Coefficient of saturation	0·507
Crushing strength, lbs. per square inch	29495·
Crushing strength after freezing, lbs. per square inch	23525·
Loss on freezing, per cent	0·0085
Loss on treatment with carbonic acid, grams per square inch	0·08
Transverse strength	3923·
Chiselling factor	6·3

No. 247.—This stone presents a much lighter grey than No. 246, and closely resembles Plate LXXV, No. 6; it is very fine in grain, approaching the lithographic type, but it contains a great number of scattered crystals of calcite.

No. 245.—When fresh this stone has a grey colour with a slight cast of brown as in Plate LXXV, No. 7; it rapidly alters to a dirty yellow tint like Plate LXXVI, No. 10, but even more yellowish. The structure is fine-crystalline, and the hardness is low. The stone could be easily cut, but, owing to its poor weathering qualities it is probably the poorest type in the quarry.

No. 244.—This example is light blue-grey in colour and resembles Plate LXXV, No. 8. It is exceedingly fine grained and with less scattered calcite crystals than No. 247. These two stones belong to the same general type and differ only in colour and in the number of scattered calcite crystals.



est of the Archæan axis.

Fig. 10. Sketch map showing the boundaries and important quarries of the Lowville, Black River, and Trenton rocks in the region west of the Archæan axis.

Miller gives the following analysis of stone from these quarries;[1] the beds are not specified:—

	Western quarry	Eastern quarry
Insoluble matter	4·14	4·20
Ferric oxide	·82	·72
Alumina	2·04	1·4
Lime	46·24	46·02
Magnesia	4·45	4·37
Carbon dioxide	41·00	40·60
Loss	·22	·82
Sulphur trioxide	·66	·36
Alkalies	·25	....

Buildings constructed of Sand Point stone show that in three years time the different types assume nearly the same external appearance owing to a bleaching whereby the differences of colour are lessened. The hard white upper beds wear the best and the grey bed (245) the worst. The brown stone (246) is medium in this respect and alters but little. After fifty years exposure, however, this latter stone is considerably altered, showing brown blotches and presenting a friable exterior. Chiselled work seems to have worn much better than the rock face blocks and presents sharp angles with the marks of the tool still apparent.

Summary.—The McNab Area.

The important quarries are situated at Sand Point and to the southward of that place on the opposite side of the ridge. The stone resembles the Black River product from the vicinity of Kingston. It occurs in good workable beds and may be shipped without difficulty as the quarries are close to the line of the C.P.R. For a detailed description of the typical stone, see No. 246, p. 208.

Literature:—Geol. Sur. Can., Pub. 977, 1907, p. 33.
Bur. Mines, Ont., Rep. 1904, pt. ii, p. 105.

The Renfrew Area.

The Palæozoic outlier in Renfrew contains several Black River patches on which some important quarries are situated. The most important of these is near Douglas station, and is referred to by Ells as being situated on the hill south of Douglas village in lot 1, concession VIII of Bromley township.[2]

The Western Area.

The Kingston district.—In the vicinity of Kingston, limestone has been quarried for many years and has been so largely used that Kingston is known as the "Limestone City."

[1] Bur. Mines, Ont., Rep. 1904, Pt. ii, p. 105.
[2] Geol. Sur. Can., Rep. R. W. Ells, Publication No. 977, 1907, p. 35.

The belt of limestone on which quarries have from time to time been worked extends across the city in a northwest direction and continues for 5 or 6 miles. At the present time only one quarry is in actual operation for the production of building stone although others are worked for road metal, etc. The producing quarry is described below and must be considered typical of the Kingston area.

Robert Wallace, Patrick St., Kingston.

The quarry is situated on the margin of the bluff which has been opened in an almost continuous line of quarries. The present workings are about 400 feet long and have been carried back 200 feet into the hill. I am informed that 500 to 600 feet in the various layers become so "tight" that they cannot profitably be worked. The succession of beds is as follows:—

6-7 feet—Overburden.
13 inches—Good stone for general work but too hard to chisel.
6 inches—Shelly.
13 inches—Good stone.
7 inches—Good sill bed.
4 inches—Shale.
4 inches—Shelly stone, rubble.
12 inches—Good stone for general purposes but is seamy.
6 inches—Shelly, rubble.
14 inches—Good stone—63.
6 inches—Good stone.
8 inches—Good stone.
4 inches—Good stone.
4 inches—Good stone.
7 inches—Good stone. Coursing bed.
6 inches—Good stone.
5 inches—Good stone.
4 inches—Good stone.
15 inches—Good stone.
6 inches—Good stone.
7 inches—Good stone.
8 inches—Good stone.
6 inches—Good stone.
9 inches—Good stone—64.
7 inches—Good stone.
7 inches—Good stone.
4 inches—Good stone.
12 inches—Good stone.

The jointing is irregular with a general east and west direction for the main partings. Large stone can be obtained with ease and many blocks 12 feet long by 3 feet wide have been taken out.

Although the stone is much alike throughout, the two beds from which specimens were selected as above are regarded by Mr. Wallace as representing the standard quality of his output.

The stone: No. 64.—In the first place it should be noted that this stone more closely resembles that from one of the beds at Brennan's quarry, Sand Point (No. 247, p. 208), than any other stone from the region east of the Archæan axis.

The colour is shown in Plate LXXV, No. 3, but the reproduction has made it a little too dark. After weathering the stone appears very much lighter, in fact almost white. The appearance of the specimen subjected to the action of carbonic acid in water is shown in Plate LXXVII, No. 15.

The greater part of the stone is exceedingly fine grained and of lithographic appearance. Scattered through this matrix are numerous crystals of calcite which give the stone the spotted appearance on weathering which is shown in Plate LXXVII, No. 15.

The physical properties are as follows:—

Specific gravity	2·725
Weight per cubic foot, lbs	169·766
Pore space, per cent	0·177
Ratio of absorption, per cent	0·0651
Coefficient of saturation	0·4
Crushing strength, lbs. per square inch	29506·
Crushing strength after freezing, lbs. per square inch	33420.
Loss on freezing, per cent	0·0224
Loss on treatment with carbonic acid, grams per square inch	0·291
Transverse strength, lbs. per square inch	2100·
Chiselling factor	5·5

Analysis: H. A. Leverin, Mines Branch laboratory:—

Insoluble matter	4·20
Ferrous oxide	·57
Ferric oxide and alumina	1·01
Calcium carbonate	87·46
Magnesium carbonate	7·00
Sulphur	·042

No. 63.—This stone is somewhat lighter in colour than No. 64, but it is otherwise very similar.

The removal of the stone is effected by sinking 2½ inch holes to a depth of about 6 feet along a line 10–15 feet back from the face. The holes are placed 8 feet apart; they are loaded with black powder and fired simultaneously. The thinner beds may be cut to size by lining with the chisel, etc. The thicker beds are cut by plug and feathers. Mr. Wallace has now one derrick in position and employs 15 men. All the product of the quarry is used for building purposes and is disposed of at the following rates:—

Building stone, hammer broken, $6 per toise delivered, $7.50 f.o.b. Kingston.

Sills, bush hammered top and bottom, 75 cents per running foot, Kingston.

Coursing stone, squared, rock face, 20 cents per square foot, Kingston.

Coursing stone, squared, bush hammered face, 50 cents per square foot, Kingston.

Stone from this or from some of the adjoining quarries has been so largely used in Kingston that it is almost unnecessary to mention any particular buildings. The following will, however, serve as examples: City Hall, Drill Hall, St. Andrew's church, post-office, and the College buildings. (See Plate XLV).

Many other quarries have been worked in the vicinity of Kingston, particularly along the Bath road and in the vicinity of Kingston Mills where a quarry on the road side shows a face of 20 feet with beds up to 1 foot thick. Much of this stone is fine grained, like the Marmora stone, but it is employed chiefly in the making of road metal (71). Quarries have also been worked on Howe island and at Collins Bay, (207), and generally throughout the district more particularly for road metal.

The stone: No. 71.—This stone presents a laminated brownish grey appearance; in all respects it closely resembles the stone from the lower bed of Brennan's quarry, at Sand Point, described as No. 246, p. 208.

No. 207.—This example closely resembles the Kingston stone but it has more scattered crystals of calcite.

An analysis by A. A. Johnston, of the Bath road stone and of the stone from Wolfe Island, is given below:—[1]

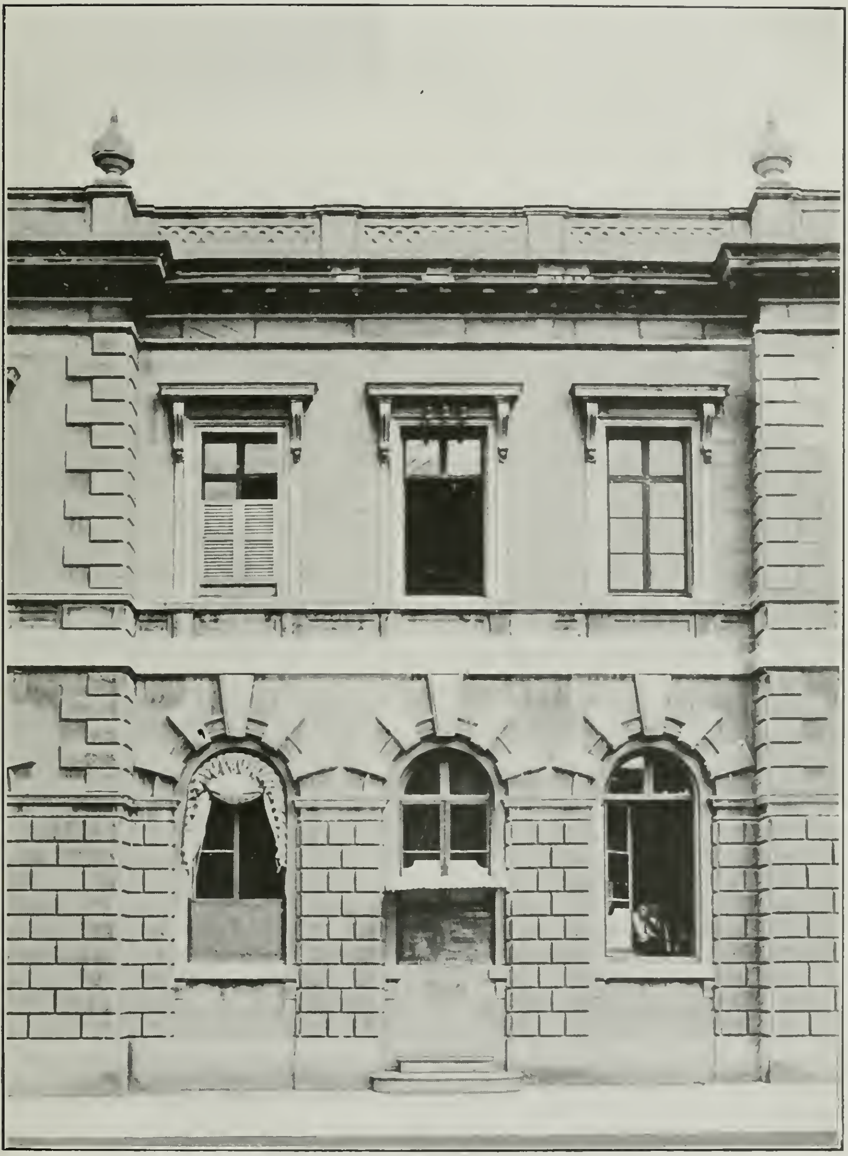
	Bath Road.	Wolfe Island.
Carbonate of lime	90·07	94·81
" " magnesia	2·52	2·33
" " iron	0·26	0·29
Alumina, soluble silica and insoluble matter	7·72	3·02
Organic matter	0·27	0·28

The Napanee district.—At Napanee are several quarries of which the following may be considered a typical example:—

P. J. Bergin, Napanee.

The quarry is close to the town and is opened along the face of a bluff for a distance of 400 feet, and a width of 150 feet. The face is about 16 feet high, and shows the following beds:—

[1] Geol. Sur. Can., Rep. 1888–89, pp. 25–26 R.



Kingston Limestone. Post-office, Kingston, Ont.

4 feet—Thin bedded, road metal.
8 inches—Limestone bed.
2 feet 6 inches—Thin bedded, three inch material.
18 inches—Still thinner beds.
7 inches—Coursing stone, considered the best bed—91.
3 inches—Limestone bed.
4 inches—Limestone bed.
4 inches—Limestone bed.
5 inches—Limestone bed.
6 inches—Limestone bed.
12 inches—Thin bedded.
7 inches—Limestone bed.
5 inches—Shelly bed.
5 inches—Limestone bed.

The main joints run 30° W. of N. they are variable in position but are usually from 4 to 5 feet apart. The other set of joints is not so well developed.

The stone: No. 91.—This stone presents the colour shown in Plate LXXV, No. 2. The bed is not homogeneous but consists of irregular layers of a type like the Kingston stone interbanded with a coarser and more crystalline variety. It is also marred by the presence of cavities lined with crystals of white calcite. On the whole, this stone is of a rather rough character; it would weather irregularly and would be somewhat hard to dress.

Miller gives an analysis from Rollin's hill, Napanee, which probably represents this stone:—[1]

Silica	1·44
Ferric oxide and alumina	1·68
Lime	53·82
Magnesia	0·98
Carbon dioxide	42·40

The stone is used for lime making, for road metal and for foundations. The coursing bed only is employed for walls.

Rough hammer broken stone is sold at from $1.25 to $1.50 per toise. The coursing stone is sold at four cents per running foot measured in the wall.

Eastward from Napanee along the road to Strathcona are several small quarries from which stone is obtained from time to time; the more important of these are as follows:—

R. J. Pybus, Napanee.

This quarry is about two miles east of Napanee on the west side of the river. The opening is 200 feet by 300 feet with a face of 50 feet. The upper 15 feet is thin and shelly and is succeeded by a 10 inch bed of blue stone, a 20 inch bed of white and a 2 foot bed of blue. The 20 inch white bed is most prized; it is soft and easily dressed and has been used for trimming many

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 28.

of the buildings in Napanee. The formation is almost free from joints so that the stone may be obtained in practically any size desired. These beds lie at a lower level than the other quarries along the Newburg road. Mr. Pybus quotes the following prices:—

Sills, bush hammered, $1.25 per running foot f.o.b. Napanee.
Heavy bases, bush hammered, $1.40 per running foot f.o.b. Napanee.
Dimension stone, $1.25 per cubic foot f.o.b. Napanee.

This stone may be observed in the Church of England, the Court House and in business blocks in Napanee. The white colour as well as the sharpness of angles is preserved for many years.

J. M. Wilson, Strathcona.

This quarry is situated on the Newburgh road in Camden. The opening is about 100 feet by 50 feet with a depth of 7 feet. The succession of beds is as follows:—

2 feet—Overburden.
4 inches—Solid bed.
18 inches—Solid bed.
1 foot—Somewhat seamy.
6 inches—Shaly.
6 inches—Best bed, used for sills—93
4 inches—Solid bed.
8 inches—Solid bed.
8 inches—Solid bed.

The jointing is a little west of north with the divisions 4 to 6 feet apart.

The stone: No. 93.—Except for the fact that it is slightly darker in colour, this stone may be considered as identical with that from Aylesworth's quarry described below as No. 93.

The stone from all the beds is very much alike and has been used extensively in Napanee, *e.g.*, in the Wales block. After a limited exposure the stone turns blue and then gradually assumes a white colour; this peculiarity is common to the product of all the quarries along the Newburgh road.

East of Wilson, quarries are operated by R. J. Shetlor, W. A. Ramsay (lot 11, con. I, Camden), J. Ramsay (lot 12, con. II, Camden), and L. Ballance.

The stone is quite similar to Wilson's but it occurs in heavier beds up to 16 inches thick. The product is used for houses and was formerly in demand for bridge building.

J. B. Aylesworth, Newburgh.

This quarry is about a mile north of Newburgh and has been worked to a limited depth only. The upper bed is from 12 to 15 inches thick and is underlaid by two beds of from 10 to 12 inches each—92.

The good stone in this as well as in other quarries in the district occurs at a low level, along the river or in the hollows; the hill tops are composed of thin shelly material.

The stone: No. 92.—This stone is a true grey of a rather light shade and is shown in Plate LXXV, No. 4. On weathering it becomes bluish at first but eventually assumes a very light colour. The specimen which had been treated with carbonic acid showed a base of even lighter colour than that in Plate LXXVII, No. 15. The dark spots shown in this figure are replaced by the most delicate wavy lines, which indicate a stone of even finer grain and with less scattered crystals than the Kingston type to which it is closely related. The physical characteristics which follow should be compared with those of the Kingston stone (No. 64, p. 211).

Specific gravity	2·717
Weight per cubic foot, lbs	169·286
Pore space, per cent	0·166
Ratio of absorption	0·061
Coefficient of saturation	0·26
Crushing strength, lbs. per square inch	29654·
Crushing strength after freezing, lbs. per square inch	25756·
Loss on freezing, per cent (gain of 0.099)	0·000
Loss on treatment with carbonic acid, grams per square inch	0·182
Transverse strength, lbs. per square inch	2382·
Chiselling factor	4·95

Miller gives an analysis of a sample from Newburgh thus:—

Lime and magnesia carbonate	93·3
Insoluble siliceous material	1·98
Alumina and ferric oxide	1·00
Phosphorus	0·06
Sulphur	0·14

The Belleville district.—The important quarries in the vicinity of Belleville are situated at Point Anne, about 4 miles east of the city. Operations have been conducted at this point for many years but the product at the present time is not extensively used for purposes of construction. Two large cement plants are erected at Point Anne, one of which, the Canadian Cement Company, is in active operation. The Point Anne Quarries Company convert their product into crushed stone or ship it in the rough for crib work. Arthur Macdonald and J. H. Macdonald carry on operations for building stone exclusively.

James H. Macdonald, Point Anne, Lot 20, Broken Front, Thurlow, Hastings county.

On this property the upper two feet are thin bedded and useless. Beneath this capping lie a 17 inch bed of light blue limestone (112), a 20 inch bed of darker blue stone (113), and a 2 foot bed of intermediate colour.

The stone: No. 112.—The colour is grey with a cast of brown and is shown in Plate LXXV, No. 5. On weathering, it assumes an appearance almost identical with that of the Kingston stone shown in Plate LXXVII, No. 15. In structure this example resembles the Kingston stone but it is scarcely so fine in grain; on the other hand, the scattered crystals of calcite are smaller and more numerous. This Point Anne stone may be considered intermediate between No. 64, p. 211 and No. 218, p. 238.

Specific gravity	2·706
Weight per cubic foot, lbs.	168·76
Pore space, per cent	0·07
Ratio of absorption, per cent	0·028
Coefficient of saturation	0·582
Crushing strength, lbs. per square inch	20322·000
Crushing strength after freezing, lbs. per square inch	17400·
Loss on freezing, per cent	0·028
Loss on treatment with carbonic acid, grams per square inch	0·017
Transverse strength, lbs. per sq. in.	2561·
Chiselling factor	5·6

No. 113.—This example is of the same general character as No. 112; it differs only in its darker colour, which resembles Plate LXXV, No. 11.

Miller gives the following analyses of Point Anne stone:—[1]

	1	2	3	4	5	6
Silica	1·64	1·80	....	0·47	0·60	0·80
Ferric oxide	0·53	0·71	0·71	·55	0·78	1·02
Alumina	0·21	0·43	0·95			
Lime	54·06	53·46	51·80	55·01	54·67	54·31
Magnesia	0·55	0·64	0·53	0·40	0·54	0·65
Carbon dioxide	42·90	42·60	41·10	....	....	....
Loss	0·10	1·00	....	....	....	....
Sulphur trioxide	0·41	....	....	....	....	....
Insol. residue	....	....	5·56	....	....	....

1 and 2—Chip piles at Point Anne quarries.
3—Face of railway cut on quarry grounds.
4—Top bed, Belleville Portland Cement Co.
5—Middle bed, Belleville Portland Cement Co.
6—Bottom bed, Belleville Portland Cement Co.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 6 .

Another analysis, made with a view of using the stone as flux, is quoted by Miller as follows:—[1]

Carbonate of lime	88·746
Carbonate of magnesia	4·13
Insoluble siliceous matter	3·88
Alumina and ferric oxide	1·80
Sulphur	0·159

The stone is quarried without the use of explosives and is cut by plug and feathers. It is found that the grain is cleaner and that the blocks are more readily split in a north and south direction than in any other. The upper bed is used mostly for bases, sills, veranda caps, etc. Pieces 8 feet long are easily obtained. The second bed has produced sills 10 feet in length. Only two men are at present employed. Mr. Macdonald quotes the following prices for stone unloaded at the quarry:—

Sills, bush hammered top and bottom, rock face, 80 cts. per running foot.

Sills, bush hammered, top, bottom and face, $1 per running foot.

Veranda caps, 16 inches square, bush hammered top and bottom, rock face, $2 each.

Arthur Macdonald, Point Anne, West half Lot 20, Broken Front, Thurlow, Hastings.

The stone is the same as in J. H. Macdonald's quarry, but two additional beds are exposed of which the upper is 6 inches thick and of a light blue colour and the lower 20 inches thick with a dark blue aspect.

Point Anne quarries. M. Haney, Toronto.

On this property are two extensive openings on which work is being actively prosecuted. The first quarry is 300 feet by 150 feet and is worked to a depth of 8 feet. The succession of beds is as follows:—

5 feet—Broken beds, in some places good 6 inch layers.
18 inches—Solid blue limestone.
18 inches—Solid blue limestone.

The joints run 10° S. of E. with another set at right angles. The direction and the spacing of the joints are very irregular. The total output is crushed.

The second opening is an old working which shows a 14 inch and a 12 inch layer under 5 feet of thin bedded material. A small derrick is installed here and 6 ton blocks are removed. The product is mostly crushed, but some is shipped for backing, sea walls, etc.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 27.

The equipment of the works consists of:—

1 Marion steam shovel of 70 tons capacity.
4 rock drills.
4 boilers.
2 compressors.
2 engines.
1 dynamo.
3 crushers, Gates, No. 8, No. 4, No. 2.
1 motor for travelling belt.

The removal of the stone is effected by the use of dynamite in 8 foot holes. The shattered rock is lifted by the steam shovel.

The solid stone is all a bluish limestone similar to that described from Macdonald's quarry; as it is not used for building purposes it requires no further description.

The Canadian Cement Co.

The beds in the cement quarry are the same as in Haney's. It is stated however that much stone from this quarry was formerly used for canal construction and that a white upper layer, particularly desirable on account of its softness, was employed for fine building purposes in Belleville. The tower of the Church of England and the cut stone of Albert College are said to represent this quarry.

The Crookston district.—Northward from Belleville to Crookston and along the line of the Canadian Pacific railway east and west of the latter place numerous exposures of limestone are to be seen. At Crookston are two important quarries, and at Tweed one. These quarries are situated on heavy bedded dark coloured limestone, suitable for heavy construction, monument bases, etc. Excellent building stone is obtained from the same beds; the practice being to employ for this purpose the smaller pieces derived from the dressing of heavier blocks. The stone is much alike at Crookston and Tweed, and differs from the fine grained lithographic type exposed along the Archæan boundary. It is possible that these beds should be ascribed to the Trenton rather than to the Black River; the literature is indefinite on this point and no collection of fossils was made to determine the horizon.

Honorable Wm. Gibson, Beamsville, Ont., Lot 10, *Con. IX, Huntingdon, Hastings county.*

This quarry is situated close to the line of the North Hastings railway, on the east side; it is opened in the side of a bluff which runs approximately parallel to the track at Crookston station.

In descending order the following beds are exposed:—

5 feet 6 inches—Even bedded limestones parting at intervals of 1 foot or 18 inches, somewhat shattered.

2 feet—Friable stone parting easily and fading into the next bed.

3 feet—Solid compact blue limestone, best bed.

Crookston Limestone. Roman Catholic School, Belleville, Ont.

Crookston Limestone. Abutments, Roman Catholic Church, Belleville, Ont.

5 feet 6 inches—Blue limestone parting into 8, 10, and 12 inch beds.
14 inches—Blue limestone.
12 inches—Blue limestone.
14 inches—Blue limestone.
4 feet—Thinner bedded blue limestones.

The beds are parted throughout by shaly layers containing fossils. The friability of the less compact beds is due to irregularly distributed shaly matter. The most pronounced jointing is E. 50° S. Less evenly developed jointing planes cut the strata in other directions but there is no difficulty in obtaining large dimension stone. These joints are often filled with pink calcite.

The rock has been quarried by means of deep 3 inch holes and the use of black powder. The stone was squared by plug and feathers. The method of quarrying has resulted in a large amount of waste. The excavation is about 800 feet by 300 feet.

The stone: The product of this quarry is a bluish grey limestone with a somewhat clayey aspect; much of it is marred by a tendency to irregular fracture, owing to clay partings and the presence of small "dries." The 3 foot bed is more compact and may be chiselled with greater facility than any other layer in the quarry. Stone from this bed is described in detail under Quinlan and Robertson's quarry below.

The greater part of the output has been used for bridges on the Grand Trunk railway. A large amount was also used in the construction of the Victoria bridge, Montreal.

At the time of my visit quarrying operations had been suspended.

Quinlan and Robertson, Montreal.

This quarry is situated on the same ridge and immediately to the south of that described above. The sequence of beds and the general character of the stone is therefore very similar; the 3 foot bed is persistent but the others vary somewhat in thickness. The excavation is about 600 feet by 200 feet.

The stone: No. 239.—This example is taken from the 3 foot bed and is to be regarded as the best stone in the quarry. The colour is a somewhat brownish grey and is shown in Plate LXXV, No. 10. After weathering, the stone assumes a colour like the base of Plate LXXVII, No. 15; the markings are finer and consist of dark brown irregular lines and dots. In structure this specimen resembles the Point Anne stone, but it is slightly more granular; in this respect, however, it does not approach the stone from Thebault's quarry at Ottawa and it is far removed from the granular crystalline type east of that city.

Specific gravity	2·713
Weight per cubic foot, lbs.	168·135
Pore space, per cent	0·699
Ratio of absorption, per cent	0·26
Coefficient of saturation	0·11
Crushing strength, lbs. per square inch	18826·
Crushing strength after freezing, lbs. per square inch	13935·
Loss on freezing, per cent	0·026
Loss on treatment with carbonic acid, grams per square inch	0·1507
Transverse strength, lbs. per square inch	2545·
Chiselling factor	5·6

Miller gives the following analysis of a "general sample from the Crookston quarries":—[1]

Silica	3·42
Ferric oxide	0·82
Alumina	0·52
Lime	52·22
Magnesia	0·72
Carbon dioxide	41·53
Loss	0·21
Sulphur trioxide	0·36
Alkalies	0·32

James Kiraey, Crookston.

A small quarry is operated by Mr. Kiraey near the junction of the Canadian Pacific with the North Hastings branch of the Grand Trunk railway to the southward of Crookston. The product is used exclusively for monument bases.

J. S. Murphy, Tweed, Ont.

The quarry operated by Mr. Murphy is situated on the farm of Mr. Frank Meraw, about a mile north of Tweed. On this property, 10 to 15 acres of very evenly bedded limestones are exposed. The area is intersected by pronounced joints running irregularly in a north and south direction. Another set, still less regular, cuts these at right angles. The joints are far apart and permit the quarrying of very large dimension stone. Although much stone of the same formation is seen in the vicinity, no other quarry has been opened, owing probably to the presence of extensive fracturing.

The upper bed which is 3 feet thick is the only one used. The stone is a compact blue limestone and can be chiselled with very little conchoidal chipping. Throughout the mass, the bedding is indicated by the occurrence of thin partings of bitumen distributed in an irregular manner. This material shows as unsightly blotches on stone which has been split parallel to the bedding; it seems to persist for a long time. Beneath the upper bed lies

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 61.

a 5 foot layer of somewhat darker and more argillaceous stone which possesses a strong tendency to part along the planes of bedding; this layer is not worked at present.

The rock is removed by black powder in 2 inch holes which are placed a considerable distance back from the working face so that large blocks are removed by the blast. It is sometimes necessary to use explosives to raise the blocks.

The product is used chiefly for monument bases and for building in Tweed. Like other heavily bedded stones, it is better adapted to works of large proportions than to ordinary building. On weathering, the stone assumes a much lighter colour after the manner of all dark Black River limestones. The Methodist church in Tweed is constructed of stone from this quarry, and, as evidence of the possibility of obtaining large stone, may be mentioned the engine bed of the Brockville waterworks which is 5 feet 6 inches by 6 feet 6 inches and 1 foot thick, and the pillars in Robertson's store in Tweed, which are 16 feet long and 20 inches square.

At present Mr. Murphy employs only one man and does a business of about $1500 annually.

The Madoc-Marmora district.—North of Madoc are several quarries in Black River limestone and south of that village are some old quarries on the margin of the sedimentary series. In the vicinity of Central Ontario Junction and northward to Crow lake extensive exposures of a stone very similar to the Madoc type are to be seen; quarries have been opened in these rocks near Marmora. On account of the similarity of the stone at Madoc and at Marmora it is convenient to group the two places together.

Several limestone outliers or "islands" north of the village of Madoc have been exploited for building stone for local consumption. The stone from all these quarries very closely resembles the product of the "lithographic" quarry at Marmora, it is hard, light coloured, brittle and possessed of a conchoidal fracture, but it is very durable and satisfactory as a building stone for rock face work. In all cases the stone is near the surface, occurs in large quantity, and is very easily quarried. The following four properties are among the more important.

James McCoy, Madoc, Lot 8, Con. V, Madoc, Hastings county.

The exposure shows a depth of about 20 feet. The stone is all of a uniform, compact, fine grained character and of light colour; it is disposed in thin beds with very little shaly parting. The maximum bed is less than 1 foot in thickness and the average is much less—225.

The formation is strongly jointed N.W., and S.E., and shows a less pronounced series of joints in a direction at right angles to this.

The stone: No. 225.—The colour of this stone is browner than that of the fine grained stones of semi-lithographic character from Kingston, Napanee, etc., it is represented in Plate LXXVII, No. 10. On weathering, the stone assumes a much lighter colour but does not whiten to the same extent as the samples from farther south. The structure is exceedingly fine and shows few if any scattered crystals of calcite; some of it is undoubtedly of true lithographic character. For a description of some of the physical properties see the account of the stone from Marmora (No. 278, p. 223). The uniform character of the stone and its even bedding make possible the selection of material for coursing and for the preparation of sills, lintels, etc., without great expense. Like all stone of this type, it possesses a conchoidal fracture, which causes chips to break out under the chisel and renders difficult the preparation of smooth faces on dressed work.

R. Farrell, Madoc, Lot 5, Con. IV, Madoc.

The quarry shows a vertical face of about 12 feet. The stone is all thin bedded with a maximum of 8 inches. A great deal of thin material ranging from 1 to 2 inches detracts somewhat from the value of the property.

Hugh McIntosh, Madoc, Lot 7, Con. V, Madoc.

The stone of this quarry is similar in character to those described above.

James Holland, Madoc, Lot 9, Con. V, Madoc.

This quarry produces a stone of the same character as those described above.

Lot 2, Con. XIII, Huntingdon.

A small quarry was opened many years ago on this lot. The stone is of the same fine grained lithographic character as those in Madoc, but it is thicker bedded, producing stone of 14 and 16 inches in thickness.

The Pearce Co., Limited, Marmora.

At the rapids in the village of Marmora, a greenish diabase of the Archæan is exposed by the denudation of the overlying limestones of the Trenton group, which present more or less abrupt escarpments, particularly on the west side of the river. Here, about 75 feet of the basal Trenton (Black River) limestone are exposed and show even bedded, fine grained stone, varying in thickness from 1 to 18 inches. The abrupt banks, on account of the overburden, do not present an ideal location for quarrying, but about a half mile down the river where the ascent is more gradual a quarry was opened nearly a hundred years ago. The upper 6 feet of the exposure consists of layers 6 to 8 inches in thickness followed by one of 1 foot. Five feet of 4 to 10 inch beds follow, below which is a foot of thin bedded material and then 14 inches of heavier stone to the bottom. All the beds of the upper 8 or 9 feet consist of compact, somewhat crystalline, brownish grey limestone containing a few small fossils. The layers of the next 3 or 4 feet, down to the shaly band, are lighter in colour, very fine in grain and almost of lithographic quality except for the presence of scattered crystals of calcite (278). The bottom 14 inches consist of very fine grained smooth stone, darker in colour than the layer immediately above but lighter than the top layers. This bed has a strong tendency to cleave along the bedding planes.

Marmora Limestone. Old Church at Marmora, Ont.

Plate XLIX.

Marmora Limestone. New Roman Catholic Church, Marmora, Ont.

No machinery of any kind is installed and such quarrying as may be done is crude and intermittent.

The stone: No. 278.—The colour of this stone is not well represented in any of the plates; it most resembles Plate LXXVII, No. 2, but it is without the slight reddish cast there shown. On weathering it becomes still lighter. The structure is lithographic but some scattered crystals of calcite detract from its value. The polished surface is darker than the rock face and shows the wavy stratification lines and the scattered crystals of calcite already referred to.

Specific gravity	2·723
Weight per cubic foot, lbs	169·827
Pore space, per cent	0·066
Ratio of absorption, per cent	00·024

Crushing strength, lbs. per square inch, 37705·. (The highest result for any stone referred to in this report).

Most of the beds of this quarry produce a building stone of a hard and durable character in sizes convenient for handling. The marketable output varies from 5 to 14 inches in thickness and is practically inexhaustible. The stone splits easily along the bedding, and at right angles to that direction breaks with a clean fracture so that rectangular blocks are easily prepared. For rock face work the stone is highly desirable, but as it is somewhat brittle and is possessed of a strong conchoidal fracture it does not chisel easily. Dressed work is liable to be marred by the flaking off of shell-like chips unless great care is taken in the operation.

A church constructed of this stone in 1826 shows that it stands the weather well; sharp points and chisel marks have been retained without change during the 84 years of exposure. The colour has, however, altered. The surface of the stone soon becomes whitened but the alteration is confined to the surface only. Chips from the old building show that the change has not extended beyond a paper thickness into the stone. This tendency to whiten on exposure has at least the advantage of making the stone from different layers assume approximately the same hue. Besides the church already referred to, an old building erected about 1822 by the Marmora Iron Co. is still standing and as far as the stone work is concerned is in excellent condition. In later years the stone has been largely employed locally; among important buildings may be mentioned the Church of England and the Roman Catholic church in Marmora. The latter building is a fine structure erected in 1904. The rock face work is excellent but the dressed stone is marred by the conchoidal chipping already referred to. The practice of using stone from different beds detracts from the general appearance of the building. Some of the stone is 14 inches thick and sills and coping of 6 eet in length were observed. The steps of this building, constructed of concrete, present a sad appearance in contrast with the rest of the structure. (Plate XLIX.)

William and Robert Bonter, Marmora, Lot 8, Con. III, Marmora, Hastings county.

On the south side of Crow lake is situated what is known locally as the "old lithographic quarry." This property was opened about 17 years ago by the American Lithographic and Asbestos Co. and extensive operations were carried on for about 3 years. The excavation is roughly 150 by 100 feet with a depth of 20 feet. The following beds are exposed in descending order:—

3 feet—Thin bedded and fractured limestone.

1 foot—Light brown, fine grained stone (blue lithographic).

2 feet—Thin bedded stone (cement beds).

1 foot—Blue lithographic.

1 foot—Blue lithographic.

18 inches—Thin bedded blue lithographic.

10 inches—Blue lithographic.

14 inches—Coarse, somewhat crystalline brown compact limestone (leatherlug).

15 inches—Fine smooth whitish limestone (white lithographic).

While operating the quarry the company installed a 110 horse-power engine, 3 gang saws, 1 rubbing bed, and 1 planer. Although a channelling machine was in operation for a short time, the exploitation was largely effected by the use of dynamite. According to local observers and in all probability in accordance with the facts the final closing of the plant was due to the injudicious use of this shattering explosive. The building is still in fair repair and of the equipment there remain the three saws, a rubbing bed and a horse hoist, all capable of being again put in commission.

The lithographic stone was sawn into slabs and smoothed. The leatherlug was sawn into slabs 3 to 4 inches thick with the intention of using it as curbing stone. Over 100 such slabs, some of them 3 feet by 6 feet, are still on the premises but they are broken and destroyed by frost.

It is not the intention of the report to discuss the suitability of this stone for lithographic purposes; it seems to have been employed with a fair measure of success. As a building material it possesses the same advantages as the stone from Pearce's quarry nearer Marmora.

Miller gives the following analyses of lithographic stone from these quarries:—[1]

	Light blue-grey stone.	Dark blue-grey stone.
Insoluble residue	3·71	3·60
Organic matter	0·40	1·29
Carbonate of lime	89·98	88·03
Carbonate of magnesia	2·78	2·50
Soluble silica }	0·73	0·49
Alumina }		0·57
Ferric oxide	0·15	0·35
Ferrous oxide	0·10	0·04
Water	1·25	1·36
	99·10	99·23

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 61.

The finer grades of stone from this quarry possess an undoubted value as a decorative material. Cut across the bedding and polished, a delicate wavy lamination is revealed which somewhat resembles opalized wood. Cut parallel to the bedding there are produced clouded effects in tones of grey. By careful manipulation very delicate and intricate carvings can be made. It is not intended to produce the impression that this material approaches the true marbles in beauty, but as a decorative material of the second grade it is not to be disregarded.

It is an interesting fact that the shavings from the planers if wetted and allowed to stand set to a cement of considerable strength.

The Burnt River district.—Two important quarries have been opened in the township of Somerville in Victoria county; one of these is in active operation while the other is now idle.

Wm. Britnell, 1127½ *Yonge St., Toronto, Lot* 13, *Con. VI, Somerville, Victoria county.*

This property consists of 9 acres on which an extensive opening shows the following succession of beds:—

2 feet—Overburden.
20 inches—Solid bed of blue limestone, building stone—15.
14 inches—Solid bed of blue limestone, building stone like 15.
5 feet—Hard limestone, but is badly jointed and not suited to building purposes.
12 inches—Good blue limestone, building stone.
20 inches—Thin bedded limestone in six beds 1, 2 and 3 inches thick. Rubble.
6 inches—Solid blue limestone, can be extracted in large blocks—17.
1 foot—Thin bedded with clay and sand.
14 inches—Grey and red limestone.
14 inches—Grey and red limestone.
22 inches—Grey and red limestone.
8 inches—Grey and red limestone; best bed to chisel.
16 inches—Grey and red limestone.
1 foot—Red limestone—13.
3 inches—Irregular parting.
14 inches—Hard red limestone—114.
10 feet—Thin bedded stone like the upper layers.

The stone: No. 15.—The colour of this stone is a light brownish grey resembling that shown in Plate LXXVI, No. 11. On exposure it assumes a lighter colour. The structure is fine grained and almost lithographic in character, but it is not so fine and uniform as the stone from the outliers north of Madoc or the better type of Marmora stone. Slightly granular and in some cases darker bands appear between belts of the very fine type. On the whole, however, it is a fairly uniform, compact and durable stone.

No. 17.—This stone shows the colour represented in Plate LXXVII, No. 11. While parts of the specimen are fine grained and lithographic, it is, on the whole, so filled with calcite crystals and marked by distinct stratification planes that it departs widely from the lithographic type. While presenting a more desirable colour than No. 15, this example is much less uniform in structure and would part more readily into thinner sheets and would be liable to present a more irregular surface on weathering.

No. 14.—The colour of this example is shown in Plate LXXVII, No. 5. How well it matches with the red Medina sandstone will be observed on comparing Nos. 4 and 5. Treatment with carbonic acid changes the colour slightly, adding a slight cast of yellow to the red and bringing out a finely mottled effect. This stone when polished presents an extremely attractive appearance suggesting Tennessee red marble. The operation of polishing brings out a mottled effect which would scarcely be suspected from an inspection of the rock face (Plate LXIX). Under the microscope the rock is seen to be made up of a closely aggregated mass of the most minute crystals of calcite which do not average more than 1/25 mm. in diameter. The red colour is not perceptible in thin sections, and, owing to the fineness of the grain, the cementing material can scarcely be observed.

The results of the physical tests follows:—

Specific gravity	2·83
Weight per cubic foot, lbs.	175·313
Pore space, per cent	0·74
Ratio of absorption, per cent	0·26
Coefficient of saturation	0·61
Crushing strength, lbs. per square inch	32184·
Crushing strength after freezing, lbs. per square inch	32180·
Loss on freezing, per cent	0·019
Loss on treatment with carbonic acid, grams per square inch	0·038
Transverse strength, lbs. per square inch	4291·
Chiselling factor	0·15

An analysis by H. A. Leverin shows that considerable insoluble matter is present, as well as a dangerous amount of unoxidized iron.

Insoluble matter	4·32
Ferrous oxide	1·33
Ferric oxide and alumina	·40
Calcium carbonate	75·34
Magnesium carbonate	19·00
Sulphur	·058

No. 13.—This stone resembles No. 14, but instead of a uniform red colour it shows a mottled effect in green and red. The grain is uniformly fine and the stone is somewhat softer than No. 14.

Although it has been customary to use these red stones for the roughest purposes on account of their hardness, I cannot but regard them as constituting decorative material of considerable value. The difficulty of carving would perhaps prevent their use for chiselled work, but for polished panels or pillars for external use, where great wearing qualities and a high degree of strength are required, I should expect them to appeal strongly to an architect. It has already been noted how well the red stone harmonizes with the Credit Valley sandstone.

Miller gives the following analyses of stone from this quarry:—[1]

	Top layer.	4 ft. 10 in. of upper part of face.	3 ft. bed just below top layer.	4 ft. above siliceous layer.	Bottom siliceous layer.
Silica	1·56	·72	1·68	3·94	11·34
Ferric oxide	·52	·41	·65	·82	1·52
Alumina	·39	·80	1·14	1·57	4·72
Lime	51·44	50·31	47·28	45·74	28·10
Magnesia	1·37	2·72	5·46	4·10	4·92
Carbon dioxide	41·83	42·30	43·30	40·84	....
Loss	1·41	1·25	....	....	....
Sulphur trioxide	....	·37	....	·39	·31
Alkalies	....	....	....	·24	....

Most of the product of this quarry is converted into crushed stone, but a considerable amount of building stone is shipped from time to time. The demand for building stone varies with the seasons, being most active in the spring, at which time most of the output is used for this purpose. The harder beds are employed for lake front construction, etc., for which purpose large quantities have been shipped to Toronto. From some of the thicker layers dimension stone 4 feet by 4 feet has been prepared.

The quarry is equipped with two derricks of five tons capacity each. Steam drills are employed using single bitted drills with a 2 inch cutting edge. Rackrock and black powder are used in holes from 2 to 8 feet deep. The crushing plant consists of one Gates crusher operated by a 25 horse-power engine. This machine has a capacity of from 80 to 90 tons in a day of 10 hours. Twenty-six men are employed at wages ranging from $1.50 to $1.60 per day and two boys at $1 per day.

Samuel White, Burnt River, South half Lot 17, *Con. III, Somerville, Victoria county.*

The excavation on this property is 100 feet by 100 feet with a depth of 20 feet. The beds exposed present the following series in descending order:—

3 feet—Highly fossiliferous bed, with red and white calcite replacing fossils in places. The rock is much broken and has a tendency to split along bituminous parting planes—21.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii. p. 113.

8 inches—Shaly bluish limestone.

1 foot 10 inches.—Like 21.

9 inches—Shale.

6 inches—Hard blue non-fossiliferous, finely laminated limestone with a tendency to split along the bedding planes—18.

1 foot—Hard whitish fossiliferous limestone—19.

7 inches—Hard whitish fossiliferous limestone—19.

6 inches—Hard whitish fossiliferous limestone—19.

8 inches—Similar to above but thin bedded and separable into layers.

1 foot 6 inches—Hard white solid limestone, no fossils.

1 foot 9 inches—Like above—20.

4 feet 6 inches—The same as 20, but shows partings at intervals of 4 inches, 4 inches, 8 inches, 4 inches, 8 inches, 6 inches, 5 inches, 2 inches, 12 inches, and 6 inches. Most of these partings are irregular and are marked by a film of bituminous matter. This stone is hard, brittle, "plucky" and almost lithographic in character.

A somewhat variable set of joints cuts the formation at about 25° W. of S. A still more variable series occurs in a direction ranging from 20° to 55° N. of W. The use of high explosives has so shattered the rock on the face of the quarry that it is almost impossible to judge of the character of the joints, the size of the blocks obtainable or the compactness of the different layers. The bedding is excellent and the floors are horizontal.

The stone: No. 18.—A fine grained but not lithographic grey limestone presenting a colour comparable with Plate LXXV, No. 4. Lamination is distinct and the stone weathers rather rapidly to a dirty yellow colour.

No. 19.—A light coloured lithographic type of stone comparable with the Marmora stone. It contains veinlets and scattered crystals of calcite.

No. 20.—A very light coloured limestone of the lithographic type; it contains but few scattered crystals of calcite, possesses a marked conchoidal fracture and would be somewhat hard to work.

No. 21.—A dark grey limestone resembling Plate LXXV, No. 14. The stone is rendered rough and undesirable by the presence of large veinlets and spots of pink and white crystallized calcite, which represents the replacement of fossils by the mineral.

A siding formerly connected the quarry with the G. T. R. but the track has been removed. On the property are Blake crushers, elevators, screens and bins, also an engine and boiler by the Good Roads Machinery Co. of Hamilton. A dismantled derrick in a poor state of repair, a quantity of track and a number of quarry cars might still be of service if operations should be resumed.

In the Burnt River district is a third quarry situated about a mile to the northeast of the village. The stone is similar to that from Britnell's quarry. Here also may be included the quarries at Coboconk which are operated chiefly for lime-making but from which building stone similar to some of the

Burnt River product is obtained. Miller states "The rock burned here is similar to that in the escarpment at Burnt river. The nine upper beds in the quarry used for lime have an aggregate thickness of 18 or 20 feet; under these beds are layers which are said to be unsuited for lime-burning but make good building stone. They have thicknesses of 12, 2, 4 and 9 inches respectively. They are fine grained and lithographic in character."[1]

The Longford district.—Formerly several companies or individuals operated quarries in the exposures of Black River limestone along the west shore of Lake St. John in Rama township, Ontario county. With the exception of one quarry—the property of Wm. Thompson of Orillia—all the workings are now under the control of the Longford Quarry Co. As producers of building stone these quarries rank among the most important in the province and are therefore worthy of description in detail.

The Longford Quarry Co., Wm. Thompson, president, Orillia; Andrew Craig, manager, Longford Mills, Lots 20 to 28, Front Range, Rama, Ontario county.

Along the shore of Lake St. John there is exposed a bluff of limestone which stands about 20 feet above the water. Westward from the shore of the lake the country rises above the height of this bluff and consequently exhibits beds of stone belonging to a higher series. These upper beds supply the stone quarried at Longford Mills. A continuous line of quarries about 300 feet deep extends for half a mile along the track of the Grand Trunk railway north of the village. At different places the succession of beds varies somewhat, but the following series represents an average section:—

18 inches—Dark blue limestone, thin bedded, decayed. Used for rubble and furnace flux.
9 inches—Good average stone—152.
5 inches—Good average stone, sill bed.
14 inches—High grade stone—149.
7-14 inches—Variable bed, but good stone like 149.
20 inches—Shelly, rubble only.
12 inches—Good footing stone—150.
14 inches—Good building stone—151.
Base of workings.
5 feet—Shale and rotted material.
10 inches—Good average stone.
27 inches—Good average stone.
20 inches—Good average stone.
12 inches—Good average stone.
12 inches—Good average stone.
12 inches—Good average stone.
5 feet—Brownish stone in different beds, friable, sandy.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 113.

The 9 inch bed and the two 14 inch beds are regarded as the most desirable stone. The 12 inch bed second from the bottom is not so good for dressed work, but makes excellent coursing stone. The lower 14 inch bed is the best for heavy construction; it is very solid and even in texture and is capable of being removed in large blocks. One series of joints runs almost due east and west; the other set, however, has a direction a little west of north so that the blocks are not rectangular in shape. On the stripped surface, places were observed where the joints are sufficiently far apart to permit the removal of blocks 10 feet by 20 feet in size. It is questionable however whether such large pieces could actually be obtained, as cracks may exist which do not show on the weathered surface. Pieces 9 feet by 4 feet have however been shipped.

The stone: No. 151.—The colour of this stone is represented in Plate LXXVI, No. 8. The structure is of the lithographic type but small crystals of calcite are present in lines representing the planes of stratification. On weathering, the stone becomes very white with fine dark specks throughout. The weathered surface of this stone and the other examples from these quarries presents a nearer approximation to pure white than any other stone in the province; with the possible exception of the Aylesworth stone from Newburgh.

Specific gravity	2·71
Weight per cubic foot, lbs	168·5
Pore space, per cent	0·373
Ratio of absorption, per cent	0·13
Coefficient of saturation	0·27
Crushing strength, lbs. per square inch	22968·
Crushing strength after freezing, lbs. per square inch	21625·
Loss on freezing, per cent	0·013
Loss on treatment with carbonic acid, grams per square inch	0·309
Transverse strength, lbs. per square inch	2281·
Chiselling factor	6·9

(Under the action of the chiseling machine the slabs of stone invariably broke; in consequence the above result is probably a little too high. Despite its high transverse strength the stone appears to be very susceptible to shock).

No. 152.—This sample is lighter in colour than No. 151; its appearance is represented in Plate LXXV, No. 7. On weathering, the colour is identical with that of No. 151, but the spots are replaced by very fine wavy lines as in the Newburgh stone.

Specific gravity	2·701
Weight per cubic foot, lbs	167·85
Pore space, per cent	0·408
Ratio of absorption, per cent	0·152
Coefficient of saturation	0·95

Plate L.

Longford Quarries, Longford Mills, Ont. General View.

Level Upper Beds, Longford Quarries, Longford Mills, Ont.

Crushing strength, lbs. per square inch	25000·
Crushing strength after freezing, lbs. per square inch	19723·
Loss on freezing, grams per square inch	0·0049
Loss on treatment with carbonic acid, grams per square inch	0·189
Transverse strength, lbs. per square inch	2324·
Chiselling factor (somewhat doubtful as the stone broke and shattered like No. 151)	4·86

It is interesting to note that these two stones, which are so much alike in all other respects, differ so greatly in the coefficient of saturation. The fine lines observed in No. 152 represent minute openings in the rock which permit of the rapid imbibition of water. It is to be expected that No. 152 would be much less durable than No. 151 under the action of frost.

No. 150.—Resembles both the above but is probably nearer to No. 152.

No. 149.—Resembles both the stones described but is nearer to No. 151.

Miller gives the following analyses:—[1]

	Bed probably corresponding to No. 152.	Top rotten bed.	Yellow bed.
Lime	53·42	52·42	34·28
Magnesia	·72	·85	16·25
Carbonate dioxide	42·68	42·00	44·70
Ferric oxide	·62	·22	·54
Alumina	....	·41	·72
Sulphur trioxide	·17	·30	....
Alkalies	·05	....	....
Silica	....	....	....
Insoluble residue	2·78	1·38	2·80
Loss on ignition	....	1·79	....
Water	·72	....	·06
Sulphuric acid	....	....	·44

With the exception of the top layer which is removed by the use of powder, all the stone is quarried by plug and feathers. It is found that holes 1 foot apart and 3 inches deep suffice for the splitting of the thickest layers. As the parting planes between the different beds are well developed nothing more than crow bars is required to raise the layers. Ball drills are used for the plug holes. Three Ingersoll baby drills using $\frac{3}{4}$ inch steel, and operating on direct steam are employed for removing the upper layer. Twelve derricks are in place in the quarries. A spur 2300 feet long from the Grand Trunk railway runs through the quarries and affords a ready means of loading and shipping the product. Thirty men are employed; quarrymen receive $2.25 and laborers $2 per day of ten hours. The following prices are quoted all f.o.b. Longford Mills:—

Sills, bush hammered top and bottom, rock face, 45 cents a running foot.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 91.

Rubble, 60 cents a ton.

Rough stone, varies greatly according to size.

Longford stone has been extensively used both for heavy construction and for architectural purposes; it is probably more widely used in Toronto than any other limestone. The following list shows some of the more important structures in which the product of these quarries may be observed:—

King St. subway, Toronto.
Queen St. subway, Toronto.
Sir Wm. Mackenzie's residence, Avenue road, Toronto.
Canadian Pacific Railway tunnel, Hamilton.
Mr. Mercer's residence, Toronto.
Post-office, North Bay.
Roman Catholic church and Bishop's palace, North Bay.
T. and N. O. and C. P. R. stations, Sudbury.
Custom House, Peterborough.
Collegiate Institute, Peterborough.
Church of England, Orillia.
Y. M. C. A. building, Orillia.
Roman Catholic church, Orillia.
Post-office, Orillia.
Carnegie library, Orillia.

Georgian Bay district.—Limestone of the Trenton and Black River formation is exposed at various points along the shore of Georgian bay. In these exposures several quarries have been worked, but, as far as the writer can learn, the product has not been used as a building material except locally and to a very small extent. The Midland Iron Furnace Co. operates a quarry for flux on lots 19 and 20 of the fifth concession of the township of Tay. "Some of the rock is fine grained and lithographic in character, like that in the township of Marmora and other localities farther east. The quarry has a diameter of about 100 yards and a face 12 or 15 feet in height."[1] The Cramp Steel Co. has a quarry at Collingwood from which a fine grained lithographic limestone is procured for use as flux in metallurgical operations. Other quarries exist in the same locality, as well as a number of smaller ones which are operated for lime-making throughout the district.

Summary—The Western Area.

It has already been pointed out that this area constitutes a narrow band extending along the western flank of the Archæan rocks from Kingston to Georgian bay. For convenience in description it may be divided into districts as below:—

Kingston district.—Quarries at Kingston, Wolfe island, Garden island.

Napanee district.—Quarries at Napanee and eastward on road to Newburgh.

Belleville district.—Quarries at Point Anne.

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[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 110.

Crookston district.—Quarries at Crookston and Tweed.

Madoc-Marmora district.—Quarries near Madoc and Marmora.

Burnt River district.—Quarries at Burnt river and Coboconk.

Longford district.—Quarries at Longford Mills.

Georgian Bay district.—Quarries at Midland and Collingwood.

The stone is mostly a fine grained compact variety approaching the lithographic in character. At Kingston it is dark, at Belleville blue, and in all the other districts except the Crookston it is quite light in colour. In this latter district the stone has more of the dark appearance and wavy bituminous partings characteristic of the Black River stone of the eastern region.

The stone from all these quarries weathers much whiter, possesses a conchoidal fracture, and is somewhat brittle. The pore space is very slight and the crushing strength high—a sample from Marmora showing the extraordinary strength of 37,705 lbs. per square inch.

The stone breaks well; it can be chiselled with reasonable facility but is liable to chip out under the tool. Detailed descriptions of this type are given as below:

No. 64.—Kingston, page 211.
No. 112.—Point Anne, page 216.
No. 92.—Newburgh, (Napanee district), page 215.
No. 278.—Marmora, page 223.
Nos. 151 and 152.—Longford, page 230.

Besides this compact lithographic type, a hard red crystalline variety is quarried at Burnt river (No. 14, page 226) and a dark type in the Crookston district (No. 239, page 219).

Literature:—Geol. Sur. Can., Rep. 1863, pp. 178; p. 181; p. 816.
" " " " 1901, pp. 172–176A.
Bur. Mines, Ont., Rep. 1902, p. 194.
" " " " 1904, pp. 43–44; pp. 59–61; p. 91; pp. 112–113; p. 110.
Geol. Sur. Can., Rep. 1888–89, pp. 25–26R.

The Limestones of the Trenton Formation.

Although the rocks of this formation are widespread there are not very many important quarries throughout its whole extent. The reason for this lies largely in the fact that much of the stone is thin bedded and a great amount of useless material is mingled with the valuable stone. The only really important quarries now in operation are those near Ottawa. The following areas of Trenton rock may be recognized:—

The Ottawa River.—This area extends along the Ottawa river valley, south of the Black River strip, to the western boundary of the Province.

The Stormont-Glengarry.—This area occupies a large part of Stormont and Glengarry within the Black River ring. There are no important quarries.

The Carleton.—Occupies the centre of the Black River ring in the eastern part of Carleton county.

The Renfrew.—Several small patches associated with the Black River in Renfrew.

The Western.—This area covers a large part of central Ontario; it forms the shore of Lake Ontario from the border of the Black River to beyond Bowmanville. Thence it extends northward as a broad belt with its western boundary on Georgian bay near Collingwood.

The Ottawa River Area.

H. Robillard and Son, 236 Stewart St., Ottawa, East half Lot 22, Rideau Front, Gloucester, Carleton county.

The extensive quarries of this firm have been worked over an area of about 6 acres to a depth of 10 feet. The succession of beds is as follows:—

4 feet—Shelly stone used for lime, road metal and rough rubble.
6 inches—"Sill bed" soft and easily chiselled—208.
14 inches—Fine grained, close texture, hard blue stone—210.
9 inches—Darker but resembles the 6 inch bed—209.
12 inches—Variable bed, stone like 209.
5 feet—Beds of variable thickness in different parts of the quarry. in places 2 ft. stone can be obtained. The material is like the 6 inch and the 9 inch bed.

Joints cross the formation at 40° S. of E., and also at right angles to that direction. These partings occur at intervals of 6, 8, 10 to 20 feet.

The stone: No. 208.—This stone has a brownish grey colour and has the appearance of being flecked with white. Plate LXXVII, No. 13 will give an impression of the stone if it be viewed from a little distance. On weathering, it assumes a colour like Plate LXXV, No. 9, but this colour should be modified by the addition of darker spots representing aggregations of clear calcite crystals.

The main mass of the stone is composed of the remains of organisms and consequently presents a crystalline character. The matrix also is crystalline, and besides cementing the fragmental portions, it appears as blebs of clear crystalline calcite, which are arranged parallel to the stratification of the stone. On the freshly fractured surface these blebs are not very perceptible but on polished or weathered faces they become more conspicuous. It is not to be understood that these marks detract from the value of the stone; they are too small and too uniformly scattered through the whole mass to have any ill effect.

The physical properties are indicated below:—

Specific gravity	2·709
Weight per cubic foot, lbs.	168·536
Pore space, per cent	0·315

Ratio of absorption, per cent	0·116
Coefficient of saturation	0·91
Crushing strength, lbs. per square inch	17994·
Crushing strength after freezing, lbs. per square inch	15650·
Loss on freezing, per cent	0·046
Loss on treatment with carbonic acid, grams per square inch	0·207
Transverse strength, lbs. per square inch	2863·
Chiselling factor	5·7

No. 210.—The colour of this stone lies between Nos. 4 and 14 of Plate LXXV. In structure it differs from No. 208 in being much finer in grain, but of distinctly crystalline character. It is more splintery in fracture and would be much harder to chisel.

No. 209.—This stone so closely resembles No. 208 that little comment is necessary. The crystalline blebs referred to in the description of No. 208 are not present in any amount. This example may therefore be regarded as a more homogeneous stone than that of the other bed.

The following analyses of the Robillard stone are from the Report of the Geological Survey for 1899, pp. 32–33R.

	First Bed.	Third Bed.	Fifth Bed.
Hygroscopic moisture	·03	0·04	0·98
Carbonate of lime	87·87	98·25	98·68
Carbonate of magnesia	1·13	0·78	0·9
Phosphate of lime (tribasic)	0·39	0·37	0·17
Alumina	0·04	0·04	0·17
Silica, soluble	0·05	0·02	0·02
Bisulphide of iron	0·13	0·06	0·04
Insoluble mineral matter	0·59	0·60	0·32
Organic matter	0·08	0·04	0·01
	100·28	100·16	100·31

In this quarry, stone of almost any dimension required can be obtained and sections of the 6 inch bed have been removed having dimensions of 20 feet by 10 feet. The output has been largely used throughout the Ottawa valley and has been shipped as far as Montreal. Robillard stone is used for finishings in buildings of which the rock face work is constructed of the coarser local stone in the Chazy, Calciferous, and Black River areas. The product may be seen in numerous structures in Ottawa, as the Banque Nationale, Sacred Heart church, etc.

The plant consists of a boiler and two steam drills, two derricks and a large amount of minor apparatus. An average of 20 men are employed. Drillers receive $2.50 and laborers $1.75 a day.

Dimension stone, roughly squared by plug and feathers, is delivered in Ottawa at 40 cents a cubic foot, but this varies somewhat according to the beds. Dressed sills are sold at 60 cents a running foot in Ottawa. The haul to Ottawa is three miles.

Laurentian Stone Co., Ottawa, Middle Third, Lot 22, Rideau Front, Gloucester, also on Lot 24, north of the Montreal Road.

The stone on this property is the same as that of Robillard.

S. Gosselin, Ottawa, Robillard P.O., East Third, Lot 22, Rideau Front, Gloucester.

On this property about 2 acres have been quarried and 20 remain. The succession is as follows:—

4–5 feet—Rubble.
6–8 inches—Sill bed as in Robillard.
12–16 inches—Blue stone.
7–12 inches—Represents the 9 inch bed of Robillard.
7 feet—Irregular beds 6 inches to 2 feet thick.

The stone is essentially the same as Robillard's. Black powder is used for explosive. All dimension stone is made by plug and feathers. Six men are employed. Mr. Gosselin has kindly furnished the following scale of prices:—

Sills, 25 cents per square foot on bed.

Dressed sills, rock face, 50 cents per running foot.

Rubble, 85 cents per ton.

Shoddy, hammer broken, $1.50 per ton.

Dimension stone less than one foot thick, 40 cents to $1 per superficial foot according to size.

Dimension stone over a foot thick, 50 cents to $1 per cubic foot according to size.

Landings, 50 cents to $1.50 per superficial foot.

The stone may be seen in the recent addition to Water Street hospital in Ottawa.

Thos. Pridmore, Robillard P.O., Lot 20, Rideau Front, Gloucester, Carleton county.

The succession of beds and the character of the stone are different in this quarry, as may be seen by comparing the following section with those given for Robillard and Gosselin.

3 feet—Blue limestone, rather variable and thin bedded.
6–8 inches—Solid blue stone bed.
1 foot—Solid blue stone bed.
4 inches—Blue stone.
1 foot—Solid bed.
3 feet—Solid bed, frequently coalesced with the one above.
6 inches—Solid bed.

The stone is much alike throughout and is represented by specimen 211.

The stone: No. 211.—The colour of this sample is very like that shown in Plate LXXV, No. 14. It is much darker than the stone from Robillard's quarry.

In texture this stone lies between the two samples from Robillard's, being finer than in Nos. 208 and 209 and coarser than in No. 210. In hardness also it seems to be intermediate between these two types. The product has been used for architectural purposes and has been found to work with reasonable facility; it may be seen in Mr. Snow's residence in the vicinity and in the church in Jamesville.

Kirk and Winning, Ottawa, Lot 23, Rideau Front, Gloucester.

This property adjoins Robillard on the west. The succession is as follows:—

6 feet—Rubble and building stone of variable thickness.
6 inches—Solid bed.
8 inches—Solid bed.
6 inches—Solid bed.
1 foot—Variable layers.
14 inches—Solid bed.
2 feet 8 inches—Softest and best bed (22 inches bed)—212.
4 feet—Darker limestone, not solid throughout.
3 feet—Like above.

The main series of joints runs 20° W. of N. at intervals of 4, 6, 8, and 10 feet. There is a slighter development of jointing at right angles to this direction.

In this quarry about 2 acres of stone have been extracted. The equipment consists of one 18 horse-power boiler, one steam drill, and a 4 ton derrick. The rock is dislodged by black powder and cut by plug and feathers. Ten men are employed.

The stone: No. 212.—This example is a trifle lighter in colour than No. 209 from Robillard's quarry. On certain of the fractured surfaces the white flecked appearance is very striking. The physical properties are doubtless very like those of 208.

The stone may be seen in the Ottawa Collegiate Institute, the Mortimer building and in the Y. M. C. A. building in Ottawa.

E. Thebault, Billings Bridge, Lot 23, Junction Gore, Gloucester.

This quarry is situated east of the Hogsback on the Rideau and south of the road. Quarrying operations have been conducted for five years but the excavation is not extensive. The following succession is presented:—

8 inches—Thin material for rubble.
1 foot—Solid limestone.
1 foot—Solid limestone.
1 foot—Solid limestone.
18 inches—Solid limestone.
18 inches—Solid limestone.
2 feet—Solid limestone.
2 feet—Solid limestone.
8 feet—Solid limestone.

The jointing is about north and south at intervals of 6 to 8 feet. The other series of joints is very irregular with interspaces varying from 1 to 9 feet.

The stone from all the beds is practically the same (218). This should prove a very valuable quarry as there is little waste and stone of any desired width or thickness is easily obtained.

A small derrick is installed and five men are employed.

The stone: No. 218.—The colour of this example is the brownish grey shown in Plate LXXV, No. 14. On weathering, or on treatment with carbonic acid, it becomes like Plate LXXV, No. 9, but it is marked by very small black dots giving a "pepper and salt" effect. This stone is fine crystalline in grain and in this respect is almost the same as No. 211 from Pridmore's quarry. The physical characteristics follow:—

Specific gravity	2·712
Weight per cubic foot, lbs	168·636
Pore space, per cent	0·366
Ratio of absorption, per cent	0·135
Coefficient of saturation	0·61
Crushing strength, lbs. per square inch	17604·
Crushing strength after freezing, lbs. per square inch	17600·
Loss on freezing, per cent	0·049
Loss on treatment with carbonic acid, grams per square inch	0·016
Transverse strength, lbs. per square inch	2447·
Chiselling factor	5·1

The product is used in Ottawa for rock face work and for dressed stone. The following prices are quoted:—

Sills, rock face, hammered top and bottom, 50 cents per running foot, Ottawa.

Shoddy, $2.50 per cubic yard, Ottawa.

R. O'Connor, Billings Bridge, Lot 23, Junction Gore, Gloucester.

On this property several small pits have been opened but no extensive quarrying has been done. In one excavation there is seen an upper 4 foot bed with a 1 foot and a 10 inch layer below. The stone is much like Thebault's but a little bluer. It is stated that heavy stone is obtained from this quarry for purposes to which the thinner stone from the Montreal road is not adapted.

The stone: No. 219.—In colour and in general physical features this example may be compared with No. 211 from Pridmore's quarry.

In the vicinity of Hammond and Plantagenet are several quarries in Trenton limestone, but as none of these are now in operation the most important only is selected for description.

Percival Whinney, Plantagenet, Lot 9, Con. VI, Plantagenet North, Prescott county.

The quarry is close to the line of the Canadian Pacific railway and is opened in the side of a bluff which is capable of affording an unlimited supply of material. The succession is as follows:—

3 feet—Thin bedded stone.
2 feet—Solid bed.
2 feet—Solid bed.
1 foot—Solid bed.
2 feet—Solid bed.

Farther along the bluff and in a more extensive opening the beds are exposed as below:—

3 feet—Thin material.
1 foot—Solid bed.
2 feet—Solid bed.
6 inches—Thin material.
1 foot—Solid bed.
2 feet—Solid bed.
18 inches—Solid bed.
2 feet—Separable into two beds.
2 feet—Solid bed.
2 feet—Solid bed, in places continuous with the bed above.
10 inches—Solid bed.
10 inches—Solid bed.

The main joints run north and south and the checking is not sufficient to prevent the extraction of large blocks. The bedding is good and the stone of much the same quality throughout, although two types may be recognized, a granular variety and a close grained bituminous example. The latter shows wavy bituminous partings and resembles the stone at Clarence Creek and Rockland in the Black River formation. The granular crystalline type forms alternate bands in the same bed with the close grained type (180 and 181). The even bedding and the variable thickness of the beds make it easy to obtain excellent coursing stone without undue expense.

The stone: No. 180.—This stone, which represents the granular type referred to above, is quite comparable with No. 211 or No. 219 pp. 236 and 238, or with No. 178, p. 204.

No. 181.—This specimen shows a mixture of stone like No. 180 with a very fine grained type; the two varieties are interstratified with wavy bituminous partings. While suitable for heavy construction, this stone is not adapted to building purposes of a finer kind.

This quarry is clean and in excellent shape for a renewal of operations. It is dry, close to a railway, and easily worked. The stone is desirable for heavy coursing and for canal and bridge construction. There is no present production.

D. Howes, L'Orignal, one and a half miles south of the town within corporation.

At the opening, the beds are horizontal, but, a short distance back from the face, they are tilted at an angle of 30° to the southwest with a strike of 35° S. of E.

The main opening is about 12 feet deep and shows in descending order 4 or 5 feet of thin material, then two layers of a foot each with heavier beds below. Well pronounced joints cut the formation at 25° W. of S., and another series of less distinctness is present in the opposite direction.

The stone shows irregularity of bedding throughout and is possessed of the wavy bituminous partings common in the formation. In places the rock is very fossilferous—182—183.

The stone: No. 182.—In colour this sample resembles Plate LXXV, No. 14. It consists largely of the broken shells of organisms which are cemented by a somewhat crystalline matrix. It is fairly soft, but the presence of large shells makes the rock split irregularly and prevents fine chiselling.

No. 183.—Like No. 182 but somewhat coarser, with numerous shells and masses of branching fossils (Bryozoa). This is a solid and fairly soft rock, but it is not adapted for fine work.

There is no regular production from this quarry.

Samuel Parissian, L'Orignal.

This property (the old Murray quarry) adjoins the Howes quarry on the south. The excavation is about 25 feet deep and shows many beds, the thickness of which does not exceed 1 foot. The stone is fossiliferous and of a bluish colour like the material from Howes' quarry. The property is not being worked at present and its condition is not such as to justify exact remarks as to the characters of the various layers. The horizon here may be of Black River age.

Summary—The Eastern Trenton Region.

While a few small quarries are situated in the other Trenton areas mentioned there is no production of stone in the region east of the Archæan axis comparable with that of the Ottawa river area. Two types of stone are produced—the crystalline bluish limestone from Ottawa, and the darker banded type from Plantagenet, L'Orignal and the upper part of the quarry at Rockland. The Ottawa stone is well known and has been largely used throughout eastern Ontario for architectural purposes; a detailed account is given on pages 234 to 238.

Literature:—Geol. Sur. Can., Rep. 1863, p. 166; p. 620; p. 817.
" " " " 1863–66, p. 283.
" " " " 1896, p. 63 A.
" " " " 1897, p. 58 A.
" " " " 1899, pp. 24–26 G; 133–136 A; pp. 32–33 R.
Bur. Mines, Ont., Rep. 1903, p. 28.
" " " " 1904, pt. ii, pp. 37, 38.

The Western Area.

The Trenton limestones of the western area have not been extensively worked despite the broad extent of country covered by these rocks. The following districts may be established:—

The Belleville.

The Prince Edward county.

The Peterborough.

The Belleville district.—North of Belleville are several quarries along the bank of the river from which thin bedded stone is procured for rough construction. C. Donovan is the largest producer, who, besides procuring rough material for lime-burning and other purposes, gets out a quantity of coursing stone. The heavier beds are from 4 to 6 inches in thickness. The face of the quarry is about 20 feet. Stone is also obtained from the bed of the river where the blocks are upturned by the action of flood ice in the spring—94.

The stone: No. 94.—This stone is of the dark grey, granular crystalline type and may be compared with No. 178 or No. 181.

Hammer broken stone is valued at $4 per cord in Belleville.

E. G. Stapley supplies a similar stone from this vicinity.

The Prince Edward district.—The Trenton limestone exposed in Prince Edward county is for the most part very thin bedded and has never been extensively employed for building purposes. Near Picton, however, are several small quarries of which the following may be considered typical.

James Bedborough, Picton.

The quarry is situated to the south of the town and shows the following succession:—

1 foot—Soil.

6 inches—Broken stone.

1 foot—Shale.

2–5 inches—Limestone bed—90.

2–5 inches—Limestone bed.

1 foot—Thin bedded limestone and shale.

2–5 inches—Limestone bed, etc.

The stone: No. 90.—A rough, grey, highly fossiliferous limestone of no promise as a building material.

Mr. Bedborough produces about 50 cords a year for local foundations; a similar amount is produced from quarries belonging to Daniel Sullivan and Miss Hadden.

The Peterborough district.—The Black River, Lowville and Trenton limestone are exposed at various points in Peterborough county. The writer could learn of no quarries in actual operation for the production of building stone and in consequence only one was visited. Miller[1] mentions two quarries, one on lot 24, con. XVI, Smith, and one near Warsaw in Dummer, also a small opening east of Havelock on the line of the C.P.R. I understand also that a small quarry has been opened at Stony lake.

Quarry east of Havelock.

From a rock cut on the C.P.R. a half mile east of Havelock a small quantity of stone has been procured for building purposes. The beds dip west at an angle of 15° and are intersected by joints striking N. 40° W. The upper bed is 5 feet thick but most of it would not yield stone over 14 inches thick. Beneath this are 8 feet of shelly, thin bedded stone, highly fossiliferous and occasionally with layers 1 foot thick. It is all much broken, however, and does not give promise of yielding valuable material.

The stone: No. 2.—This stone is of a brownish colour somewhat resembling Plate LXXVII, No. 13. The structure is granular crystalline and the rock is made up of cemented fragments of organisms. In this respect as well as in the character of the grain, it is very like the stone from Ross' quarry at Hawkesbury or from the quarries east of Ottawa. On weathering, the stone seems to darken in colour; it is fairly soft and should be capable of easy carving.

Miller give the following series of analyses of the Peterborough county limestone:—[2]

	1	2	3	4	5	6	7	8	9
Insoluble residue	....	6·5	1·54	4·99	1·76	2·18	2·20	3·60	6·24
Silica	1·96	....	....	....	....	....	....	....	
Ferric oxide	·61	·40	·30	·55 }	·38	·32	·50	·56	·54
Alumina	2·37	·54	·10	·20 }					
Lime	51·22	50·60	53·14	51·10	53·40	52·76	53·08	52·30	50·30
Magnesia	·70	·65	·65	·69	·57	·60	·60	·41	·97
Carbon dioxide	40·75	40·41	42·37	42·44	42·50	41·93	42·16	41·47	40·52
Loss	2·29	....	....	....	1·34	1·83	1·18	1·91	1·22
Sulphur trioxide	·24	·31	·10	·11	·13	....	·23	·39	·26
Alkalies	....	....	....	....	....	·18	....	....	

No. 1—Small quarry just east of Havelock.
No. 2—Clear lake near Burleigh Falls.
No. 3—Lot 42, con. XVI, Smith, just below top of cliff.
No. 4—Same locality, different bed.
No. 5—Topmost layer, cliff near hotel.
No. 6—Lot 44, con. XVI, Smith.
No. 7—Lot 45, con. XVI, Smith, top of cliff.
No. 8—Lots 1 and 2, just south of Lakefield boundary.
No. 9—Between second and third locks.

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 97-98.
[2] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 98.

Fig. 17. Sketch map showing the chief quarries in the Niagara formation in Ontario.

THE LIMESTONES (DOLOMITES) OF THE NIAGARA FORMATION.

The limestones of this formation constitute the upper part of the escarpment (cuesta) reaching from Queenston heights to the Bruce peninsula. Along this line numerous quarries have been operated from which excellent stone for both heavy construction and for architectural purposes has been obtained. Although general remarks on the stone from such an extended area are of little value it may be said that Niagara stone is generally of a dolomitic character, it is usually of a light colour with a yellowish cast and it is more porous than the average stone from the older formations already described. The quarrying industry is centered around the following points, which will serve to demarcate areas for the purpose of description:—

The Queenston area.
The Thorold area.
The Beamsville area.
The Hamilton area.
The Central area.
The Owen Sound area.
The Wiarton area.

The Queenston Area.

At the present time two companies are operating near St. Davids in Lincoln county—the Power City Stone Co. and the Queenston Quarry Co. The former company crush all their product while the latter firm work two quarries, from one of which only building stone is obtained. For the purposes of the present report therefore a description of this quarry is indicative of the Queenston area.

Queenston Quarry Co., Charles Lowrie, president, St. Davids; N. P. Sanders, superintendent, St. Davids, Lots 47, 48, 49, *Con. X, Niagara, Lincoln county.*

The building stone quarry of this company is situated about 300 yards back from the face of the cuesta and shows a different series of beds from that presented by the face. An idea of the magnitude of past operations may be obtained from the fact that 12 acres have been quarried to a depth of 30 feet. The succession of beds is as follows:—

6 feet—Stripping.

2 feet—Grey stone, fossiliferous, sandy, used for rough work only, and for lime.

10 feet—Solid grey stone like above—275.

4 feet—Solid bed, light blue limestone, resembles the Thorold stone.

10-11 feet—Solid bed, dark blue limestone—276.

The upper part of the grey stone is honeycombed in places, whereby its value is reduced; the blue stone is fine and even in grain, the lower beds being better than those above. There is not sufficient jointing to interfere with the quarrying of blocks of any desired size. Pieces containing 100 cubic feet are often raised.

The stone: No. 276.—This limestone has a distinctly bluish cast and is represented in Plate LXXV, No. 8. On weathering, it loses the blue colour but assumes a pleasing grey tint like Plate LXXV, No. 7.

The structure is granular crystalline, the stone being largely made up of fragments of fossil organisms; in this respect it resembles the Chazy stone from Ross' quarry in East Hawksbury or the Trenton stone from the quarries east of Ottawa. Except for the lighter colour, its general appearance and structure are comparable with the examples mentioned. Certain of the physical properties are, however, quite different as may be seen by comparing the following table with those given for the eastern stones:—

Specific gravity	2·789
Weight per cubic foot, lbs	162·015
Pore space, per cent	6·92
Ratio of absorption, per cent	2·67
Permeability, c.c. per square inch per hour	5·
Coefficient of saturation	0·32
Crushing strength, lbs. per square inch	18691·
Crushing strength after freezing, lbs. per square inch	12689·
Loss on freezing, per cent	0·092
Loss on treatment with carbonic acid, grams per square inch	0·0581
Transverse strength, lbs. per square inch	2361·
Chiselling factor	4·6

Analysis: H. A. Leverin, Mines Branch laboratory:—

Insoluble matter	1·12
Ferrous oxide	·90
Ferric oxide and alumina	·60
Calcium carbonate	72·37
Magnesium carbonate	24·12
Sulphur	·064

No. 275.—This is a brownish grey rather than a blue stone and is shown in Plate LXXVI, No. 13. On exposure, or on treatment with carbonic acid, it alters very little in colour. The texture is crystalline like No. 126, but the stone is much more open and would show a much higher pore space and a correspondingly lower crushing strength. The physical properties which were determined are as follows:—

Transverse strength, lbs. per square inch	1619·
Chiselling factor	6·4

Quarrying is effected almost entirely by the use of plug and feathers. It is found that stone 5 feet thick splits with a smooth even fracture by this method. When powder is employed the Knox method is used. The stone is handled by five steam derricks of 10 tons capacity each. A railway siding affords ample facilities for shipping. About 40 men are employed at present.

The following prices are quoted, all f.o.b. St. Davids.

Dimension stone, 40 cents per cubic foot.

Shoddy, cut, $18 per cord.

Shoddy, rough, $9 per cord.

Rubble, $3 per cord.

Sills, rough, 25 cents per running foot.

Sills, bush hammered, top, bottom and ends, 60 cents per running foot.

Sills, bush hammered, top, bottom and ends, logged, $1.25 per running foot.

Examples of Queenston stone may be seen in the following structures:—

Custom House and Post-office, Niagara Falls, Ont.

Post-office, Cornwall.

Post-office, St. Catharines.

Power houses, Niagara Falls, N.Y.

Ont. Power Co., overflow building, Niagara Falls.

Goat Island bridge, Niagara Falls.

Canadian Power Co., Niagara Falls.

Clifton hotel, Niagara Falls.

Electric Ry. bridge over intake, Can. Power Co., Niagara Falls. (Plate LII.)

Brock's monument, Queenston heights.

Welland canal, Grand Trunk Railway bridges, etc.

The quarry for crushed stone is situated on the brow of the cuesta at St. Davids. The excavation is about 500 feet by 200 feet, exposing the following succession of beds:—

2 feet—Stripping.

18 inches—Thin beds.

4 feet—Rough honeycombed rock, of greyish colour.

1 foot—More compact rock, soft.

5 feet—Compact bed, shattered by explosives, soft grey.

1 foot—Thin beds, soft grey.

10 feet—Almost solid blue limestone, resembles the stone of the building stone quarry.

6 feet—Cement rock.

All the product of this quarry is crushed and the product conveyed by chutes to cars on the siding of the Michigan Central railway.

Power City Stone Co., J. H. Symmes, president, Niagara Falls; Robin Boyle, secretary, Niagara Falls.

The property of this company adjoins that of the Queenston Quarry Co. The excavation is abut 300 yards long and has been carried 100 feet into the hill. The same beds are exposed as in the quarry of the other company. With the exception of a little rubble no building material is produced, the whole of the product being crushed fer macadam, etc. The plant is provided with the necessary apparatus for quarrying, crushing and loading. About 30 men are employed. The average price for crushed stone for macadam is 90 cents per cubic yard, f.o.b. St. Davids, and for concrete 80 cents per cubic yard.

The Thorold Area.

Near Thorold, Merritton, and St. Catharines, and eastward along the cuesta are a number of quarries in Niagara limestone. While it is convenient to include these quarries in one geographical group it does not follow that the stone is similar in them all.

A high grade building stone is produced from the properties of Walker Bros. and Wm. Cartmell, at Thorold, while harder and more compact material comes from most of the other openings in the vicinity. The more important quarries of the second class are the following:—

The Battle quarries at Thorold.

Kearney and Campbell, lot 14, con. X, Grantham.

Peter Belton, lot 17, con. VII, Louth.

Walker Bros., Merritton, Lots 31 *and* 32, *Stamford, Welland county.*

The property consists of about 12 acres on which 3 or 4 acres have been quarried to a depth of 18 feet or more. There are several openings of which the two more important show the following succession:—

6 feet—Stripping.	8 feet—Stripping.
18 inches—Solid bed.	7 feet—Solid bed.
12 inches—Solid bed.	8 feet—Solid bed.
6 feet—Thin, 4 inch beds.	6 feet—Solid bed.
6 feet—Solid bed.	

The jointing is not developed sufficiently to interfere with the obtaining of stone of the largest dimensions required. The good stone (88) is much alike in all the beds.

The stone: No. 88.—This example is lighter than the Queenston stone and is shown in Plate LXXVII, No. 2. The colour is permanent, as scarcely any difference is seen after treatment with carbonic acid. The structure is very similar to that of the blue Queenston stone. The physical properties are listed below:—

Specific gravity	2·726
Weight per cubic foot, lbs	162·653
Pore space, per cent	4·395
Ratio of absorption, per cent	1·68
Permeability, c.c. per square inch per hour	4·
Coefficient of saturation	0·56
Crushing strength, lbs. per square inch	10331·
Crushing strength after freezing, lbs. per square inch	11500·
Loss on freezing, per cent	0·142
Loss on treatment with carbonic acid, grams per square inch	0·0963
Transverse strength, lbs. per square inch	1529·
Chiselling factor	7·2

Plate LII.

Queenston Limestone. Electric Railway Bridge over the Intake, Canadian Power Co., Niagara Falls, Ont.

This would appear to be a very desirable stone; the colour is good and permanent, the saturation coefficient is sufficiently low that no danger of injury by frost is to be apprehended, and the stone has the advantage of being very easily carved.

The equipment consists of six derricks, four of which are operated by steam from individual boilers, two Sargeant drills, two steam pumps, and a quantity of minor quarrying apparatus. Black powder is used when an explosive is necessary.

A large amount of cut stone was formerly produced from this property but none has been made during the last three years. At the present time only three men are employed. Mr. Walker quotes the following prices, all f.o.b. quarry siding.

Rough stone, $4 per cord.
Shoddy, 60 cents per superficial foot.
Dimension stone, 50 cents per cubic foot.

The stone may be seen in the following structures.

Armouries, Hamilton, Toronto, Chatham, St. Catharines.
Imperial Bank walls), Niagara Falls.
mperial Bank, St. Catharines.
Frenchman's Creek bridge.
Niagara boulevard.

Wm. Cartmell, Thorold, Lots 4 and 5, Thorold, Welland county.

The property consists of about 18 acres on which 6 acres have been quarried to a depth of 35 feet. At the present time 14 feet of stripping have to be removed; beneath this lies 9 feet of beds ranging from 1 foot to 2½ feet in thickness. This stone is hard, full of cavities and of less desirable colour; it is succeeded by a blue stone similar to Walker's but a little darker in colour. This bed, which is 14 feet thick, is solid in places, but it usually parts into a 6 and an 8 foot bed. Adequate equipment is in place but operations have been largely suspended, only three men being employed.

Owing to the fracturing by dynamite the character of the jointing cannot be determined. The bedding is irregular with bituminous partings. The lower beds should yield excellent stone for heavy construction.

The equipment consists of a derrick, steam drills and a 20 horse-power traction boiler. Twelve men are employed. Dimension stone was obtained from this quarry for the construction of locks Nos. 56 and 57 on the Welland canal. At the present time the product is all crushed. The haul to the nearest shipping point is 2½ miles.

Peter Belton, Lot (—) Con. VII, Louth, Lincoln county.

Mr. Belton's quarry has been opened along the brow of the cuesta for a distance of 200 yards. The width varies from 50 to 150 feet. The following beds are exposed:—

2 feet—Soil.

4 feet—Apparently solid but in weathering breaks into layers 4 to 6 inches thick.

18 inches—Fairly solid layer.

18 inches—Solid bed.

3 feet—With irregular lenticular partings. Weathers spotted. Fragments weather rapidly showing dark centre with a broad band of lighter material outside—85.

The upper layers show crystals of zinc blende and gypsum thoughout the rock.

The stone: No. 85.—The fresh stone has a colour similar to Plate LXXV, No. 4. The weathered stone is like Plate LXXVI, No. 5. The structure is fine crystalline. The rapid alteration to which this stone is subject must detract from its value.

Examples of stone from this quarry may be seen in Power House No. 1. Niagara Falls, N.Y.

Joseph Battle, Thorold.

These quarries are of considerable extent, reaching for one-fourth of a mile along the escarpment east of the canal at Thorold. The upper 15 feet of rock show thin bedded stone much shattered by dynamite; the maximum layers do not appear to exceed 1 foot in thickness. Beneath the limestone are 9 feet of smooth, fine grained, non-fossiliferous cement stone which has been quarried by tunneling under the overlying limestone.

An extensive plant, consisting of travelling derricks, drills, and crushing apparatus is installed. The product is all crushed and may be loaded directly into scows on the canal or shipped from a siding of the Niagara Central railway. No building stone is produced.

Kearney and Campbell, Thorold, Lot 14, Con. X, Grantham, Lincoln county.

This property belongs to Jacob A. Ball and is worked by Kearney and Campbell under lease. The quarry is about 200 feet by 100 feet and presents the following succession of beds:—

18 inches—Stripping.

3 feet—Soft, reddish, friable limestone.

3 inches—Soft parting.

2 feet—Limestone bed, would give 18 inches stone.

10 inches—Limestone bed.

4 feet—Limestone, distinctly bedded, in places parts into thin beds.

3 inches—Solid bed.

1 foot—Solid bed.

5 inches—Solid bed.

10 inches—Solid bed.

4 feet—Solid bed of good blue limestone.

3 feet—Solid bed of good blue limestone—86.

The stone: No. 86.—This is a dark brownish grey stone and presents very nearly the colour shown in Plate LXXV, No. 11. In structure it is hard and compact, presenting a fine grained base in which are imbedded larger crystals of calcite. The fracture is somewhat splintery and the stone would be hard to dress.

The stone from this quarry is sold in the rough in St. Catharines at from $5.50 to $6 per cord. The output was formerly about 600 cords a year but this production has fallen to 150 cords. The stone may be seen in McKinnon's dash works in St. Catharines.

The Beamsville Area.

Near Beamsville are the large quarries formerly operated by the Hon. Wm. Gibson. Besides these there are numerous small quarries near Grimsby, Jordan, Vineland, and eastward to the Thorold area.

Hon. Wm. Gibson, Beamsville, Lots 13 *and* 14, *Con. VI, Clinton, Lincoln county.*

The quarries extend beyond the limits of the lots mentioned above and have been opened along the brow of the mountain for nearly a mile with an average width of 30 rods. Beneath a very light stripping, from 10 to 15 feet of heavy bedded greyish limestone have been exposed by quarrying operations. While there seems to be a division indicated between the upper 7 and the lower 8 feet, it cannot be stated that there is a very sharp line between the two or that each bed is solid stone throughout. Parting planes cross the beds at low angles so that the stone is divided into large lens-like masses. The thickness of stone is therefore variable, but much of it is four feet through, and it is stated that solid material 13 feet in vertical extent could have been obtained at one time. The formation dips northward at a low angle. Joints run east and west parallel to the face of the escarpment but they are so widely spaced as to cause no difficulty in the quarrying of large blocks.

The stone is marred somewhat by the presence of cavities which contain iron pyrites and other minerals. The upper beds, particularly towards the eastern end of the quarry, are much freer from this disfigurement.

Of the specimens described below, No. 119 is from the east end and No. 120 from the west end of the quarry.

The stone: No. 119.—The colour is light yellowish brown and is shown on Plate LXXVI, No. 14. On weathering, or on treatment with carbonic acid, there is no change in colour except that due to absorbed dirt which is liable to render the stone darker. The structure is of a fine semi-crystalline character with numerous pores of visible size. The stone is of similar character throughout large blocks. As this material was formerly largely employed its physical characteristics were determined as below:—

Specific gravity	2·842
Weight per cubic foot, lbs.	153·544
Pore space, per cent	13·427
Ration of absorption, per cent	4·93
Permeability, c.c. per square inch per hour	32·7
Coefficient of saturation (this is a good example of a stone with a high porosity and yet which stands in little danger of injury by frost)	0·28
Crushing strength, lbs. per square inch	9670·
Crushing strength after freezing, lbs. per square inch	9572·
Loss on freezing, per cent	0·037
Loss on treatment with carbonic acid, grams per square inch	0·00777
Transverse strength, lbs. per square inch	931·
Chiselling factor	3·75

Analysis by H. A. Leverin shows the composition to be:—

Insoluble matter	2·24
Ferrous oxide	1·00
Ferric oxide and alumina	·15
Calcium carbonate	55·71
Magnesium carbonate	40·29
Sulphur	·015

No. 120.—Not essentially different from above.

These quarries were at one time a centre of great activity as may be seen from the following statement: "The quarries were opened by Mr. Gibson, in May, 1884, and have been worked continuously since with a large force of laborers, quarrymen and stone-cutters. The amount paid for wages in 1890 was $87,440, but last year the staff of workmen was increased, and in the month of June, 160 were employed, the wages paid to quarrymen alone in that month being $7,500."[1]

The stone is particularly adapted to works of heavy construction, but as a building stone it is a desirable material. After exposure to the weather the stone assumes a darker, but not displeasing colour. Most of the output was used in bridge and culvert construction on the Grand Trunk railway; it was also used on the Welland canal and in the construction of the St. Clair tunnel. An immense amount of this stone is still available. Dismantled derricks and other machinery are still on the property, as well as the remains of the gravity tramway by which the stone was formerly conveyed to the railway at Beamsville. Operation has been entirely suspended.

Near the village of Jordan, Niagara limestone is quarried on a small scale by several operators. A. K. Wismer obtains both limestone and sandstone in the bed of Twenty Mile creek and crushes his entire product. R. C. Rubell has a quarry 1½ miles south of Jordan, which has been opened to a depth of 10 feet over an area of 2 acres. The stone is thin bedded, the

[1] Bur. Mines, Ont., Rep. 1891, p. 97.

maximum thickness being 18 inches. Baker's quarry, near the village, produces thin bedded material suitable for flagging. The most important of these small quarries is that of Jacob M. Fretz described below.

Jacob M. Fretz, Vineland, Lot 1, Con. VII, Clinton, Lincoln county.

The quarry is situated on the top of the mountain in the face of an upper minor escarpment. The beds are therefore at a high level in the Niagara series as exposed in this region. The opening is quite small with the following succession of beds:—

3 feet—Rough, pitted limestone.
4 feet—Limestone, parting readily into thinner material.
5 feet—Limestone, parting readily into thinner material.
18 inches—Limestone, parting readily into thinner material.
6 feet—Very irregularly bedded stone, mostly thin.

While the division into beds as indicated above is a geological feature of the formation there is no real difference in the character of the stone below the upper pitted bed; it all breaks up into thin layers of which the maximum is about 8 inches. In quality all the lower beds are alike—81.

The stone: No. 81.—This is a cavernous dolomitic limestone resembling that from Gibson's quarries at Beamsville. The colour is a little darker and resembles that of Plate LXXVI, No. 13. Occasional specks of iron pyrites are seen throughout the rock.

Most of the output is used for road metal and in the construction of foundations, about 100 cords having been used for the latter purpose during the present year.

Mr. Fretz estimates the cost of quarrying at $2 per cord and he is willing to dispose of his output at $2.50 per cord in the quarry, at $4 per cord in Vineland, and at $5 per cord f.o.b. Vineland station.

The Hamilton Area.

Niagara limestone has been quarried in the vicinity of Hamilton, Ancaster and Dundas for many years; abandoned quarries mark the brow of the mountain for miles. Experience has shown however that a better quality of stone for building purposes is obtained some distance back from the edge of the cuesta; in consequence, most of the quarries that are now operating in the face of the mountain are conducted for the production of crushed stone only. The most important of this class of quarries is that of Doolittle and Wilcox at Dundas which is described below. Of building stone quarries the most important are those of Marshall and of Gallaher south of Hamilton and that of Middleton at Ancaster.

Doolittle and Wilcox, Dundas.

This extensive quarry is situated at the "Peak" near the G.T.R. station at Dundas. Ten acres have been quarried to a depth of 20 feet and 4 acres to a depth of 40 feet. The upper 20 feet consists of beds from 1 foot to 30 inches in thickness which are practically of the same character throughout—121. The lower 20 feet is quite different in character, presenting a harder, more thinly bedded stone showing a distinctly banded structure and breaking with an irregular fracture—122.

The stone: No. 121.—This stone presents a brownish colour like Plate LXXVI, Fig. 1. On weathering, it assumes a more yellowish cast. The structure is fine crystalline. The crystals are uniform in size and closely set together so that the stone would be somewhat hard to cut. Stratification planes are visible. The stone breaks easily and could be readily made into rubble or coursing stone.

No. 122.—A hard splintery dark grey stone of much the same character as No. 86 described on page 249.

An average of ten cars shipped from this quarry to the Lackawanna Steel Co. gave the following analysis:—

Calcium carbonate	55·38	per cent.
Magnesium carbonate	45·05	"
Silica	0·3	"
Alumina and ferric oxide	0·6	"
Phosphorus	0·009	"

From the upper beds an average of five cars gave 0·4 per cent of silica. The lower beds run higher in silica averaging 1·05 per cent.

This company has an extensive equipment for quarrying, crushing and loading stone. While it is not proposed to describe the plant in detail, the following list will convey an idea of the magnitude of the operations.

Siding from G.T.R. 1½ miles.

Inclined standard gauge railway to top of mountain, equipped with 1¼ inch cable operated by a powerful winding engine—250 feet elevation.

36 gauge track, one mile.

Locomotives, 3.

Small cars, 44.

Steam shovels, of 35 tons capacity, 2.

Steam shovel, 105 tons, 1.

Crusher—One McCully, No. 21, by Power Mining and Machinery Co., Cudahy, Wis.

Crushers—One No. 8, one No. 7½, one No. 7 Austin.

Electric power plant.

Electric pulsator drills, Canadian Rand Co.

Total crusher capacity, 6000 tons per day.

Acreage of property, 115.

Men employed, 100.

Pay-roll, $60,000 a year.

Quarrying is effected by sinking a line of holes about 6 feet apart and an equal distance back from the face. These holes are sunk to a depth of 20 feet and are charged with dynamite. The broken rock is loaded into cars by steam shovels and conveyed to the crushers. The crushed stone passes down chutes to bins at the siding whence it is loaded into the cars.

Sixty per cent of the product is used at Hamilton and Buffalo as flux for iron furnaces. The average price for crushed stone, f.o.b. Dundas, is 65 cents per ton.

James Marshall, Hamilton, Lot 14, *Con. VII, and Lot* 16, *Con. VI, Barton, Wentworth county.*

Mr. Marshall has opened quarries at several points on his property; in all, about 5 acres has been quarried to an average depth of 15 feet showing the following succession in one of the openings:—

2 feet—Stripping.
3 feet—Rough, fossiliferous, cavernous stone.
1 foot—Sometimes solid, sometimes divided into layers.
1 foot—Solid bed.
18 inches—Solid bed.
3–4 feet—Solid bed.

All the beds beneath the upper rough 3 foot bed are essentially alike and show a fine laminated appearance. The product of this quarry is used entirely for lime-burning.

A second opening, the output of which is used more particularly for building, presents the following beds:—

2 feet.—Stripping.
3 feet.—Hard upper bed, not used for building stone.
6 feet.—Thin bedded stone.
4 feet.—Honeycomb, used for lime-burning.
4 feet.—Light brown coursing stone, divisible into beds of from 6 inches to 2 feet in thickness—126.
5 feet —Dark brown coursing stone, divisible into beds from 4 to 14 inches thick—127.
Cavernous beds.

It is interesting to note that a drill hole sunk by Mr. Marshall showed 284 feet of limestone down to the white Medina.

The stone: No. 126.—This stone presents the light brown colour shown on Plate LXXVI, No. 5. On weathering, scarcely any change is perceptible but prolonged exposure may result in a lighter and somewhat more yellow tint. The structure is uniform, fine grained, crystalline, with scattered pores of a size to be seen with the naked eye.

The structure is the same, except for a greater amount of pore space, as in the stone from the upper beds at Doolittle and Wilcox's quarry at Dundas. This stone saws and chisels easily; the cubes for testing prepared from it presented a particularly attractive appearance, the edges and angles being firm and sharp despite the ease of cutting. With the physical properties given below it is surprising that this stone has not come into more general use in Hamilton.

Specific gravity	2·843
Weight per cubic foot, lbs	168·512
Pore space, per cent	8·939
Ratio of absorption, per cent	3·46
Permeability, c.c. per square inch per hour	2·37
Coefficient of saturation	0·34
Crushing strength, lbs. per square inch	19548·
Crushing strength after freezing lbs. per square inch	18844·
Loss on freezing per cent	0·024
Loss on treatment with carbonic acid, grams per square inch	0·00296
Transverse strength, lbs. per square inch	3172·
Chiselling factor	6·

Compare No. 33 from Cook's quarry, Wiarton, p. 262.

An analysis by H. A. Leverin follows:—

Insoluble matter	·36
Ferrous oxide	·57
Ferric oxide and alumina	·41
Calcium carbonate	55·90
Magnesium carbonate	42·70
Sulphur	·013

No. 127.—This stone is almost as dark as Plate LXXVI, No. 1; it is practically identical with the stone from the upper beds at Doolittle and Wilcox's quarry at Dundas. It is probably less easily carved than No. 126.

Both the light and dark brown coursing stone is now used in Hamilton in preference to stone from the brow of the mountain, as it retains its colour better and is more serviceable in a general way. The light brown variety is preferred for work above ground and is used extensively for the fronts of residences. No cut stone is now prepared from the product of this quarry.

On the property, coursing stone is valued at $4.50 per cord and rubble at $2.50 per cord. The haul of two miles into Hamilton materially increases this cost when the stone is delivered at the work. Mr. Marshall is now producing about 5 cords a day. (Plate LV.)

Gallagher Bros., Hamilton, Lot 16, *Con. V, Barton, Wentworth county.*

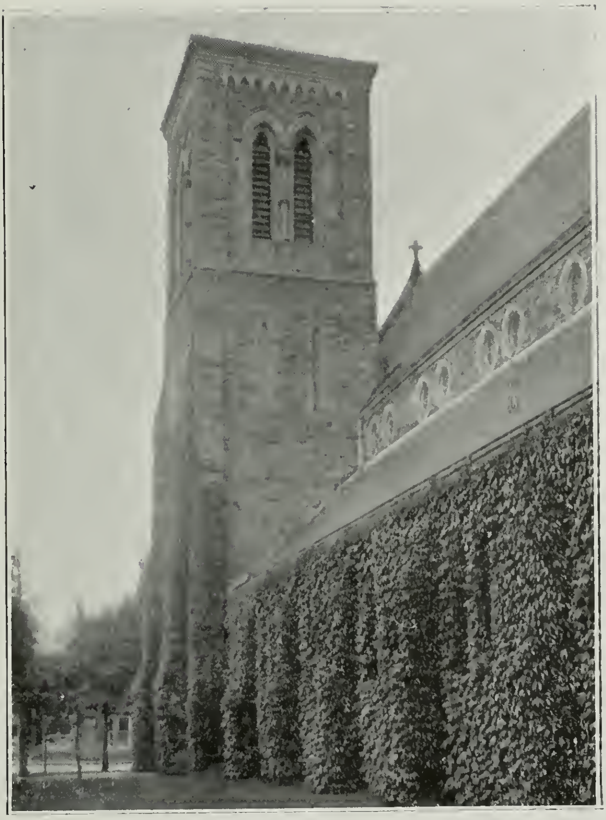
On this property, which is close to that of Marshall, 5 or 6 acres have been quarried to a depth of from 10 to 25 feet. The lower 14 feet only are used for building material, the production of such material being regarded as of little importance compared with the making of lime. Coursing stone is produced which differs but little from that of Marshall; it is valued at $3 per cord at the quarry. Rubble is quoted at $2.50 per cord. About 1,000 cords of building stone are hauled into Hamilton every year—125.

The stone: No. 125.—This stone belongs to the same type as that from Marshall's quarry; it is as dark as No. 127, but has the porous structure of No. 126.

Plate LIII

Niagara Limestone at Hamilton. Gallagher's Quarry.

Plate LIV.



Niagara Limestone. St. Patrick's Church, Hamilton, Ont.

Niagara Limestone, Marshall's Quarry, Hamilton. Residence in Hamilton.

Westward from Marshall along the same ridge are several other operators among whom may be mentioned Charles Hildreth, Horace Fenton, and James Fenton. There are also several quarries at Rymal near the line between Barton and Glanford; the chief of these is the Barnes quarry from which limestone was obtained for the blast furnace at Hamilton.

Edward J. Guest, Ancaster.

This quarry is opened on the Hamilton stone road near Ancaster; it has been excavated to a width of 50 feet and shows the following succession of beds:—

3 feet—Stripping.
2 feet—Honeycomb.
2 feet—Good solid stone.
18 inches—Honeycomb.
18 inches—Solid bed.
18 inches—Solid bed.
2 feet 6 inches—Solid bed—128.
16 inches—Solid bed.
20 inches—Solid bed.
18 inches—Solid bed.
18 inches—Solid bed.

All the lower beds are much alike; they show wavy partings with black bituminous matter and split easily into thinner material.

The stone: No. 128.—This example is almost exactly like No. 127 from Marshall's quarry at Hamilton; it is close grained and compact with few interspaces such as are shown in the lighter stone from Marshall's.

John Henry, Ancaster.

Mr. Henry's quarry adjoins Guest's and shows the same beds. A small amount of building stone is procured here in the winter. The stone is exactly the same as that described above for Guest's quarry; it is valued at $2.25 per cord on the ground.

Peter Middleton, Ancaster.

The quarry is south of the stone road near Ancaster. The following beds are exposed:—

2 feet—Honeycomb.
18 inches—Honeycomb.
3 feet—Solid, but strongly laminated.
3 feet—Solid but laminated more strongly than the bed above, shows distinct light and dark bands and vugs of celestite.
3–6 inches—Thin material.
3 feet—Solid bed, less laminated, better stone—129.
2 feet—Thin material.
3 feet—Solid bed, but with lenticular partings.

The stone: No. 129.—This is another example of the brownish crystalline dolomite like Nos. 126, 127 and 128. The colour, in this instance, is a rather yellowish brown and the stone is somewhat softer than No. 128.

Stone selected so as to avoid excessive lamination and a profusion of cavities has a uniform brown colour and weathers a pleasing grey. The Ancaster stone from this and other quarries does not turn soft and yellow like the material formerly quarried along the face of the mountain at Hamilton. Several churches in Ancaster show that the stone wears well, the only change being the alteration from a brown to a grey colour.

Mrs. Alonzo Eccleston, Ancaster.

The quarry is 150 feet by 100 feet and 30 feet deep. The building stone is the same as that of Middleton's quarry. The stone is quarried by the use of dynamite and the product is converted into lime or crushed stone.

The quarries of G. F. Webb and Geo. Mills on the mountain side at Hamilton have already been described under sandstone (see pp. 143–144). The specimen described below (123) is from Webb's quarry and is typical of the limestone now obtained for building purposes from the face of the escarpment. Old buildings in Hamilton show that much of the stone used 50 years ago has become very soft on the surface and has acquired a dirty yellow colour. Unequal weathering has rendered the planes of stratification very apparent. It is impossible to say whether the specimen described below is from the same bed that yielded the stone for these early buildings.

The stone: No. 123.—This stone presents the colour shown in Plate LXXV, No. 8. In structure it is semi-crystalline and of finer grain than the brown stones from Marshall's and from Ancaster. The fine porous interspaces are not seen but occasional larger cavities are present which are filled with crystals of calcite or with decomposed matter. If this stone represents the same type as that used from the brow of the mountain for building purposes in Hamilton 50 years ago, its weathering qualities with respect either to colour or to durability are not of a high order.

The Central Area.

Niagara limestone is encountered along the brow of the cuesta from Milton to above the Forks of the Credit and is again apparent near Orangeville. Throughout this region, which may be called the central area, there is little production of stone for building purposes. Small lime kilns have been erected at several points and larger operations for lime are conducted, more particularly at Limehouse and near Milton. Carroll and McKnight are producing crushed stone from the beds overlying the sandstone at the Forks of the Credit.

Toronto Lime Company, W. Gowdy, local manager, Limehouse.

Extensive quarrying has been conducted at this point and a face of 1,000 feet long exposed. The section shows the following series of beds:—

3–4 feet—Fairly solid bed.

4–5 feet—Solid in part, but usually divisible into thinner material.

3 feet—Like above.

10 feet—Very irregular beds, mostly thin but stone from 8 to 10 inches thick could be obtained. The lower part is in places 3 feet thick.

Cement Beds.

The stone is hard and finely porous with a light bluish colour. The intensity of colour increases with depth. The bottom 3 foot bed is blue, hard and solid and would make excellent stone for heavy construction. The entire product is converted into lime.

Joseph Hodgson, Orangeville.

The opening is about 200 feet by 50 feet on a hillside to the south of Orangeville. The beds exposed are as follows:—

3 feet—Stripping.

4 feet—Thin bedded material.

1 foot 7 inches—Solid bed.

2 feet 4 inches—Solid bed.

2 feet—Solid bed.

6 inches—Solid bed.

2 feet—Solid bed.

All of the beds tend to split into thinner material on weathering. The stone is cavernous and hard; it rapidly weathers grey and later turns a dirty yellow colour (55). The output is converted into lime or used in the construction of foundations.

The stone: No. 55.—This stone is very light in colour like Plate LXXVII, No. 3. In structure it is fine crystalline. Numerous large cavities which represent the original position of fossils detract from the value of the stone as a building material. It is hard and weathers a very unattractive dirty yellow colour.

The Owen Sound Area.

At Owen Sound two types of stone are produced; that from the east of the town is a high grade building material, while that from the north and west is more adapted to the production of crushed stone, although it is used in small quantity for purposes of construction.

Geo. A. Perkins, Owen Sound.

The property consists of 9 acres, situated on the top of the mountain to the southeast of Owen Sound. The top bed, which is 6 feet deep is the only one quarried. While solid in place, this bed is usually divided into two layers of 3 feet each. The joints, which run in every direction, are from 4 to 50 feet apart. A troublesome series of minor joints (dries) runs in a north and south direction; they are sometimes so close together as to render the stone worthless. It is estimated that about half the available material is ruined on this account. Systematic quarrying has been hindered by the presence of these checks, for it is found to be more economical to open small pits on the better parts of the exposure than to conduct large operations involving the removal of a large amount of worthless material. It is further found that the bed is not of the same quality throughout but that it presents hard and soft patches at different points. (131 hard, 130 soft).

The stone: No. 130.—The colour of this stone which is very light is shown in Plate LXXVI, No. 15. On treatment with carbonic acid no distinct difference is perceptible. On natural weathering, however, a darker colour is acquired, due doubtless to the imbibition of dirt. Like all the Niagara dolomites, the structure is of a fine-crystalline character. Occasional dark brown spots detract somewhat from the appearance of the stone, but these are not sufficiently numerous to constitute a serious objection. This stone, as representing the best of the northern Niagara dolomites, was examined in detail; the results of the tests follow:—

Specific gravity	2·825
Weight per cubic foot, lbs	157·96
Pore space, per cent	10·4
Ratio of absorption, per cent	4·24
Permeability, c.c. per square inch per hour	37·6
Coefficient of saturation	0·37
Crushing strength, lbs. per square inch	15404·
Crushing strength, after freezing, lbs. per square inch	12916·
Loss on freezing, per cent	0·0643
Loss on treatment with carbonic acid, grams per square inch	0·00805
Transverse strength, lbs. per square inch	1111·
Chiselling factor	4·4

An analysis by H. A. Leverin follows:—

Insoluble matter	·26
Ferrous oxide	·33
Ferric oxide and alumina	·59
Calcium carbonate	52·76
Magnesium carbonate	45·65
Sulphur	·026

This stone is very high in magnesium carbonate, containing the exact theoretical precentage of pure dolomite.

No. 131.—This stone is of a bluish cast and resembles Plate LXXVII, No. 2. In structure it is very like No. 130, but it is undoubtedly much more difficult to work.

Plate LVI.

Niagara Limestone, Cook's Quarry, Wiarton, Ont.

Plate LVII.

Niagara Limestone, Perkins' Quarry, Owen Sound. Post-office, Owen Sound, Ont.

All the stone shows the planes of stratification in dark irregular lines, which become less pronounced in time as the stone itself darkens on exposure.

Two derricks are erected on the property. Five stone cutters and two quarrymen are employed during the summer months: cutters receive 40 cents and quarrymen 20 cents per hour. Mr. Perkins has furnished the following list of prices:—

Coursing stone, 8 inch, 35 cts. per running foot.

Coursing stone, 10-12 inch, 40 cts. per running foot.

Dimension stone, monument bases dressed on all sides, $1.30 per cubic foot.

Sills, 5¾ inch, dressed, 40 cts. per running foot.

Rough stone in dimension blocks, 42 cts. per cubic foot.

Mr. Perkins does a business of about $2,550 annually. He finds it possible to compete with other stone as far south as Chesley on the G.T.R. and Markdale on the C.P.R.

The stone may be seen in the following structures:—

Methodist church, Markdale.

Hospital, Owen Sound.

West Side Methodist church, Owen Sound.

Methodist church, Port Arthur.

Jail, Gore Bay.

Post-office, Owen Sound. (Plate LVII.)

Church of England, Owen Sound.

The post-office in Owen Sound is a very fine example of the use of this stone. The colour has become darker and the original lamination of the rock is still perceptible. This lamination is however so even that it does not detract from the appearance of the building. The stone appears to have worn excellently. Dressed work shows less "plucking" than is common in the fine grained limestones.

Wm. Brown, Owen Sound.

Mr. Brown conducts quarrying operations on the road allowance adjoining Perkins. Two men are employed during the summer. The stone is the same as Perkins'.

David Chalmers, Owen Sound.

Mr. Chalmers has a large lime kiln near the properties described above. The same stone is used for lime-burning. An analysis furnished by Mr. Chalmers shows 55 per cent calcium carbonate and 45 per cent magnesium carbonate with only ·5 per cent of impurities.

On the hill to the northwest of Owen Sound about 100 acres of rock are accessible for quarrying operations. The formation is quite different from that exposed at Perkins' quarry and seems to belong to the Clinton rather than to the Niagara series. The chief operators are Davis, Smith and Malone, Oliver and Webster, Charles Hazelton, and O. Checkley. The stone is, for the most part, thin bedded, hard and dark in colour and is more suitable for foundations and rough rubble than for purposes of fine construction. Some of the older buildings in Owen Sound are built of this stone, but they do not present an attractive appearance, as the dressed work particularly has turned a yellowish green and not very uniform colour. A recent example of the use of this material for architectural purpose may be seen in the residence of Wm. Merritt, 4th Avenue and 11th Street, Owen Sound.

Davis, Smith and Malone, Douglas Street, Owen Sound.

The quarry is about 250 feet by 250 feet and has been sunk to a depth of 16 feet. The beds are quite horizontal and are of even character throughout. The following series is exposed:—

18 inches—Thin bedded.
5 inches—Solid bed.
6 inches—Solid bed.
3 inches—Solid bed } Called the twin beds.
3 inches—Solid bed }
Pronounced shaly parting.
7 inches—Solid bed.
8 inches—Solid bed.
Pronounced sandy parting.
8 inches—Solid stone.
9 inches—Solid stone.
8 inches—Solid stone.
9 inches—Solid stone.
10 inches—Solid stone.

Above the sandy parting the stone is grey (132) and below that line it is darker—the so-called blue (133). All the layers show the planes of stratification which become more pronounced on weathering.

The jointing is remarkably perfect in both a north and south and east and west direction. In consequence of this feature the stone is easily removed and the quarry has clean vertical walls. Many of the beds show great numbers of concretions; the lower layers are more free from this disfiguration than the upper.

The stone: No. 132.—This stone shows distinct stratification in dark wavy lines, and the substance is not uniform in colour. The general aspect is, however, very like Plate LXXVII, No. 10. On long weathering it assumes an unattractive yellowish green appearance. It is hard and unsuitable for purposes of fine construction.

No. 133.—This stone is somewhat more coarsely crystalline than most of the Niagara dolomites and presents a much bluer aspect. It is strongly banded, with brownish alteration products along the more pronounced bedding planes. The better parts present a colour resembling Plate LXXV, No. 8, but of a rather darker shade. The stone is hard, weathers rapidly and is unsuited for chiselled work.

Most of the output is shipped for rubble, the debris only being crushed. The equipment consists of a portable boiler and engine, rock drills, pump and small crusher. Ten to twelve men are employed in the quarry and eight to ten teams are engaged in hauling the stone to the rail at Owen Sound. One hundred to two hundred tons of rubble are produced per day. This output is valued at 50 cents per ton f.o.b. Owen Sound. Besides the rubble 1,500 cubic yards of crushed stone were produced during the first half of 1910.

Oliver and Webster, Owen Sound.

This firm hold about 40½ acres of land and have opened four quarries. The largest quarry is 600 feet by 200 feet with a depth of from 16 to 25 feet. The succession of beds and the quality of the stone are the same as in the quarry already described. The clean vertical jointing is well shown here and I am informed that this feature is responsible for the cheap rate at which the stone can be sold. In places where the joints are "tight," it is found to be impossible to market the output at 50 cents per ton. Two steam drills, two small crushers and three derricks are installed in this quarry. The other quarries are smaller, but one of them has the advantage that the stone can be loaded directly into cars on a siding from the C. P. R. About 200 tons of rubble are shipped per day.

The Wiarton Area.

Limestone for the making of lime and for the manufacture of cement has been produced at many points near Wiarton. Building stone is at present produced from one quarry only, a description of which follows:—

J. S. Cook, Wiarton, Lots 7 and 8, Con. XIV, Amabel, Bruce county.

Mr. Cook has opened shallow quarries at a number of places on his property. The succession of beds in several of these openings is indicated below:—

Opening No. 1.

1 foot—Shale.
2 feet—Thin material, 1 to 2 inches, rubble—36.
3 feet—Consisting of 8 inch, 4 inch, and 1½ inch beds.
6 inches—Solid bed.
1½ inches—Flagging.
5 inches—Solid bed—33.
2½ inches—Flagging.

Opening No. 2.

13 inches—Solid bed—34.
5 inches—Solid bed.
2 inches—Flagging.
7 inches—Solid bed.
2 inches—Flagging.
6 inches—Solid bed.
3 inches—Solid bed.

Opening No. 3.

20 inches.—Solid stone, used for monument bases, etc.—35.
Series of thiner beds not opened up.

In all the quarries the bedding is remarkably uniform so that sills and coursing stone can be prepared at a minimum expense. The variation in the thickness of the different beds renders it possible to secure stone of the desired thickness for almost any work. There is only one series of joints, running east and west at intervals varying from 15 to 50 feet. Strips 45 feet long have actually been quarried, as well as pillars 12 feet long and 18 inches square.

The stone: No. 33.—This stone is of very much the same character as the light brown coursing from Marshall's quarry at Hamilton; it is however slightly darker and is represented in Plate LXXVI, No. 4. The structure is fine crystalline and is identical with that of the Hamilton stone. While the grain of the stone is the same there are, in this example, rather more scattered openings of a larger character. These cavities are, however, so small as to be scarcely perceptible except on a smoothed surface. Like the Hamilton stone, this rock cuts easily and holds fine edges and points to perfection.

Specific gravity	2·831
Weight per cubic foot, lbs	158·237
Pore space, per cent	10·44
Ratio of absorption, per cent	4·13
Permeability, cc. per square inch per hour	12·75
Coefficient of saturation	0·45
Crushing strength, lbs. per square inch	21162·
Crushing strength after freezing, lbs. per square inch.	18555·
Loss on freezing, per cent	0·0204
Loss on treatment with carbonic acid, grams per square inch	0·00527
Transverse strength, lbs. per square inch	2280·
Chiselling factor	4·2

Compare No. 126, p. 253.

An analysis by H. A. Leverin shows the following composition:—

Insoluble matter	1·24
Ferrous oxide	·33
Ferric oxide	·65
Calcium carbonate	56·03
Magnesium carbonate	41·03
Sulphur	·021

The stone is therefore a dolomite with very little ferrous oxide or sulphur present.

No. 34.—Similar to the above but shows more evidence of stratification and presents a slightly lighter colour.

No. 35.—A softer, more friable and lighter coloured stone than either of the above. It somewhat resembles Plate LXXVI, No. 14, but has a cast of red not there shown.

No. 36.—This stone is almost as dark as Plate LXXVI, No. 1; it is much finer in grain and harder than the other samples and is marked by fine wavy black bituminous lines.

The removal and preparation of the stone is accomplished by plug and feathers alone. It is found that holes 18 inches to 2 feet apart suffice for the breaking of the thickest layers. The thin sheets, suitable for flagging, can be cut on the bed by lining with chisel alone.

The remarkably even character of the bedding, the quality of the stone, the freedom from excessive jointing, and the facility of quarrying should make this property an important producer in the near future.

The haul to the rail is 1¾ miles, but despite this extra expense Mr. Cook quotes the following prices, all f.o.b. Wiarton.

Rubble, $3 per cord.

Coursing stone, ready to lay, 8 inch, 12 cents per running foot.

Shoddy, 18 cents per square foot.

Sills, rough, 15 cents per running foot.

Sills, 6 inch, bush-hammered top and bottom, 35 cents per running foot.

Sills, 5 inch, bush-hammered top and bottom, 30 cents per running foot.

Door sills. 1 foot 2 inches wide, bush-hammered top and front, 50 cents per running foot.

Caps, rock face, bush-hammered top, all lengths, 35 cents per running foot.

Monument bases, rough, 45 cents per cubic foot.

Monument bases, rock face, tooled margin, $1 per cubic foot.

Monument bases, bush-hammered, $1.25 per cubic foot.

Flagging, 25 cents per square yard.

Although the quarry was idle at the time of my visit, I am informed that five men are usually employed and that the yearly business is about $1,500.

Summary—The Niagara Formation.

The location of the quarries of this formation is shown on the sketch map, Fig. 17. It will be observed that they extend along a line reaching from Queenston to Wiarton. The existence of the Niagara escarpment or cuesta is responsible for an almost continuous outcrop of rock and, in consequence, innumerable small quarries have been opened from time to time for lime-burning and for other purposes. Much stone for structural work has been obtained from quarries ranking among the largest in the province. All the stone is of magnesian character and much of it is true dolomite. Light colours in yellow and brown tints are most common, but blue and darker coloured stones also occur. The following chief types comprise the more important structural varieties.

1. A blue, crystalline, encrinal variety formerly largely quarried at Thorold and Queenston. See No. 88, p. 246 and No. 276, p. 244.
2. A fine brown, porous, dolomite of good appearance and good chiselling and wearing properties—Hamilton, Ancaster, Dundas, Wiarton. See No. 126, p. 253 and No. 33, p. 262.

3. A light coloured, very porous, easily chiselled stone in heavy beds—Beamsville, Vineland. See No. 119, p. 249.
4. A hard, rougher, less evenly bedded and less desirable building material—Hamilton, Dundas, St. Catharines, Owen Sound.
5. A cavernous, yellow to bluish dolomitic stone of hard and variable character—Limehouse, Orangeville.
6. A light coloured, porous crystalline dolomite in heavy beds—Owen Sound. See No. 130, p. 258.

The stone from the following quarries may be considered as the most desirable building material:—

Queenston Quarry Co.; Queenston.
Walker, Cartmell; Thorold.
Marshall, Gallagher; Hamilton.
Perkins; Owen Sound.
Cook; Wiarton.

Literature:—Geol. Sur. Can., Rep. 1863, pp. 321-334; p. 820.
Bur. Mines, Ont., Rep. 1891, pp. 95-96.
" " " " 1903, p. 141.
" " " " 1904, pt. 11, pp. 24; 36; 39; 49; 57; 73; 95; 109; 110; 116; 120; 123; 125.

THE DOLOMITES OF THE GUELPH FORMATION.

Owing to the heavy covering of soil, the exact boundaries of the Guelph formation are difficult to determine. For the purposes of this report, however, the rocks of this formation may be regarded as forming a lenticular area about 80 miles long by 30 miles wide, reaching from the southern border of the county of Waterloo to beyond the township of Glenelg, in the county of Grey. The formation consists of magnesian limestones, which may be recognized by their light yellowish colour and generally porous character. Geologically, the Guelph formation represents the closing stages of the Niagaran series of sediments. The stone is very much alike throughout the whole formation, but for convenience in description the following areas may be established:—

The Galt-Guelph area.
The Fergus-Elora area.
The Glenelg area.

The Galt-Guelph Area.

At Galt, Guelph, Hespeler, and Schaw, quarries have long been worked for the making of lime and road metal and for purposes of construction. The production of lime is still an important industry but building stone is obtained in small quantities only. The authorities of the Central Prison are now quarrying stone on the new site near Guelph with the intention of using the product in the erection of the prison buildings. A small amount of building

FIG. 18. Sketch map showing the distribution of the Guelph dolomite, and the more important quarries.

stone is obtained from time to time from some of the old quarries. Despite the fact that stone is not quarried to any extent at present, the chief buildings in Guelph are constructed of local stone and a large supply is still available.

Christie, Henderson and Co., Toronto. Galt quarry.

The quarry is opened on the hillside to the south of Galt; it has a width of 100 feet, but has been worked back into the hill a distance of 300 feet. The succession of beds is as follows:—

25 feet—Thin bedded material.
2 feet—Solid bed.
3 feet—Solid bed.
2 feet—Solid bed.
20 inches—Solid bed.
4 feet—Solid bed.
3 feet—Solid bed, probably the best building stone—26.

All the beds are rough and cavernous and are not adapted to purposes of fine construction. The company operates another quarry of similar type and converts all the output into lime.

The stone: No. 26.—In colour this stone is a very light grey with a slight cast of yellow; it is not nearly so yellow as Webster's stone described below. The stone is a fine grained crystalline dolomite, with numerous large cavities; it would be much harder to work than Webster's stone and would yield a rougher product.

James Webster, Galt.

A number of small quarries have been opened along the river above Galt. The following description of Mr. Webster's property is typical of them all.

The opening is about 300 feet by 100 feet and presents a face of 18 feet. The upper beds are thin, but the lower layers are fairly thick. The bedding is irregular throughout the exposure, but a bottom 3 feet bed followed by one of 2 feet is fairly constant (27). It might be said that the lower 9 feet would yield good building stone. On account of the irregular bedding, all the product requires to be dressed to size. While large cavities are present to some extent they are by no means so numerous as in the Christie, Henderson quarry.

The stone: No. 27.—This sample possesses a light yellow colour which is shown in Plate LXXVII, No. 1. Except for a darkening due to the soaking in of dirt there is no change of colour on weathering. Like all the Niagara and Guelph dolomites the structure is crystalline with scattered pores of variable size. Difference in colour and in the amount of pore space constitute the chief distinction between these stones.

Specific gravity	2·837
Weight per cubic foot, lbs	151·17
Pore space, per cent	14·62
Ratio of absorption, per cent	6·05
Permeability, c.c. per square inch per hour	155·1
Coefficient of saturation	0·48
Crushing strength, lbs. per square inch	10990·
Crushing strength after freezing, lbs. per square inch	9801·
Loss on freezing, per cent	0·232
Loss on treatment with carbonic acid, grams per square inch	0·0148
Transverse strength, lbs. per square inch	817·
Chiselling factor	6·8

It will be observed that this stone has a rather low crushing and transverse strength and a high porosity. The ease with which it may be carved is indicated by the high chiselling factor of 6.8. Under the freezing test the specimen cracked badly, but the abnormal conditions under which this test is made must be remembered; according to the coefficient of saturation the stone should be uninjured by frost.

The product is valued at $5.25 per cord, f.o.b. Galt; it may be seen in the High School building and in the Sunday School of Knox church in Galt.

Christie, Henderson Co., Toronto, Hespeler quarry.

This quarry is situated a little to the west of Hespeler. The property consists of 40 acres on which about 2 acres have been quarried to a depth of from 6 to 8 feet. The upper layers are thin and of a whitish colour. The lower beds are thicker, but the stone is hard and of a bluer colour than most Guelph stone (28). The bedding is irregular and the floor rough. There is no production for any purpose at present.

The stone: No. 28.—This sample is harder, darker and more vitreous in appearance than most of the Guelph dolomites. The colour is very like that of Plate LXXVII, No. 11. Numerous cavities are present throughout the stone. It is suitable for rough construction only.

The company has another quarry about 2 miles north of Hespeler on the line of the G. T. R. The face here is about 30 feet high and shows thin bedded material above with some heavier beds of a soft white type below. All the product is converted into lime.

Still another quarry of this company is situated about a mile west of Schaw and north of the line of the C.P.R. The beds here are similar to those in the quarry described below.

John Maloney, Queen and Dufferin Sts., Toronto.

The quarry is situated west of Schaw and south of the line of the C.P.R., in the Gore of Puslinch. In this vicinity are wide exposures of rock and many acres of quarry land on which is a very light stripping. The quarry is about 600 feet by 200 feet and shows a more regular bedding than is common in the Guelph formation. The upper 14 feet presents stone varying in thickness from 2 to 10 inches. Distinct bedding planes are shown at intervals of 4 feet, 1 foot, 2 feet 6 inches, 1 foot, 3 feet. Below this level the quarry is opened at a few points to a depth of 3 feet more, exposing beds of a rather finer character in layers up to 10 inches thick—38.

The stone is of much the same quality throughout the upper beds; it is fairly hard, finely porous and free from the cavities so often shown by the Guelph stone.

The stone: No. 38.—This stone is of much the same colour and general character as No. 26 from the Christie-Henderson quarry at Galt. It is lighter in colour and harder than the Webster stone, and superior to the Christie-Henderson stone in that it has very few cavities and none of large size. It should make an excellent building stone for rock face work.

A similar stone from this locality gives the following analysis:—[1]

Carbonate of lime	54·25
Carbonate of magnesia	45·17
Carbonate of iron	0·22
Sulphate of lime	0·34
Alumina	trace
Insoluble matter	0·08

The output is nearly all converted into crushed stone.

In the immediate vicinity of Guelph a large number of quarries have been opened, which have in the past furnished the stone of which the city of Guelph is largely built. The only one of these quarries that is now worked primarily for building stone is that of Robert Kennedy, but other properties, which are operated for lime-making, dispose of a little rubble from time to time.

Robert Kennedy, Guelph.

This quarry is situated on the north side of the river immediately to the west of the town and may be considered typical of a line of openings along the river in this direction. The upper beds are thin, but the lower stone is thicker, although disposed in very irregular beds—274.

The stone: No. 274.—Except for a slightly lighter colour this stone is very like that from Webster's quarry at Galt. The grain is rather finer and the broken surface presents a less granular appearance. There are no large cavities. The physical properties are probably much the same as in Webster's stone. (See No. 27, p. 265.)

The quarry is extended up to the road allowance so that a further output can be obtained only by sinking to greater depth.

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[1] Geol. Sur. Can., Rep. 1895, p. 17R.

Standard White Lime Co., Guelph.

One quarry of this company lies to the eastward of Kennedy's and is commonly known as Priest's quarry. The opening is 300 yards long by 50 yards wide and presents a face showing the following layers:—

4 feet—Stripping.
15 feet—Broken and irregular stone.
10 feet—Good stone in beds up to 2 feet thick—273.

These good beds extend for about 100 yards only, beyond which the stone is broken like the upper beds. The bedding is very irregular, so that all the product requires dressing in order to be used as coursing stone.

The stone: No. 273.—This is a nice, even grained, soft dolomite, almost exactly comparable with Webster's stone in colour and physical properties. The presence of a rather large amount of fossil coral detracts somewhat from its value.

The following analysis is given:—

Carbonate of lime	53·97
Carbonate of magnesia	45·37
Carbonate of iron	0·16
Sulphate of lime	0·68
Alumina	trace
Insoluble matter	0·03
	100·21[1]

The company has another quarry to the east of Guelph and south of the line of the Grand Trunk railway. The exposure shows 10 feet of thin material at the top, followed by 6 feet of beds in layers of from 6 to 8 inches. At the bottom are 10 feet of heavier beds up to 18 inches thick. The beds vary greatly in character; some are too hard and some too cavernous for good building stone. The best stone is about 8 feet from the bottom of the quarry—269.

The stone: No. 269.—This sample is of a browner colour than the Guelph stones hitherto described; it is likewise coarser in grain and seems to represent a transition from the type already described and fully illustrated by the typical sample from Webster's quarry at Galt to the brown type of Guelph stone, samples of which are described later from the prison quarry and from Ashenhurst's quarry in Erin. The colour is comparable with that shown in Plate LXXVI, No. 14. While fine pores are numerous, large cavities are not present to any extent The stone is soft enough to be chiselled with facility.

Most of the output is made into lime, but a little rubble is disposed of at the rate of 70 cents per perch.

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[1] Geol. Sur. Can., Rep. 1895. p 17R.

Henry Benallick, Guelph.

This quarry lies across the road from the one described above. It shows 3 feet of soil, 6 feet of thin beds and 10 feet of layers from 6 to 18 inches deep. A large amount of cut stone has been produced from this excavation, but operations have been entirely suspended.

The Central Prison, Guelph.

The property of the prison is situated a short distance to the southwest of Guelph. On the banks of the river, near the proposed location of the building, quarrying operations are being conducted for the production of building stone and for the making of lime.

The bluff of rock stands 75 feet above the river and has been opened in two places near the summit. In the first quarry, the material appears to be all thin bedded and hard (270) but this may be due to the fact that only the weathered surface has as yet been exploited. The second opening shows a succession as follows:—

2 feet—Soil.
4 feet—Thin, rough rock.
18 inches—Solid bed.
2 feet 6 inches—Solid bed.
2 feet 4 inches—Rougher stone, no good.
3 feet—Solid bed, best stone—271.

Vertical joints cut the formation in a southwest and in a southeast direction.

The stone: No. 270.—A dark brown, crystalline porous dolomite with a vitreous aspect. The stone is hard, thin bedded and full of large openings; it presents no promise as a fine building material.

No. 271.—This sample represents the finest type of Guelph building stone: it possesses the pleasing brown colour shown in Plate LXXVI, No. 7. On treatment with carbonic acid no perceptible alteration occurs. The grain is very even and of a fine crystalline character. There are no large cavities or included fossils. The material can be worked with facility and its physical properties are entirely satisfactory.

Specific gravity	2·853
Weight per cubic foot, lbs.	150·309
Pore space, per cent	15·58
Ratio of absorption, per cent	6·47
Permeability, cc. per square inch per hour	90·22
Coefficient of saturation	0·43
Crushing strength, lbs. per square inch	12116·
Crushing strength after freezing, lbs. per square inch	13600·
Loss on freezing, per cent	0·160
Loss on treatment with carbonic acid, grams per square inch	0·01154

Transverse strength, lbs. per square inch	1250·
Chiselling factor	8·5

An analysis made in the laboratory of the Mines Branch by H. A. Leverin gave the following result:—

Insoluble matter	0·30
Ferrous oxide	0·28
Ferric oxide and alumina	0·31
Calcium carbonate	56·15
Magnesium carbonate	43·18
Sulphur	·016

It will be observed that the stone approaches a typical dolomite in composition (calcium carbonate 54·35; magnesium carbonate 45·65) and that it has a very small amount of ferrous oxide and sulphur.

A third quarry on the prison property is situated at a lower level and shows thicker beds. This opening is on the Welsh farm and was formerly worked by Mr. Haggart. There are 2 feet of stripping, 4 feet of thin material, and 10 feet of beds varying from 6 to 14 inches thick—272.

The stone: No. 272.—This example is of a light colour and fine grain; it is comparable with No. 273 from the Standard White Lime Co's quarry at Guelph.

Fergus-Elora Area.

Several quarries have been worked along the river from Fergus to Elora. The only one now in operation is Gow's quarry in Fergus, the product of which is nearly all crushed or made into lime. Rubble and coursing stone are, however, produced as orders are received.

James Gow, Fergus, Ont.

The quarry is about 1,000 feet long and 250 feet wide with a depth of 18 feet. The following beds are exposed:—

3 feet—Stripping.
3 feet—Thin material.
12 feet—Good solid stone in layers up to 14 inches thick—39.
30 feet—Various beds, not quarried, to level of river.

The stone: No. 39.—This sample is of a light yellowish grey colour and exceedingly fine grain. Small cavities are scattered throughout the rock giving it a rough appearance. Like all the very fine grained Guelph stone, it is hard, so hard that it is unsuited for building purposes, although it is said to make a superior road metal.

Quarrying is effected by drilling 6 inch holes to a depth of 18 feet. The holes are placed 30 feet apart and 10 feet from the face; they are charged with rack-rock, about 150 to 200 pounds being used in each hole. On the property are two kilns, an engine and boiler and a No. 3 Gates crusher.

Forty men are employed. Rubble is sold at 50 cents per ton, f.o.b. Fergus. As a building material the stone is used for foundations and for the rears of buildings; it may be seen in the Ontario bank, the Wellington hotel, and the Commercial hotel, in Fergus.

At Elora, near the junction of the Irvine with the Grand river, about 75 feet of stone are exposed in vertical cliffs. The Wellington Lime Association and Mr. James Gow own quarries which have been opened in the upper beds to a depth of 20 feet. About 12 feet of this face is rather thin bedded and is much broken. The lower part is more heavily bedded in irregular layers. (Plate LIX.)

The stone: No. 41.—Like the Fergus stone, this sample is hard and of a vitreous appearance with numerous cavities. The Elora and Fergus stone is not comparable in quality with the Galt, Guelph, and Erin material.

Ashenhurst Bros., Brisbane.

In the vicinity of lots 13 and 14 in the fifth and sixth concessions of Erin is a group of small quarries of which that of Ashenhurst Bros. is selected as an example.

The quarry has a face of about 12 feet in which are exposed beds ranging from 6 inches to 2 feet in thickness. The layers are more evenly bedded than in the other districts of the Guelph formation.

The stone: No. 40.—This stone presents the light brown colour shown in Plate LXXVI, No. 10. On treatment with carbonic acid no change is apparent. The structure is uniformly crystalline and the stone presents a fine even granular appearance on fresh fracture. The grain is a little finer than that of the Central Prison stone with which this specimen is closely comparable; it is marred neither by fossils or cavities.

Specific gravity	2·853
Weight per cubic foot, lbs	149·78
Pore space, per cent	15·88
Ratio of absorption, per cent	5·56
Permeability, c.c., per square inch per hour	90·5
Coefficient of saturation	0·48
Crushing strength, lbs. per square inch	13183·
Crushing strength after freezing, lbs. per square inch	14965·
Loss on freezing, per cent	0·055
Loss on treatment with carbonic acid, grams per square inch	0·00586
Transverse strength, lbs. per square inch	2022·
Chiselling factor	5·3

It is worthy of remark that both this sample and the similar stone from the prison quarry increase in strength on freezing. The lower chiselling factor is probable due to the fact that this specimen was not freshly quarried, but was cut from the centre of a block that had served for many years as a monument base.

Much of the cut stone in Fergus and vicinity is from this quarry; it may be seen in the Imperial bank, the Farmers bank and the Commercial hotel, in Fergus. The following prices are quoted:—

Sills, standard, bush-hammered top and bottom, 40 cents per running foot.

Sills, bush-hammered top only, 30 cents per running foot.

Lintels, rock face, 30 cents per running foot.

The Glenelg Area.

In the township of Glenelg, stone is quarried at a few points along the Rocky Saugeen and its tributaries, more particularly at Durham. There is no important quarry and no present production, and in consequence the district was not visited.

Summary—Guelph Formation.

The accompanying map, Fig. 18, shows the general distribution of the rocks of this formation. Much of this region is deeply covered with soil so that exposures are not numerous. The chief quarries may be grouped in three areas, the Galt-Guelph, the Fergus-Elora, and the Glenelg.

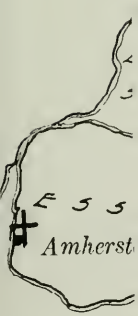
All the stone is highly dolomitic, light in colour and extremely porous. In hardness it varies greatly from place to place; much of it however is capable of being carved with facility. The beds are irregular, for the most part, so that the stone requires considerable work in order to be used as coursing material. The presence of large cavities, representing the original position of fossils, renders much of the stone very rough and quite unfits it for fine structural work. At Galt, Guelph, Elora, Hespeler, and Fergus many buildings are constructed of local stone. At the present time, however, there is very little production.

The stone from Ashenhurst's quarry in Erin, from the Central Prison quarry near Guelph, and from Webster's quarry at Galt have been selected for complete examination. See No. 40, p. 271; No. 271, p. 269; and No. 27, p. 265.

Literature:—Geol. Sur. Can., Rep. 1863, pp. 336–344; pp. 820.
" " " " 1898, p. 169A.
Bur. Mines, Ont., Rep. Royal Com., 1900, p. 45.
" " " " 1903, p. 150.
" " " " 1904, pt. ii, pp. 33, 120–122, 126–127.

THE LIMESTONES OF THE ONONDAGA (CORNIFEROUS) FORMATION.

The western peninsula of Ontario is covered with drift to such an extent that outcrops of rock are seen in but few localities. The rock formations belong



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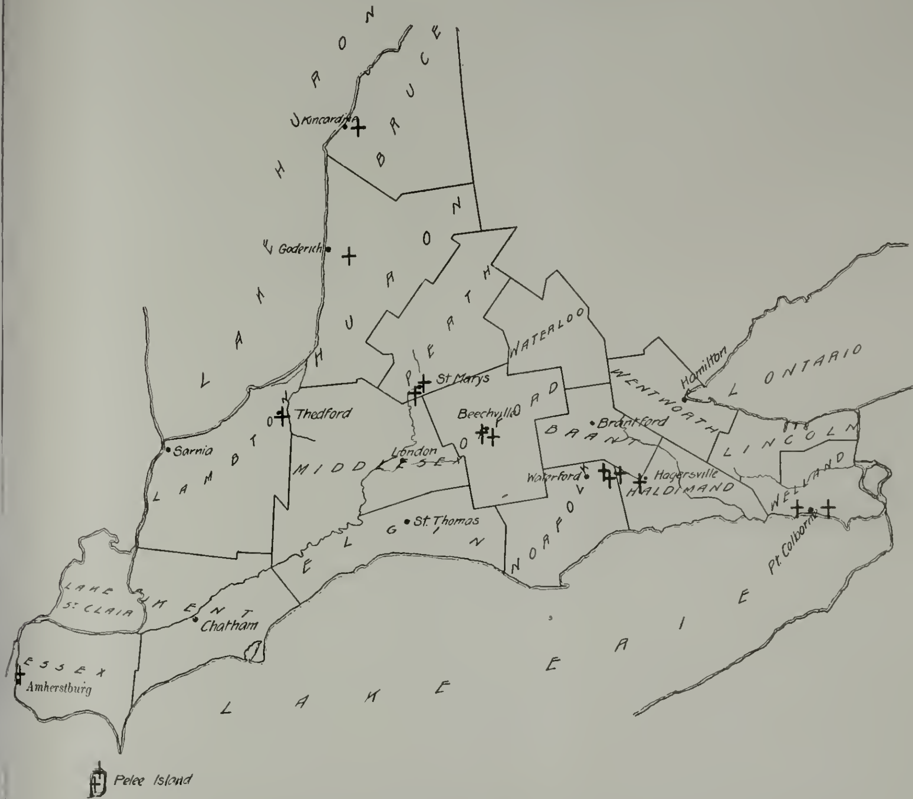

Fig. 19. Sketch map showing the location of the more important quarries in the Onondaga and Hamilton formations of Southwestern Ootario.

Guelph Dolomite. Presbyterian Church, Fergus, Ont.

Plate LIX.

Gorge of the Irvine, and Quarry in Guelph Dolomite, Elora, Ont.

to the Devonian system and are divided into three groups—a lower, *Onondaga*; a middle, *Hamilton;* and an upper, *Chemung.* The geographical extent of these formations has already been indicated and need not be repeated here. The only considerable production of stone is from the lower, Onondaga or Corniferous formation, and from this at a few points only. There are but two extensive quarries actually producing building stone at the present time; these are both situated at St. Marys near the southern boundary of the county of Perth. Formerly, larger quantities of stone were obtained from Amherstburg and from Pelee Island. The quarries at the former place are now operated for other purposes and those on Pelee Island are abandoned. Large quantities of stone are quarried for flux and for cement making near Port Colborne, and for macadam and railway ballast near Hagersville. North of this place are a few small quarries for building stone and lime-making. At Beechville are several quarries, which produce a very pure stone for lime-burning and for use in the chemical industries.

For descriptive purposes the following areas may be established:—

The Hagersville area.
The Port Colborne area.
The Beechville area.
The St. Marys area.
The Amherstburg-Pelee Island area.
The Kincardine area.

The Hagersville Area.

At Hagersville two quarries produce a large quantity of crushed stone and to the northward of the town are several small quarries, the output of which is used locally for building purposes and for the manufacture of lime.

The Hagersville Contracting Co., J. C. Ingles, manager, Hagersville; G. D. Fox, superintendent, Hagersville.

The quarry extends over 12 acres and is from 12 to 15 feet deep. Throughout this extent the stone is irregularly thin bedded and presents layers of a dark, bluish grey appearance interbanded with lighter material. Most of the layers are only a few inches thick, but, towards the bottom somewhat heavier stone is obtainable. The formation is cherty and full of fossil corals. The stone breaks badly, and, although it is an excellent material for macadam, it is not adapted to structural work except of the roughest description. Below these upper beds occurs a blue limestone in layers of 2 inches, 6 inches, 8 inches, and 12 inches thickness. A distinct mud parting, said to extend over the whole quarry, separates these limestone beds from a lower series of hard cherty layers like the upper part of the face.

The blue limestone is less coralline than the other beds and is better adapted to purposes of construction. There is however a clay parting between the layers which clings to the stone and which must be removed if the material is to be used for fine work.—95.

The stone: No. 95.—In colour, this stone resembles Plate LXXV, No. 6. On weathering, it assumes a lighter aspect. The rock consists largely of fossil shells imbedded in a somewhat crystalline matrix.

An example from these lower building beds gives the following analysis:—[1]

Moisture	0·24
Insoluble residue	5·32
Ferric oxide	1·21
Alumina	3·99
Lime	45·14
Magnesia	1·64
Carbonic acid	35·56
Loss on ignition	40·89

The plant consists of four drills operating on direct steam, two crushers, a quantity of track and a number of cars. Dynamite and powder are used as explosives. Sidings from both the M.C.R. and G.T.R. afford ample facilities for shipping.

Building stone is quoted at $3 per cord in the quarry.

Michigan Central Railway, D. E. Cronin, local superintendent, Hagersville.

The company own 80 acres of land and have quarried 10 acres to a depth of 12 feet. The upper 6 feet are hard, coralline and cherty; the lower 6 feet are less coralline and are without chert. These lower beds resemble the building beds in the quarry described above. The stone may be obtained in layers of 4 inches, 6 inches, 8 inches, and 1 foot—96.

The stone: No. 96.—A grey semi-crystalline fossiliferous limestone differing from No. 95 of the Hagersville Contracting Co. only in a somewhat lighter colour.

The equipment consists of one steam shovel for stripping, four Ingersoll-Rand drills operating on air from an Ingersoll compressor, one No. 5 and one No. 7½ Oxford crushers, track, cars and a large quantity of minor apparatus. One hundred men are employed and 1,000 tons per day of crushed stone produced. There is no production of building stone, as the company uses all the output for its own purposes.

From Hagersville westward to the vicinity of Waterford are a number of exposures of Onondaga rock on which small quarries have been opened. The chief localities are as follows:—

Lot 18, con. VIII, Townsend.

Lot 22, con. IX, Townsend.

Lot 1, con. XIV, Walpole—Wm. A. Teitz.

Lot 6, con. XIV, Walpole.

Lot 9, con. XIII, Walpole—Elias Shoap.[2]

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[1] Bur. Mines, Ont., Rep. 1903, p. 145. See also Bur Mines, Ont., Rep. 1904, pt. ii, p. 54.

[2] Bur. Mines, Ont., Rep. 1903, pp. 142–145

Building stone for local use is obtained from these quarries, but I can learn of no steady production. The output is small and quarrying is carried on at intervals only. The quarry of Wm. Teitz may be considered typical of these properties and is described below.

Wm. A. Teitz, Springvale, Lot 1, Con. XIV, Walpole, Haldimand county.

On this property about one acre is quarried to a depth of 6 feet. The upper 3 feet consist of a hard, white, coralline limestone in irregular beds (103). The lower 3 feet show beds of blue limestone ranging from 4 to 10 inches in thickness—104.

The stone: No. 103.—A hard, white coralline limestone of no value except for purposes of rough construction or lime-burning.

No. 104.—An idea of the appearance of this stone may be gained by imagining Plate LXXV, No. 4, finely dotted by Plate LXXVI, No. 10. This effect is due to the fact that the matrix is grey while the fossil fragments are of a brownish colour. The stone presents a rather coarsely crystalline appearance, but it is fairly uniform throughout and not too hard for ordinary chiselling. On the whole it may be regarded as a desirable material.

The Port Colborne Area.

Although some of the largest quarries in the province are opened in the vicinity of Port Colborne, this area can not be regarded as a producer of building stone. The stone is, for the most part, highly fossiliferous and consequently rough in character and unsuited to purposes of construction. The product is used for furnace work and in the manufacture of Portland cement.

Empire Limestone Co., Scranton, Pa., M. B. Fuller, president, Scranton, Pa.; T. R. Thomas, superintendent, Sherkston, West half Lots 3, 4, 5 and 6, Con. I, Humberstone.

The quarry covers 15 acres and has been excavated in what is practically a great coral bed. The section is as follows:—

2-3 feet—Solid coralline bed with a white crystalline matrix, bluish grey and clayey partings—56.

2 feet—Blue, cherty, coralline—57.
6 feet—Lighter coralline rock, irregularly bedded—58.
8 feet—Grey crystalline type, thin and irregularly bedded—59.
2 feet—Irregular coralline beds.
Bluer, granular crystalline rock with corals throughout, but not so numerous as in the upper beds—60.

The stone: Nos. 56, 57, and 58.—Rough coralline rocks of no possible use as building material.

No. 59.—The colour of this sample is similar to that shown in Plate LXXVII, No. 2. The structure is crystalline throughout, the rock consisting almost entirely of broken fragments of organisms. The grain is rather coarse. This would be a very good building material if it were not for occasional large corals.

No. 60.—This stone is very like No. 59; it differs only in showing a tinge of blue.

The stone is quarried on an extensive scale by the use of Rand drills and "cyclone" drills by the Cyclone Drill Co., Orrville, Ohio. By the use of this apparatus holes are sunk to a depth of 50 feet. As these holes are 5 inches in diameter they can be charged with sufficient dynamite to blow off the face of the quarry when placed 20 feet back and 12 feet apart. The company operates a compressor, and a crushing plant, makes use of 5 small locomotives and 75 cars, employs 130 men and produces 600 to 700 tons of crushed rock a day. All the product is used for furnace work and is valued at 90 cents per ton f.o.b. quarry.

Canadian Portland Cement Co., Senator Edwards, president, Ottawa; E. N. Armstrong, superintendent, Port Colborne, Lots 22 and 23, Con. 1, Humberstone; Lot 5, Con. 1, Wainfleet.

The quarry, which extends over several acres, has been opened to a depth of about 20 feet. The stone is irregularly bedded and shows dark and light bands throughout. An enormous amount of fossil coral is present in most of the beds. The upper 8 to 10 feet contain more of the dark bands; the stone is thinner and is less likely to produce building material than the lower beds. The lower 10 feet contain many beds of a greyish crystalline type in layers up to 18 inches thick—62.

The stone: No. 62.—This sample is comparable with No. 60 from the Empire Co.'s quarry.

The quarrying is done on a large scale by the use of power drills and dynamite. The product is used for the cement industry only.

The following analyses of three different examples were kindly furnished by Mr. R. E. Pettingill, the company's analyst:—

	No. 1	No. 2	No. 3
Silica	4·7	4·54	5·28
Alumina	1·16	1·04	1·0
Lime	51·56	51·74	49·67
Magnesia	1·61	1·49	1·43
Volatile matter	41·38	40·78	41·38

J. A. Reeb, Port Colborne, N. half Lot 5, Con. I, Wainfleet.

This quarry is about 200 by 100 feet in extent and 10 to 12 feet deep. The upper 8 feet consist of the cherty coralline stone as in the larger quarries at Port Colborne. The lower stone is of the grey crystallline type in thin beds.

The product is converted into lime or into crushed stone.

The Beechville Area.

The river Thames between Woodstock and Ingersoll has cut a valley through the overlying drift so as to expose the rock at different places. In the vicinity of Beechville several quarries have been worked at or below the level of the river. At the present time two quarries are being worked by the Standard White Lime Co. for the manufacture of lime. A small amount of building stone is also produced, but this industry is subservient to that of lime-burning.

Standard White Lime Co., D. D. Christie, president, Guelph, Lots 10 *and* 14, *Broken Front, Oxford W., Oxford county.*

The quarry on lot 10 extends over 5 acres and has been opened to a depth of about 11 feet: it is now below the level of the river and consequently requires constant pumping. The upper bed is white and thin bedded with bituminous partings. The lower beds show 2 inch, 4 inch, 6 inch, and 8 inch stone, but the face of the quarry is so shattered by dynamite that exact determination of the beds is difficult—29, 30.

The quarry on lot 14 extends over 15 acres and shows the following succession:—

4-5 feet—Soil.
4 feet—Thin bedded rock.
8 inches—White stone—31.
Clay parting.
6 inches—Dark limestone.
6 inches—Dark limestone.
6 inches—Dark limestone—32.

These three lower beds are sometimes so closely adherent that they may be removed in one block.

The stone: No. 29.—The colour of the fresh stone is similar to that shown in Plate LXXVI, No. 9. In structure, the stone is very fine grained with scattered crystals of calcite. The fracture is subconchoidal and splintery.

No. 30.—Similar to the above but a little harder: frequent small veinlets of crystalline calcite traverse the stone.

No. 31.—This sample has a slightly lighter colour and a rather more greyish cast like Plate LXXVI, No. 11. The stone is uniformly fine crystalline throughout and is without isolated crystals and veinlets of calcite. This is probably the most desirable building bed in these quarries.

No. 32.—A fine grained stone like Nos. 29 and 30. In bands, the stone is highly fossiliferous and does not constitute a good building material.

The purity of these Beechville limestones is indicated by the following analyses:—[1]

	Old quarry south of river.	Bremner's old quarry.
Water	0·20	0·55
Silica	0·13	0·46
Alumina	trace	7·42
Ferric oxide	....	1·50
Ferrous oxide	0·22	....
Calcium oxide	53·71	49·97
Magnesium oxide	trace	trace
Sulphur trioxide	0·35	....

The stone weathers a whitish grey with a slight cast of blue. The Beechville quarries are better known on account of the purity of the limestone for chemical purposes than for its suitability to structural work. The following prices for building stone are quoted:—

Building stone, rough, hammer broken, $4 per cord at quarry.

Building stone, selected, $5 per cord at quarry.

The St. Marys Area.

The most important building stone quarries in western Ontario are situated at St. Marys. Two companies produce cut stone, while a third, operating primarily for lime, disposes of a small quantity of rough building material. The St. Marys stone is of close grain and fine texture, it can be chiselled with reasonable facility and it presents a pleasing light grey colour. Most of the cities and towns in southwestern Ontario have made use of the product of these quarries.

The Thames Quarry Co., John Bonis, manager, St. Marys.

The quarries of this company are situated near the river, south of St. Marys. There are two openings one on each side of the highway; the one to the south is 500 feet by 300 feet and the other 400 feet by 200 feet in extent. The property consists of 21 acres in all. The south quarry shows the following series of beds in descending order:—

2 feet—Stripping.

3 inches—Bed used for cribbing only.

3 inches—Bed used for cribbing only.

8 inches—Bed, hard, high siliceous content, used for footings.

6 inches—Bed, rough, used for footings and rubble.

7 inches—Bed, rough, used for footings and rubble.

[1] Bur Mines, Ont., Rep. 1903, pp. 148–149.

14 inches—Bed, splits into thinner layers, used for flagging and rubble.

3 inches—Bed.

16 inches—Bed, used mostly for rubble.

7 inches—Bed, rubble only.

5 inches—Bed, used for rubble and flagging.

4 inches—Smooth, yellow bed, used for underground coursing.

11 inches—Bed, used for rubble but in places is solid enough for coursing.

[1]9 inches—Like above.

13 inches—Bed, splits easily, rubble.

13 inches—Bed, splits easily, rubble.

14 inches—Bed, splits easily, rubble.

14 inches—Bed, splits easily, rubble.

15 inches—Building bed, in places splits into two—145.

[1]16 inches—Like above.

[1] 8 inches—Coursing stone, finest bed in quarry, evenly bedded, smooth on both sides—138.

28 inches—Splits into three, rough coursing and heavy rubble—139.

[1]10 inches—Coursing stone, sometimes splits into two 5 inch beds, good stone for sills, veranda caps and copings—140.

16 inches—Good building stone, used for coursing and sills, sometimes splits into thinner beds—141.

14 inches—Bed, splits thin in part, sometimes used for sills, etc.

13 inches—Bed just opened.

24 inches—Bed just opened.

It will be observed that the finer grades of building stone are at the lower part of the quarry; but, as the upper beds have been removed over the whole extent of the opening and the lower ones have been quarried only at one end, there is now within easy reach a large amount of the best stone afforded by the quarry.

The main joints vary from due north to 30° west of north and occur at intervals of from 40 to 50 feet. Another set of joints cuts the formation nearly at right angles to the main joints; these are from 4 to 8 feet apart and terminate at the 28 inch bed. Another set of minor joints is developed below this level. There is no difficulty in obtaining stone 10 to 12 feet long and 4 to 5 feet wide.

The stone: No. 138.—The colour is represented in Plate LXXV, No. 15. On exposure, the colour becomes much lighter. On treatment with carbonic acid the stone presents an appearance somewhat like Plate LXXVII, No. 15, but the dark spots are smaller and less pronounced. The stone is made up of fragmental remains of organisms imbedded in a fine grained matrix. This matrix is more readily attacked by carbonic acid so that the broken shells appear as darker spots on the etched surface.

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[1] See account of Horseshoe quarry.

The physical properties are as follows:—

Specific gravity	2·709
Weight per cubic foot, lbs	167·513
Pore space, per cent	0·92
Ratio of absorption, per cent	0·34
Coefficient of saturation	·72
Crushing strength, lbs. per square inch	18242·
Crushing strength after freezing, lbs. per square inch	20194·
Loss on freezing, per cent	0·015
Loss on treatment with carbonic acid, c.c. per square inch per hour	0·3221
Transverse strength, lbs. per square inch	3474·
Chiselling factor	5·5

No. 139.—The colour is very similar to that of the above example and is shown in Plate LXXV, No. 13. On weathering, the grey tint is gradually lost and the stone assumes a lighter colour. The dark-specked and etched surface shown by No. 139 is not apparent here as the stone is much finer in grain and such fossil fragments as are present are of much smaller size.

Specific gravity	2·715
Weight per cubic foot, lbs	167·867
Pore space, per cent	0·93
Ratio of absorption, per cent	0·34
Coefficient of saturation	0·9
Crushing strength, lbs. per square inch	22075·
Crushing strength after freezing, lbs. per square inch	23014·
Loss on freezing, per cent	0·028
Loss on treatment with carbonic acid, c.c. per square inch	0·298
Transverse strength, lbs. per square inch	3015·
Chiselling factor.—Not satisfactorily determined, but it is certainly lower than in No. 138.	

It is remarkable that in spite of the high coefficient of saturation both these stones should increase slightly in strength on freezing. That the stone with the quarry water unexpelled is severely injured by frost is well known to the operators, and I can explain the apparent contradiction only on the assumption that a process of recementation takes place under the freezing test as conducted in the laboratory. (See introduction page 66).

No. 140.—This stone presents the same colour as No. 138. It is, however, of finer grain, although more fossiliferous. On the whole, owing to the fossils and to a more pronounced banding, it should be ranked as a rather rougher type than No. 138.

No. 145.—This stone is of the same general type as No. 138; it is, however, slightly lighter in colour and more coarsely crystalline in structure.

No inclusions or large fossils detract from the value and it must be regarded as a very desirable stone.

An analysis from one of the upper beds is as follows:—[1]

Water	0·14
Silica	2·32
Ferric oxide	0·88
Alumina	0·17
Calcium carbonate	94·24
Magnesium carbonate	2·10

The plant consists of a portable boiler furnishing steam for deep drilling, two plug drills, one 30, one 25 and one 10 horse-power motor, one compressor, and four power derricks. The company intend to install a crusher to dispose of waste material. Rack-rock and stumping powder are used to dislodge the rough rock; the building beds are quarried by means of plug and feathers alone. Thirty men are employed. The quarries are provided with a spur from the Canadian Pacific railway, and similar shipping facilities may soon be afforded by the Grand Trunk.

Mr. Bonis has kindly furnished the following list of prices all f.o.b. St. Marys.

Rough stone, hammer broken, $3.25 per cord.

Coursing stone, 8 inch drilled, 10 cents per running foot.

Coursing stone, 10 inch, drilled, 15 cents per running foot.

Coursing stone, 9 inch, drilled, 9 cents per running foot (less evenly bedded).

Coursing stone, 5 inch, broken, $6 per cord.

Coursing stone, 6 inch, broken, $6 per cord.

Coursing stone, 15 inch, drilled, 25 cents per running foot.

Coursing stone, 12 inch, drilled, 20 cents per running foot.

Sills, 5 inch, bush-hammered top, tooled margin, rock face, 45 cents per foot.

Sills, as above, logged one inch, 50 cents per foot.

Door sills, bush-hammered top, ends and face, bedded, 6 inches thick, 13 inches wide, 75 cents per running foot.

Lintels, for four brick, 45 cents per running foot.

Lintels, for five brick, 50 cents per running foot.

Broken stone for flux, 56 cents per ton.

Examples of stone from this quarry may be seen in the following structures:—

Howard Park Methodist church, Toronto.

Church of England, Lucan.

Armouries, Durham.

School, Woodstock.

Schools, Brantford.

Numerous buildings in St. Marys. (Plate LXI.)

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[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 151.

The description given for the west quarry applies equally well to the east opening; the only difference is that some of the beds have a less tendency to split.

The St. Marys Horseshoe Quarry Co., R. H. McWilliams, president, Durham; E. H. Broderick, local manager, St. Marys.

This quarry is about 600 feet long by 200 feet wide. The long diameter lies in a southwest direction, which represents the dip of the beds. The angle of dip is low towards the west but near the east end the beds incline as much as 20°. At this point the layers are broken, but there does not seem to be any displacement, as the 50 feet of opening still farther to the east show the beds in a practically horizontal position. The bottom layers, 30 feet down at the west end, come within 3 feet of the surface at the east end. The floor of the quarry corresponds with these layers, which are also the same as the bottom beds of the Thames quarry. The western deep end of the opening shows practically the same layers, bed for bed, as the Thames quarry. Some of the layers which have a tendency to split in the latter quarry are more solid here; for instance, the 9 inch bed is always solid and is perhaps the best layer in the quarry—(142.) The 28 inch bed is also coherent throughout. The east end of the quarry, although very shallow, exposes certain layers which are lower than any others exposed on the properties of either company; this stone is of a different character and is described below as specimen 143.

The beds marked [1] in the description of the Thames quarry, namely the 9 inch, the upper 16 inch, the 8 inch, and the 10 inch beds, are here considered as the most valuable for building purposes.

The stone: No. 142.—This sample resembles No. 138 from the Thames quarry in its general features. The structure and colour are much alike but the present specimen is more fossiliferous and shows more evidence of stratification.

No. 143.—This sample is of a lighter colour than either No. 138 or No. 139; it presents the appearance illustrated in Plate LXXVII, No. 10. The structure is crystalline and of about the same grain as that of No. 138. On weathering, a brownish tint is acquired. Scattered fossils and occasional aggregates of calcite crystals are to be seen. The physical properties are probably similar to those of No. 138.

At the present time, the company is converting the most of its output into crushed stone which is used for macadam and concrete work. The prices of the various kinds of stone are about the same as those given for the Thames quarry.

Standard White Lime Co., James Sclater, local manager, St. Marys.

This quarry, which covers over 3 acres, has been opened in the side of a hill northeast of St. Marys. The present face shows the following series:—

20 feet—Overburden.
3 feet—Thin bedded material.
8 inches—Magnesian bed, building bed—144.

Onondaga Limestone. Horseshoe Quarry, St. Mary's, Ont.

Plate LXI.

Onondaga Limestone. Municipal Buildings,
St. Mary's, Ont.

16 feet—Limestone beds of varying thickness. This stone while making excellent lime, checks on exposure and is not adapted to purposes of construction—146.

The stone: No. 144.—The colour is a light yellowish brown resembling No. 14 or 15 of Plate LXXVII. The stone is somewhat cavernous and shows distinct stratification lines. The joint planes have served for the infiltration of iron oxide whereby the stone is badly stained. Mr. Sclater states that this layer contains 9 per cent of magnesium carbonate.

No. 146.—A brown and yellowish banded, almost compact limestone, which, for the reasons given above, is never employed for purposes of construction.

The building stone is used for foundations and is valued at $3 per cord unloaded at quarry.

The Amherstburg-Pelee Island Area.

Large quantities of stone for structural purposes were formerly obtained from Amherstburg and from Pelee island. Although there is no present production of building stone from either locality, the quarries represent the only available source of supply for the extreme western part of the lower peninsula of Ontario. The stone is very similar at the two places, which are accordingly embraced in one area.

Solway Process Co., Detroit, Michigan, F.R. Hazard, president, Syracuse, N.Y., Lots 6, Cons. I and II, Anderdon. Essex county.

On the lots indicated, about 120 acres, known as the "quarry reserve," show limestone sufficiently near to the surface to make quarrying operations possible. Part of this land is the property of the Solway Process Co.; the rest is controlled by the Cuddy-Falls Co., of Amherstburg. As the only considerable openings are on the property of the former company, they are selected for description, although it is not the intention of the company to produce stone for structural purposes.

The beds dip southwest at an angle of from 10° to 15° and the quarry has been opened down the slope, so that the depth increases from a few feet at the northeast margin to 33 feet at the southwest end. The face here is fully a quarter of a mile long. In addition to this large opening, a smaller but still extensive quarry has been sunk in the floor of the original workings to a depth of over 20 feet. The succession of beds throughout the entire exposure is as follows:—

10–16 feet—Stripping.

6–8 feet—Thin bedded material, 8 inches maximum; hard, white and fossiliferous—10.

Strong parting.

3 feet—Brown magnesian limestone, in variable beds with a 6 inch layer of white fossiliferous stone at the bottom.

18 inches—Solid bed of soft, brown, magnesian limestone—9.

Strong parting.

4 feet—In places solid; towards the northwest it is broken into layers of from 10 to 14 inches and is topped by a foot of white, coralline rock—11.

8 feet—Brown magnesian limestone, soft, breaks easily, divided distinctly by bituminous partings, weathers grey, fine dimension stone—8.

10 feet—Solid bed, but shows distinct bituminous partings with a peculiar interlocking, columnar structure. These divisions occur at intervals (from the top) of 18 inches, 2 feet 8 inches, and 2 feet 6 inches. Below the lower parting the stone is marred by cavities filled with crystals of white calcite and is imperfect in other ways. Specimen 7 is from about the middle of the bed.

Bottom of building beds—Floor of old quarry.

1 foot—High grade limestone.		
4 feet	"	"
18 inches	"	"
18 inches	"	"
20 inches	"	"
2 feet 6 inches	"	"
1 foot	"	"
20 inches	"	"
2 feet 6 inches	"	"
2 feet 6 inches	"	"
Bottom of new quarry	"	"

All these beds split easily into thinner material and are not adapted to building purposes although they are highly prized for chemical work—6.

4–5 feet—Lower building beds; brown magnesian limestone in beds up to 14 inches thick—12.

Flinty nodular limestone, not opened up.

While most of the beds indicated are fairly continuous, variations occur which render a detailed description applicable to one place only. For instance, the 4 foot bed is really more than 4 feet thick at the southeast end of the face, while it is less than 4 feet at the northwest end and is broken into an average of eight layers. The strong partings, indicated in the section, are continuous throughout the exposure. (Plate LXII.)

The stone: No. 11.—The colour is a very light brown and is shown in Plate LXXVI, No. 12. On weathering, the stone becomes darker in colour and the included fossils appear as white dots and lines. The general appearance of the weathered stone is not pleasing. The matrix is fine granular in character, with numerous larger calcite crystals representing fragments of shells, etc.

The physical properties are as follows:—

Specific gravity	2·773
Weight per cubic foot, lbs.	155·813
Pore space, per cent	9·966
Ratio of absorption, per cent	4·00
Permeability, cc. per square inch per hour	1·56

Onondaga Limestone. Amherstburg Quarries.

Onondaga Limestone. Hagersville Quarries.

Coefficient of saturation	0·43
Crushing strength, lbs. per square inch (single test)	15883·
Crushing strength after freezing, lbs. per square inch.	16990·
Loss on freezing, per cent	0·0913
Loss on treatment with carbonic acid, grams per square inch	0·118
Transverse strength, lbs. per square inch	2064·
Chiselling factor	5·2

No. 6.—This stone is hard and splintery with distinct stratification planes. The colour is very light like Plate LXXVII, No. 3. The structure is exceedingly fine grained and similar to that of the lithographic type from Eastern Ontario.

No. 7.—The colour of this stone is similar to Plate LXXVI, No. 15. It further differs from No. 11 in possessing a finer grain. The stone could probably be cut with greater ease but it would give a less durable product than No. 11.

No. 8.—Intermediate in structure between No. 7 and No. 11.

No. 9.—Like No. 7. The colour of both these examples is probably secondary.

No. 10.—A very different type of stone. The colour resembles Plate LXXVII, No. 2. The stone is fairly hard and crystalline, in places resembling the true crystalline limestones. Bedding is very perceptible, with numerous fossils along the planes.

No. 12.—A fine grained type resembling Nos. 7 and 9. The rock appears to be fresher and to present a better colour.

Miller gives an analysis of the brown building beds as below:—[1]

Insoluble matter	1·52
Ferric oxide and alumina	·33
Lime	30·34
Magnesia	20·89
Carbon dioxide	46·78
Sulphur trioxide	·18
	100·04

The company has installed a crushing plant, air and steam rock drills, pumps, track and cars. Rack-rock is used as explosive. About 250 tons of crushed stone are at present produced per day. Thirty-four men are employed. Shipping facilities are supplied by a siding from the Michigan Central railway and a dock at the river.

Large dimension blocks were obtained from these quarries for the construction of the lock at Sault Ste. Marie. The stone has also been employed for architectural purposes and may be seen in the Roman Catholic churches at Windsor and at McGregor; it has also been used to a considerable extent in Amherstburg. The indiscriminate use of stone from different beds gives a mottled yellow, brown, and white appearance to new buildings. As the

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 42.

brown stone soon weathers grey, this difference in colour becomes less distinct with time, but a close inspection shows that the tint does not become uniform even in old buildings.

Building stone is valued at $4.50 per cord, f.o.b. quarry siding.

Wm. McCormick, West Dock, Pelee Island.

The quarry is about one half mile north of the west dock and 300 yards from the shore; it is opened in the south side of a ridge, which extends in an east and west direction with a width of 150 yards. The face is from 300 to 400 feet long and, although obscured by vegetation and debris, shows the following succession at one point:—

2 feet—Thin bedded stone, 2 to 3 inches thick.
14 inches—Solid bed.
2-3 feet—Variable beds, sometimes 1 foot thick.
4 feet—Solid bed.
3 inches—Bed.
20 inches—Bed parts into an upper 14 inch and a lower 6 inch layer.
2 feet—Thin material.
3 feet—Solid bed.

At another point, the series is somewhat different as follows:—

2 feet—Thin bedded.
14 inches—Solid bed.
1 foot—Thin material.
2 feet—Solid bed.
8 feet—Fairly solid throughout—Specimen 115.
2 feet—Solid bed.
1 foot—Bed }
1 foot—Bed } In places thinner, in others united to thicker layers.
1 foot—Bed }
2 feet—Bed }

The lower beds are cleaner and contain fewer fossils than the upper layers. The jointing is north and south, and east and west. The former series, particularly, present even, smooth, vertical planes. Large blocks of stone are easily obtainable and several huge pieces are now lying in the quarry. These were obtained 20 years ago with the intention of sawing them into paving stone for use in Toronto; the advent of cement put an end to this industry.

The stone: No. 115.—The stone shows the yellowish brown colour of rather muddy character represented in Plate LXXVI, No. 6; on weathering, it is still brownish, but shows white lines and dots caused by the presence of fossil shells. In structure it is comparable with the Amherstburg stone already described.

The physical properties are as follows:—

Specific gravity	2·719
Weight per cubic foot, lbs.	151·07
Pore space, per cent	10·98
Ratio of absorption, per cent	4·54

Permeability, c.c. per square inch per hour..........	45·
Crushing strength, lbs. per square inch...............	8090·
Crushing strength, after freezing, lbs. per square inch..	6354·
Loss on freezing, per cent..........................	0·0707
Loss on treatment with carbonic acid............	0·10525
Transverse strength, lbs. per square inch.........	1404·
Chiselling factor..................................	6·9

Stone from this quarry was used extensively in the construction of the Welland canal.

John McCormick, North Dock, Pelee Island.

A cliff of limestone is exposed along the north shore of the island, on which quarrying has been attempted at several points. The most important opening is about 250 feet wide and has been worked 600 feet into the cliff to a depth of 20 feet. Unlike the west quarry the stone here is thin bedded and irregular, but some layers from 10 to 14 inches thick are available. The best building stone is represented by these thicker layers—116.

The stone: No. 116.—A fine grained, soft dolomitic stone of light brown colour. This stone is much lighter in colour and of finer grain than No. 115. The weathered aspect is grey; the change in colour being largely due to the inclusion of dirt rather than to any chemical change in the stone.

A dock at the quarry affords excellent facilities for shipping, and a practically unlimited supply of stone is available. Although certain of the beds are suitable for building stone, the necessity of removing a large amount of poor material makes their extraction impossible unless a market be found for the rougher portion. Stone from this locality was used for filling the cribs protecting the Pelee passage lighthouse, and more recently some was obtained for the piers at Port Stanley.

Ten years ago stone was valued at $3 per cord on the dock.

Wm. Fleming, Pelee Island.

An immense amount of loose stone is cast up on the south shore of Pelee island by the waves of the lake. Occasionally Mr. Fleming ships some of this material for lime-burning.

Miller gives the following series of analyses of Pelee Island limestones:—

No. 1.—West quarry, surface.

No. 2.—West quarry, 6 feet down.

No. 3.—West quarry, 8 feet down.

No. 4.—West quarry, 10 feet down.

No. 5.—West quarry.

No. 6.—North quarry, thick layer.

No. 7.—North quarry.

No. 8.—North quarry, 12 feet down.

No. 9.—North quarry, bottom of thin layer.

No. 10.—South side of island.

No. 11.—South side of island.

No. 12.—South side of island.

No. 13.—South side of island.

ANALYSES OF PELEE ISLAND LIMESTONES.[1]

	1	2	3	4	5	6	7	8	9	10	11	12	13
Insoluble residue	......	1·24	....	1·50	1·38	2·20	0·90	1·44	2·26	2·54	1·32	1·62	0·89
Silica	1·38	....	1·40	....	....	....	....	....	....	....	....	....	....
Ferric oxide	0·49	0·32	0·45	0·31	0·33	0·52	0·30	} 0·42	0·31	} 0·32	0·34	0·40	0·19
Alumina	0·45	trace	0·47	0·20	0·43	trace	trace		0·12				
Lime	51·60	47·20	43·06	45·14	50·08	43·34	49·70	45·72	43·70	44·36	50·32	45·52	50·04
Magnesia	2·01	6·06	10·05	7·63	4·40	9·08	4·30	7·22	9·48	8·05	3·49	7·51	4·00
Sulphur trioxide	0·30	0·39	0·32	0·30	0·26	0·42	0·20	0·67	0·53	0·19	0·26	....	....
Carbon dioxide	42·80	43·69	42·28	43·51	43·80	43·94	43·65	43·76	44·54	43·59	43·21	43·95	43·59
Loss	......	1·05	....	1·40		0·82	0·48	0·72	....	....	....	1·03	0·37
Alkalies	......	....	0·40	0·40	....	....	0·10	....	....	....	....	....	....

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 43.

The Kincardine Area.

A small amount of building stone has been obtained in the valley of the Penetangore river near Kincardine. The exposure extends over four lots only.

A. W. Holland, Kincardine, Lots 6 and 7, Con. III, Kincardine S., Bruce county.

John Keys, Kincardine, Lots 8 and 9, Con. III, Kincardine S., Bruce county.

The bottom of the river valley which crosses these lots is about 50 feet below the general level of the country. The upper limit of the rock is not determinable owing to the heavy layer of mixed rock and soil lying on the slopes of the valley. Solid rock occurs in the bed of the creek and may be seen at one or two points as high as 20 feet above the water. The upper 16 feet consists of thin bedded material not exceeding 4 inches in thickness (261); below this lie an 18 inch bed and a 12 inch bed (262) which are very irregular in stratification and bituminous in character. Farther down stream still lower beds are exposed in layers of 8 and 10 inches. This stone resembles the upper thick beds but it is less bituminous; though reedy in character it is soft and easily worked—263.

The stone was used in the construction of a bridge in Kincardine in 1885. An examination of the piers shows that the rock wears well and that it assumes a unique bluish brown appearance on weathering.

There is no production at present and little likelihood of further operations except for the making of lime, with building stone as an accessory product.

The stone: Nos. 261, 262, and 263.—The base of all these stones is of a light brownish grey colour like Plate LXXVII, No. 12. The structure is fine grained crystalline. The different examples differ only in the amount of bitumen present and in the distinctness of the stratification. The stones are soft and easily chiselled.

With the Kincardine stone may be included certain quarries in the township of Colborne. Judging from the account given in the Twelfth Volume of the Geological Survey Reports (pp. 33–34R) it would appear that the stone is very thin bedded in a typical quarry on lot 8, con. I, of Colborne, Huron county. The following descriptions and analyses are taken from the above report.

Fourth bed—6 inches thick, an ashy brown, very fine crystalline, almost compact limestone.

Carbonate of lime, per cent.	95·27
Carbonate of magnesia, per cent.	2·77
Carbonate of iron, per cent	0·31
Carbonate of manganese	trace
Alumina, per cent	0·01
Silica (soluble), per cent.	0·04

Insoluble matter, per cent.	1·30
Organic matter, per cent	0·27

Thirteenth bed—3 inches thick, a yellowish brown, fine crystalline, dolomitic limestone.

Carbonate of lime, per cent.	81·75
Carbonate of magnesia, per cent.	15·06
Carbonate of iron, per cent	0·72
Carbonate of manganese.	trace
Alumina, per cent	0·11
Silica (soluble), per cent.	0·02
Insoluble matter, per cent.	2·57
Organic matter, per cent	0·08

Twenty-fourth bed—6 inches thick, a light yellowish brown, fine to moderately coarse crystalline somewhat magnesian limestone.

Carbonate of lime, per cent.	91·46
Carbonate of magnesia, per cent.	6·22
Carbonate of iron, per cent	0·48
Carbonate of manganese.	trace
Alumina, per cent	0·06
Silica (soluble), per cent.	0·02
Insoluble matter, per cent.	1·74
Organic matter, per cent	0·05

Summary—The Onondaga Formation.

Although the extent of the formation is large, rock exposures are by no means common, as the country is, for the most part, deeply covered with soil.

In the vicinity of Port Colborne some large quarries are worked for furnace flux and in connexion with the cement industry. The stone here is rough and extremely fossiliferous; although some good beds of blue-grey building stone occur, they are so intermingled with rough material that the district gives no promise as a producer of building stone, except as an accessory product.

The quarries at Hagersville are devoted to the production of crushed stone. Some of the lower beds make good building material, but it has been used locally only. Certain small quarries west of Hagersville produce limestone of fair quality, but the output is small and of local importance only.

The Beechville quarries operate in a very pure limestone, highly desirable for chemical purposes and for lime-burning. Building stone is also produced, in beds up to 10 inches thick, for local consumption. On weathering, this stone turns whitish grey with a slight cast of blue.

The most important quarries are those of the Thames Quarry Co., and The Horseshoe Quarry Co., at St. Marys. Here is produced a grey limestone of semi-crystalline character and good chiselling qualities. On weathering it assumes a lighter colour, but the whitening is never so pronounced as in the case of the Black River stones. (See Nos. 138 and 139, page 279.)

In the townships of Colborne and Kincardine a small amount of thin bedded bituminous stone is quarried.

At Amherstburg and on Pelee island large quarries have been operated in beds of very different character, consisting of brownish, porous, crystalline dolomite. The Amherstburg stone is good building material; the Pelee Island stone is deficient in strength and much of it is very thin bedded. (See No. 11, page 284, and No. 115, page 286.)

Literature:—Geol. Sur. Can., Rep. 1863, pp. 361–380; p. 821.
" " " " 1863–66, p. 283.
Bur. Mines, Ont., Rep. Royal Com. 1900, pp. 47–48.
" " " " 1902, pp. 34–35; pp. 123–127.
" " " " 1903, p. 143.
" " " " 1904, pt. ii., pp. 25, 32, 33, 35, 51, 53, 66, 88, 91, 95, 116, 118.

Mich. Geol. and Biol. Survey, Geol. Ser. No. 2. The Monroe Formation, 1900.

THE HAMILTON FORMATION.

The geographical extent of the Hamilton formation has already been indicated; actual exposures of rock are few and such limestone layers as are exposed are so interbedded with shales that profitable quarrying operations could only be effected in connexion with a brick or tile plant. Limestone may be obtained at various points along the Aux Sables river, in the vicinity of Thedford, and on the shore of Lake Huron in the township of Bosanquet, but actual quarrying has been attempted only at a few points near Thedford and here on the smallest scale.

James Cornell, Thedford.

In a creek valley to the north of Thedford the characteristic shales of the formation are exposed and have been utilized for the manufacture of tile and brick. Two beds of limestone, one of 10 inches and the other of 14 inches in thickness, are obtained in quarrying the shale. This stone is used locally for building purposes—147.

Northeast of Thedford a ridge of rock comes very near the surface and has been opened at several places for the purpose of securing building stone. The excavations are too insignificant to be called quarries and no work has been done for years. The stone is described below as specimen 148.

The stone: No. 147.—A hard, thin bedded, semi-crystalline, highly fossiliferous stone of grey colour.

No. 148.—The better parts of this sample present a colour comparable with that shown in Plate LXXVII, No. 11. On weathering, it appears to behave very badly and to rapidly assume a dirty brownish yellow tint. The stone is largely of crystalline character and contains many fossils; it is apparently unsuited for other work than local construction of a rough character.


FRENCH R.
Parry Sound
Renfrew

LAKE NIPISSING
FRENCH R.
North Bay
Lake Talon
Mattawa River
OTTAWA RIVER
GEORGIAN BAY
PARRY SOUND
NIPISSING
Parry Sound
MUSKOKA
Gravenhurst
HALIBURTON
VICTORIA
ONTARIO
Lake Simcoe
Maxwell's
Bancroft
HASTINGS
LENNOX
RENFREW
Haley's
Renfrew
Arnprior
Fitzroy Hr.
Calabogie
Tatlock
Almonte
Mississippi L.
Bedford
PETERBOROUGH
NORTHUMBERLAND
Madoc
Actinolite
FRONTENAC
ADDINGTON
Rideau L.
Lyndhurst
Brockville
Kingston
Gananoque
Legend
Archaean boundary
Crystalline limestone
Crystalline limestone with other rocks
Marble quarries
Granite quarries

Fig. 20. Sketch map of the Archæan area of Southern Ontario.

CHAPTER IV.

The Granites and Gneisses of Southern Ontario.

Although gneiss and granite with the related rock —syenite— occur over wide areas in the Archæan region of Central Ontario, they have not been exploited to any great extent. The actual total production is insignificant and quite out of proportion to the possibilities of the country. In view of the gradually increasing demand for granite that has arisen in connexion with the erection of monumental structures in the cities, it is regrettable that more activity has not been displayed in the exploiting of this class of stone. Formerly, granite was quarried near Kingston, at Brockville, and from some of the islands in the St. Lawrence near Gananoque. The only present production is from the region north and west of this latter town. Gneiss has been obtained from North Bay and Gravenhurst and in very small quantities for local use at other places. A quarry is in operation near Parry Sound, which is more to be recommended on account of the facility with which the stone can be obtained than for the excellence of the material itself.

While it is not the purpose of the present report to deal with undeveloped deposits it is advisable to draw attention to reported occurrences of granite suitable for purposes of construction. Unfortunately, the available literature is very meagre in comment as to the suitability of much of the reported granite to structural use.

Remarks of an economic nature are to be found concerning the area along the St. Lawrence, but, with regard to the interior, such statements are generally of an indefinite character. We must conclude, however, that large masses of good granite are to be found throughout the Archæan area.

Gneiss occurs throughout the region and covers thousands of square miles of territory; as it is not a highly desirable stone, and as the occurrences are so numerous, the reader is referred to the geological maps for information as to its distribution. In much of this gneiss the lamination is so indistinct that it is designated gneissoid granite or granite-gneiss. In fact, the transition from a typical granite to a true gneiss is so gradual that all varieties from quite massive to strongly laminated are to be found in the great Laurentian area.

The following list of references will be found useful to those desirous of further information regarding reported areas of granite. As, with the exception of the St. Lawrence area, these deposits have been worked little or not at all, they were not examined for the purposes of this report. With the granites are included the syenites which occur in some abundance in Haliburton, Peterborough, and Hastings.

The More Important Occurrences of Granite and Syenite in Eastern Ontario.

Addington.

Kaladar—Bur. Mines, Ont., Rep. 1902, p. 207. *Kaladar granite differs from that farther west.*

Carleton.

Arnprior to Ottawa—Geol. Sur. Can., Rep. 1899, p. 34 G.

Carleton—*ibid*, p. 39 G.

March—*ibid*, p. 34 G.

Torbolton—*ibid.*

Frontenac.

Bedford—Bur. Mines, Ont., Rep. Royal Com., p. 92. *Associated with iron ores. Red and black granite on the K. and P. railway*

Deadman's Cove—Geol. Sur. Can., Rep. 1901, p. 174 A.

Kingston—Bur. Mines, Ont., Rep. Royal Com., p. 74. *Red quartz syenite, description and economic account*, pp. 83, 84. *Description of property and account of economic conditions at time.*

Kingston (north of)—Geol. Sur. Can., Rep. 1901, p. 180 A. *Red granite.*

Kingston Mills—Geol. Sur. Can., Rep. 1901, pp. 183, 184 A.

Hinchinbrooke—Geol. Sur. Can., Rep. 1894, p. 82 A.

Olden—*ibid.*

Palmerston—Bur. Mines, Ont., Rep. 1895, p. 218. *Associated with iron ores, and at Ragged Chute.*

Storrington—Geol. Sur. Can., Rep. 1894, p. 82 A.

Haliburton.

Cardiff—Geol. Sur. Can., Memoir 6, pp. 256-283. *Nepheline syenite.*

Glamorgan—Lots 30, 33, 34, 35, Con. III; 32, 11; 27-32, IV; and others.

Glamorgan—*ibid*, pp. 283-288. *Nepheline syenite.*

Harcourt—*ibid*, pp. 288-291. *Nepheline syenite.*

Lutterworth—Lot 12, Con. IV—*ibid*, p. 256. *Nepheline syenite.*

Monmouth—Lots 16, Con. IX; 24, XII; 27, XII; 23, XI; 18, VII, and others—Geol. Sur. Can., Memoir 6, 1910, pp. 256-283. *Full description of nepheline syenite occurrences.*

Monmouth—Geol. Sur. Can., Rep. 1897, p. 45 A. *Granite gneiss.*

Hastings.

Cashel—Geol. Sur. Can., Rep. 1898, p. 107 A.

Dungannon—*ibid.*

Dungannon—Geol. Sur. Can., Memoir 6, 1910, p. 305 et seq.

Elzevir—Lot 6, Con. V. Geol. Sur. Can., Rep. 1863-66, p. 92.

Faraday—Geol. Sur. Can., Memoir 6, 1910, p. 305 et seq. *Alkali syenite.*

Lake—Geol. Sur. Can., Memoir 6, 1910, p. 51. *Massive granite at Lake Copeway.*

Limerick—Geol. Sur. Can., Rep. 1898, p. 107 A.

Madoc—Geol. Sur. Can., Rep. 1863-66, p. 92. *Extensively in Madoc.*

Madoc—Lot 1, Con. VI—*ibid.* *Quarried for furnace hearths.*

Madoc—Lot 14, Con. V—*ibid.* *Apparently not good.*

Madoc—Lot 10, Con. VI—*ibid.* *Apparently not good.*

Marmora—Geol. Sur. Can., Rep. 1899, p. 125 A. *Rough shattered granite, the Huckleberry rocks.*

Marmora—Geol. Sur. Can., Rep. 1871-72, p. 130. *Large granite mass.*

Mayo—Geol. Sur. Can., Rep. 1898, p. 107 A.

Monteagle—Geol. Sur. Can., Memoir 6, 1910, p. 305 et seq. *Alkali syenite.*

Wollaston—Geol. Sur. Can., Rep. 1898, p. 107 A. *Nepheline syenite.*

Lanark.

Bathurst—Geol. Sur. Can., Rep. 1863, p. 812. *Fine red granite.*

N. Burgess—Geol. Sur. Can., Rep. 1892-93, p. 82.

Leeds.

Barrow island—Geol. Sur. Can., Rep. 1863, p. 811. *A fine granite from the island to Brockville.*

Brockville—Geol. Sur. Can., Rep. 1900, p. 134. *A reddish granite at Brockville and on adjacent islands.*

N. and S. Crosby—Geol. Sur. Can., Rep. 1892-93, p. 82.

Forsythe, Juniper, Leek, and Grindstone Island (in part American)—Bur. Mines, Ont., Rep. 1902, p. 297. *Granite showing shades of red and a varying texture on the different islands.*

Lansdowne—Geol. Sur. Can., Rep. 1900, p. 138 A. *Red granite dykes.*

Willetsholme—Bur. Mines, Ont., Rep. 1902, p. 297. *A blue granite, very handsome when polished.*

Parry Sound.

French river, mouth of—Geol. Sur. Can., Rep. 1876–77, p, 202. *Dykes of coarse red granite.*

McDougall—Lot 17, concession III—*ibid*, p. 205. *Coarse granite.*

Parry Sound—*ibid*, p. 199. *Straggling veins of granite.*

Peterborough.

Methuen—Geol. Sur. Can., Rep. 1871–72, p. 130. *Red granite on Pine Plains.*

Methuen—Geol. Sur. Can., Memoir 6, 1910, p. 291. *Syenite.*

Methuen—Geol. Sur. Can., Rep. 1899, p. 123 A. *Large granite area.*

Anstruther—Geol. Sur. Can., Rep. 1897, p. 45 A. *Large granite gneiss area.*

Cavendish—Geol. Sur. Can., Rep. 1899, p. 123 A. *Continuation of Anstruther granite.*

Harvey—*ibid.* *Continuation of Anstruther granite.*

Renfrew.

Brougham—Lot 18, concession III.—Geol. Sur. Can., Rep. 1896, p. 55 S. *Dykes of granite.*

Brudenell—Geol. Sur. Can., Memoir 6, 1910, p, 305, et seq. *Alkali syenties.*

Hyland Chute—Geol. Sur. Can., Rep. 1901, p. 35 J. *Heavy masses of reddish granite.*

Lyndoch—Lot 12, concession XII—Geol. Sur. Can., Rep. 1901, p. 35 J. *Fine grained granite.*

Raglan—Geol. Sur. Can., Memoir 6, 1810, p. 305 et seq. *Alkali syenites.*

Renfrew, etc.—Geol. Sur. Can., Publication No. 997, 1907, p. 45. *General statement of the occurrence of massive red granites in the Pembroke Sheet area.*

Renfrew, etc.—Geol. Sur. Can., Rep. 1901, p. 74 J. *Many granites suitable for building in Renfrew, Addington, Leeds, and Carleton.*

Victoria.

Digby—Geol. Sur. Can., Rep. 1892–93, p. 7 J. *Granite veins.*

The Kingston Area.

The Kingston Granite Quarry.

This property is situated at Deadmans cove near Kingston; it was formerly operated by the Canadian Granite Co., of which Mr. Alexander McLean was president.

To the north of the granite area occurs a belt of greyish gneiss, banded with red and cut by stringers from the granite mass. The gneissoid formation strikes 30°W. of S. The granite forms a hill rising slightly above the level of the gneiss. In the side of this elevation the quarry has been opened to a depth of 50 feet. The excavation is about 200 feet long by 100 feet wide.

The jointing is very marked and has doubtless contributed one reason for the cessation of operations. A strong series of joints strike southeast with a dip of 70° to the southwest: these partings are clear cut and, in some places, they are not more than one foot apart. A second series runs 50° E. of N., or approximately at right angles to the first set with a vertical dip. A third set of joints, which is however much less in evidence, runs at 60° S. of E. with a dip of 75° or 80° to the northeast. Another set of partings, which probably represents the sheeting planes of the granite mass, strikes 30° W. of N. and dips at a low angle (about 30°) to the northeast. Horizontal cracks of an irregular character, and evidently of later origin, are also to be seen. In this connexion Mr. McLean states: "There are a great many natural seams, and that is the difficulty; perhaps if we get down to a considerable depth that will improve, but we cannot say as yet that there is any improvement. We have got out some very large blocks, but the waste is very considerable." [1]

[1] Bur. Mines, Ont., Rep. Royal Com., 1900, p. 83.

Mr. McLean further states: "This granite takes a beautiful polish, better than any I have ever seen. It is worth from 15 to 20 per cent more than the ordinary granite to cut. It is used for ornamental purposes, columns for buildings, etc. There is a good demand for the product, but the price, owing to Scotch and New Brunswick competition, is very low."

The stone: No. 70.—This stone presents a general bright red aspect with light bluish dots. It consists of red feldspar (orthoclase) blue quartz, and a small amount of black mica which is in places replaced by hornblende. Under the microscope, it is seen that decay has begun in the orthoclase and to some extent in the mica, but nevertheless the rock is comparatively fresh. A small amount of pyrite, as well as other accessory minerals, is present. The polished surface has a unique appearance due to the bluish cast of the quartz. The physical properties are as follows:—

Specific gravity	2·68
Weight per cubic foot, lbs.	166·72
Pore space, per cent.	0·319
Ratio of absorption, per cent.	0·119
Coefficient of saturation.	·7
Crushing strength, lbs. per square inch.	30421·
Loss on treatment with carbonic acid, grams per square inch	0·0045
Transverse strength, lbs. per square inch	3382·

A large amount of this stone is still available but there has been no production for many years.

The Gananoque Area.

Granite has been quarried on the islands in the St. Lawrence between Gananoque and Brockville, on the mainland near Gananoque, and in the city of Brockville itself.

The Islands.—Granite quarrying has been prosecuted for a great many years on several of the islands in the river near Gananoque. The most important openings have been made on Grindstone island in the State of New York. As the granite on the Canadian islands is somewhat similar it seems advisable to briefly describe these larger openings in which more detail of structure is visible.

Grindstone island, Miss Jennie Forsythe, Montreal.

The opening known as Forsythe's quarry is the largest on the island, although several other owners have done considerable work at different places.[1] The bluff of rock on which the quarry is opened stands about 60 feet above

[1] W. L. Webster, 78 Broad St., New York; Geo. McCarthy, Grindstone island; Mrs Packard, Grindstone island.

the level of the water, so that a good working face, backed by plenty of material is presented. The opening is large, but it is irregular in shape. The chief joints run 25° W. of S. with a vertical dip; these joints are variable in spacing, being in places very close together, and in others sufficiently far apart to permit the quarrying of very large blocks. The horizontal sheeting is shown by irregular partings from 4 to 12 feet apart which divide the rock into large lens-shaped masses. In addition to these regular joints, a large amount of irregular shattering is observed, but, owing to the present condition of the quarry, it is difficult to say whether they are original or due to the use of explosives. The presence of aggregations of dark hornblendic matter (knots) adds to the difficulty of obtaining large blocks free from flaws. Despite the difficulties presented by the jointing, the presence of knots and the development of gneissoid structure in places, experience has proven that some large dimension stone can be obtained.

Two types of stone have been quarried, a rather coarse grained variety used for monumental purposes (203), and a fine grained red variety, which has been employed in the making of paving stones.

The stone: No. 203.—A coarse grained red granite of rather bright appearance owing to the sharp contrast between the large crystals of red orthoclase, white quartz, and black biotite. Under the microscope the biotite is seen to be partly replaced by green hornblende with which is associated a small amount of magnetite. Incipient decay is visible in the feldspar crystals, but it has not advanced to any dangerous extent. Some of the feldspar individuals are more than half an inch in diameter.

Leek Island.

The stone here is like that of Grindstone island, but as the rock rises only 20 feet above the water the amount of material that can be obtained without pumping is somewhat limited.

Juniper Island, Miss Jennie Forsythe, Montreal.

On this island the rock rises about 20 feet above the water and an excavation of 300 feet by 200 feet has been opened to a maximum depth of 10 feet. The rift is horizontal and the grain vertical in an east and west direction. The jointing is similar to that seen on Grindstone island; the upper sheet is fully 8 feet thick. Despite the considerable amount of checking, some dimension stone has been obtained.

The stone: No. 204.—This example is finer in grain, less brilliant in appearance and of a somewhat darker colour than the Grindstone island stone; it polishes well and presents a rich but not brilliant appearance.

Granite Island, Miss Forsythe, Montreal.

On this island are two small openings. The rock stands only 10 or 15 feet above the water level. The main joints strike southwest and are cut by a minor set approximately at right angles. The rock has been badly broken by explosives but some cut stone has been made from the output.

The stone: No. 205.—It is difficult to speak of the character of this example from the specimen obtained, which is in an advanced state of decay. The grain is somewhat finer than that of the last sample, the feldspar is of a light red colour while the quartz has a tinge of blue. The dark minerals present a dull appearance. It is not to be inferred from this description that the fresh stone is of undesirable character.

On several other islands stone has been quarried, but the above description is indicative of the possibilities of the area. There is no present production from the district, nor has any granite been quarried for several years. It would appear that, although the shipping facilities are excellent and although much of the stone presents a handsome appearance when polished, the difficulty of obtaining large pieces without undue waste has militated against a continuous production.

D. J. Gordon and Son, Gananoque.

This firm is at present the only important producer of granite in the province. The quarries are situated at different points to the northward of Gananoque. Most of the output is made into paving blocks, but some stone has been shipped for structural and monumental purposes. Most of the openings are small and scattered over a considerable area, the practice being to make new openings from time to time rather than to conduct extensive operations at any one point. The largest present working is on lot 7 (?), con. II, Leeds, where the monumental and structural stone is being obtained. The quarry has been opened in the side of a hill which is capable of furnishing a very large amount of desirable stone. The main joints strike east and west and north and south and occur at intervals of from 10 to 20 feet. The horizontal sheeting planes are less regular in development, and are, in some parts of the exposure, very close together, but in other places they are entirely absent for as great a distance as 10 feet. Stone 6 feet by 5 feet by 1 foot 4 inches has actually been quarried—200.

The stone: No. 200.—This rock presents a dark greenish grey appearance in the rough. When polished it is a very handsome stone and is represented in Plate LXX. The chief mineral constituent is a brownish tinted orthoclase which occurs in crystals of a half inch or more in diameter. A small amount of plagioclase is present as well as intergrown feldspars of different kinds. Next in importance are crystals of dark greenish hornblende with which is associated a considerable amount of magnetite. Small amounts of augite also occur, but the crystals of this mineral are in a poor state of preservation. Quartz is also present in very small amount. The rock should not properly be called a granite but a syenite. Owing to the presence of some augite, which mineral is more abundant in other parts of the area, the rock would be classified as an *augite syenite*. To this class belong many of the beautiful stones imported from Norway and with which, therefore, the present example is comparable. The particular beauty of rocks of this type depends largely on the iridescent character of the feldspar crystals. Some beautiful examples are known in Ontario from the region near Port Coldwell north of Lake Superior. The physical properties of the present specimen are indicated below:—

Specific gravity	2·746
Weight per cubic foot, lbs	168·82
Pore space, per cent	0·33
Ratio of absorption	0·124
Coefficient of saturation	0·73
Crushing strength, lbs. per square inch	23152·
Crushing strength after freezing, lbs. per square inch	20536·
Loss on freezing, per cent	0·006
Loss on treatment with carbonic acid, grams per square inch	0·00088
Transverse strength, lbs. per square inch	2791·

The other openings made by this company have been worked, more particularly for the production of paving blocks, but many of the granites obtained are quite suitable for structural work. Some of the more important types are briefly described below:—

Lot 10, *con. III, Leeds*.—The rock here is well exposed and is jointed nearly east and west and north and south at intervals ranging up to 20 feet. The formation is, however, somewhat gneissoid in structure with the lamination running 30° S. of W. In this direction also appear streaks of lighter coloured red granite which makes the obtaining of uniform blocks difficult. The first horizontal sheet is 6 feet thick, so that large blocks can readily be obtained, but they are marred by the red bands mentioned above. The rift is horizontal and the grain vertical in an east and west direction.

The stone: No. 198.—This example is a coarse red granite, resembling very closely No. 204 already described. Although undoubtedly of the same general type as the Juniper island stone, the present specimen shows a lighter colour owing to the red of the feldspar being less intense.

N.E. quarter lot 7, *con. II, Leeds*.—On this property is a large opening with a face of 25 feet, showing sheeting planes of an irregular character at intervals of 6, 11, and 10 feet from the top. The stone is not well coloured or uniform and has been employed for paving blocks only.

Lot 6, con. II, Leeds.—The stone in this quarry is much redder than the product of the other workings; it is, however, banded with grey, but the company hopes to eventually obtain large blocks free from this imperfection. A gneissoid formation borders the granite mass to the westward—201.

The stone: No. 201.—This sample must be regarded as typical not only of the present locality, but of the occurrence at Lyndhurst, and of the fine grained red granites generally as developed in the Gananoque area. This stone does not differ materially from the Kingston type. The finer grain and somewht more laminated structure together with the lighter red of the feldspar constitute the only differences. As in the Kingston stone, the quartz presents a light blue tint.

Lot 10, con. 11, Escott.—A large mass of granite is exposed on this lot and the company is proceeding with extensive development work. The horizontal rift and east and west grain are exceptionally well developed, and, even on the head, the stone breaks with a smooth fracture. It is stated that this material is 10 per cent easier to cut into paving blocks than the product of any other opening yet made in the district.

The quarry is opened in the side of a hill and shows a stone of good uniform grain and colour, which is however marred by the presence of small red veins and knots of hornblendic matter (202). The main joints strike 15° S. of W. with a dip of 18° to the south. The other set strikes 40° W. of N. The first series is very widely spaced, as much as 30 feet intervening between partings. The joints of the second series occur at intervals of from 2 to 10 feet. The jointing is unquestionably good, so that large stone can be obtained with facility. Unfortunately, no large pieces have yet been obtained free from the imperfections mentioned. It is hoped that further development will reveal stone free from these objectionable features.

The stone: No. 202.—This example is of a lighter colour than the Brockville stone, which it resembles in some respects. The grain, however, is much finer—in fact the grain is the finest of any of the Gananoque stones referred to in this report. Under the microscope, the rock is seen to be composed of feldspar crystals, among which the variety known as microcline is well developed, a greater amount of quartz than is common in the locality, and a small quantity of black mica. When free from the imperfections mentioned in the description of the quarry, this granite presents a uniform grain and a very pleasing colour; it should make a desirable material either for decorative or rock face work.

Lyndhurst.—Near this point the company operates a quarry which produces a stone of the same character as that from lot 5, con. II, Leeds (201). This red stone has been obtained in large pieces, free from the grey bands, and has been employed for structural and monumental purposes.

The quarry for monumental stone is operated by Mr. D. J. Gordon personally. Here a derrick and other essentials have been installed. The paving stone industry is conducted in the following way:—

The company do the drilling and blasting, thereby producing what is known locally as a "motion." The displaced stone is then made into paving blocks by piece work, the workmen receiving three cents per stone for the making. It is estimated that the cost of the "motion" is ¼ ct. per block and that loading and drawing to the railway require an outlay of 1¼ cts. per block. This makes the cost of production $45 per 1,000 without any allowance for management, etc. These blocks, with a guarantee to wear 25 years, are valued at $52.50 f.o.b. Gananoque. The size of the block is required to fall within the following dimensions—length 9 to 14 inches, width 3½ to 5 inches, depth 5 to 5½ inches.

Monumental stone is valued at 80 cts. per cubic foot and building stone at 40 cents per square foot of face, the depth being at least 8 inches, both f.o.b. Findley station. Dressed sills are valued at $2 per square foot on the bed.

The company employs about 100 men, 75 being engaged in making paving blocks and the remainder in miscellaneous work. The annual output is about $50,000 in paving blocks and $5,000 in building and ornamental stone.

Examples of the granite may be seen in the Grand Trunk Railway stations at Brampton, Brantford, and Paris. Monumental stone has been shipped to Hamilton, Berlin, Sarnia, London, Guelph, Peterborough, Toronto, and Montreal.

Street and O'Brien, Gananoque.

This company does a business of a similar character to that of D. J. Gordon and Son. As the same type of stone is quarried from the same general region a further description is unnecessary.

Robert Keys, Gananoque.

The quarry is about 1½ miles west of the town. The product is crushed for the making of macadam.

Black and Burgess, Gananoque.

This property is not now in operation. It was described by Miller as follows:—"Another quarry is that of Messrs. Black and Burgess of Gananoque, at Willetsholm, six miles west of Gananoque, the stone being a blue granite, obtaining its unusual colour from the dark blue feldspar crystals which also give it a lustrous shimmer when polished and make it particularly valuable for monumental work." [1]

[1] Bur. Mines, Ont., Rep. 1902, p. 297.

The Brockville granite.

The western part of the city of Brockville is underlaid by a great mass of granite in which quarries have been opened from time to time and from which a small amount of building stone has been obtained. Variations occur in the granite mass, so that samples may be obtained in various shades of red. The depth of colour depends on the tint of the feldspar, which ranges from light pink to chocolate colour. An average specimen is described below.

The stone: No. 324.—This example is of average grain but of somewhat darker colour than most of the stone in this vicinity. The chief mineral constituent is a flesh-red orthoclase feldspar, which occurs in individuals up to one-half inch in diameter. Microcline and plagioclase also appear among the feldspar crystals. Quartz occurs in much less abundance and in smaller crystals. The dark constituent is black mica with which is associated a considerable amount of magnetite. The microscope does not reveal any serious decomposition in the present sample but other specimens are in a much less satisfactory condition; this is to be expected in stone obtained from the surface. The physical properties of the stone are enumerated below:—

Specific gravity	2·658
Weight per cubic foot, lbs.	166·647
Pore space, per cent	0·201
Ratio of absorption, per cent	0·075
Coefficient of saturation	0·67
Crushing strength, lbs. per square inch	26209·
Crushing strength after freezing, lbs. per square inch	24634·
Loss on freezing, per cent	0·0048
Loss on treatment with carbonic acid, grams per square inch	0·000164
Transverse strength, lbs. per square inch	2480·

As far back as 1858 a building known as Brough's flour mill was constructed of this granite; local authorities cite the fact that this building has been burned four times as a proof of the fire-resisting quality of the stone. A good example of the use of this material is to be seen in the waterworks building and in the recently erected electric station.

Architects desiring a granite of subdued red tones and one capable of receiving a good polish without undue cost would find a readily accessible material in the Brockville stone. Unfortunately there is no regular production and a quarrying industry can scarcely be said to exist.

The Parry Sound Area.

As already stated, gneiss has been quarried in small amount at several places; the production has however never been sufficient to place the industry on an economic basis. At North Bay, Russell and Buffet have quarried a small amount of red and black banded well laminated gneiss for use in foundations; this material has also been used for sills to a very limited extent. At Gravenhurst, a little grey biotite gneiss has been obtained; it is stated that some of this material was shipped to Toronto. Both the above samples represent the older gneisses of the region, those in which the lamination is not horizontal and in which the structure is highly crystalline (Laurentian). A second and later series of gneisses is found in certain areas and is often associated with the crystalline limestones (Grenville). This type of gneiss is less coarsely crystalline and shows fine lamination, with the layers in an approximately horizontal position. Material of this kind is quarried near Parry Sound and is described below.

R. R. Hall, Parry Sound, Lot 25, Con. III, McDougall, Parry Sound.

The quarry is opened in the west and north faces of a bluff of rock which rises about 75 feet above the general level. The strike of the formation is 32° west of south and the dip 10° to the southeast. Distinct horizontal partings or bedding planes occur at intervals of from 2 to 4 feet, and well developed joints in both a north and south and east and west direction divide the rock into blocks of convenient size for handling. Along the planes of lamination the stone is very easily split and even across the grain it breaks with remarkable facility. The ease with which this stone may be quarried and cut is attested by the fact that in the four years of working no explosive has been used. Wedges and crowbars are found to be sufficient both for quarrying the stone and for breaking it into sizes convenient for purposes of rough construction.

The stone: No. 319.—This rock is a finely laminated gneiss which has probably been formed from a very ancient clay slate by metamorphic processes. There are about 30 laminae to the inch, which show on the vertical surface as fine pink and black alternations. The mineral constituents are quartz, orthoclase and black mica, with a considerable amount of pink garnet. Rocks of this type are so common over wide stretches of central Ontario that a detailed description of this individual example can be of little value. The physical properties given below may, however, be of value as indicating, in a general way, the physical characteristics of this type of rock.

Specific gravity	2·67
Weight per cubic foot, lbs	165·588
Pore space, per cent	0·628
Ratio of absorption, per cent	0·237
Coefficient of saturation	·8
Crushing strength, lbs. per square inch	33453·
Crushing strength after freezing, lbs. per square inch	32271·
Loss on freezing, per cent	0·0066

Loss on treatment with carbonic acid, grams per square inch..............	0·0015
Transverse strength, lbs. per square inch..	1546·
Chiselling factor........................	0·5

An interesting feature connected with the crushing strength tests was the uniform development of wedge-like residual pieces indicating the existence of a well defined grain in the rock. Considering the nature of the rock the crushing strength is remarkably high—greater than that of the hard Kingston granite. The transverse strength on the other hand is low.

The stone is valued at $6 per cord delivered in Parry Sound. It may be seen in the foundation of the Court House and Registry Office and in many minor structures in Parry Sound.

Hastings Quarries, Limited, Jas. Pearson, manager, 10½ Terauley St., Toronto.

This company was organized since the field work in connexion with this report was done; in consequence, no account of the property is available. The stone is a rather fine grained granite of a dull red colour: it shows a crushing strength of 33,220 lbs. per square inch.

CHAPTER V.

The Crystalline Limestones and Marbles of Southern Ontario.

The great Archæan area of Ontario, the boundaries of which have already been indicated and which are shown on the accompanying map, consists of a complex series of gneisses, granites and other crystalline rocks, either fresh or in various stages of alteration. In certain parts of this wide area, more particularly the southeast portion in Hastings, Lanark, Frontenac, Leeds, Haliburton, Renfrew, Peterborough, and Victoria, are extensive belts of crystalline limestone extending, for the most part, in a northeasterly direction. Roughly speaking there is about 100 square miles of territory formed of rocks of this type. While most of the stone is too coarse, too friable, or too impure for structural work, some of it, on the other hand, is so fine and so beautifully marked as to deserve the name of marble. Between these two extremes are large quantities of stone of an intermediate type eminently suited to architectural purposes of the highest kind. The geology of these belts has occupied the attention of investigators from the earliest days and a large literature on the subject is consequently available. The most complete account is contained in Memoir No. 6 of the Geological Survey of Canada,[1] to which the reader is referred. The authors establish the fact that the great belts of crystalline limestone and dolomite were originally sedimentary beds which have been altered to their present condition by the intense metamorphism which they have suffered. They recognize four types as follows:—

(1) Blue limestone, representing the stone which has been least altered and which shows its crystalline character only under the microscope.

(2) White crystalline limestone.

(3) Crystalline limestone with granular amphibolite.

(4) Crystalline limestone with feather amphibolite.

In many places the white crystalline limestone is fine in grain and constitutes a true marble; in others it is coarser, yet still suitable for building, while much of it is too coarse and friable for purposes of construction.

The limestone containing amphibolite represents original beds which contained impurities; by the processes of metamorphism these impurities have been caused to crystalline as amphibole either in a granular or feathery form. Besides amphibole, thirty-six other minerals are known to have arisen in the same way. Of these substances the most important are pyrite, chondrodite, and serpentine. The first of these, on account of its bad colour effect on weathering, constitutes a serious objection to the stone which contains it. The second mineral occurs as small yellow dots in many otherwise fine

[1] Geol. Sur. Can., Memoir No. 6, Adams and Barlow, Geology of the Haliburton and Bancroft areas.

examples. The third substance—serpentine—occurs in beautiful clouds and masses in much of the limestone and with it forms *serpentine-marble* or *verde antique*. The serpentine is itself in sufficient bulk in places to be quarried as a separate decorative material, but it is usually so mingled with the crystalline limestone that serpentine and serpentine-marble will be considered together, although there is no very sharp distinction from the other variegated marbles in which a little serpentine may occur.

The reported occurrences of crystalline limestone, marble, serpentine, and serpentine-marble are so numerous that it was impossible to visit all the localities. Before proceeding with a description of the properties actually examined, the following list of localities, which will also serve as a bibliography, is given. In most cases, the original description refers to the use of the material for decorative or structural purposes. No attempt is made to include all the localities in which the materials in question are known to occur.

Reported Occurrences of Crystalline Limestone and Marbles in Lower Ontario.

Carleton.

Torbolton, Fitzroy Harbour.—Geol. Sur. Can., Rep. 1863, p. 882.
" " " Geol. Sur. Can., Rep. 1894, pp. 58–59A.
" " " Geol. Sur. Can., Rep. 1888–89, p. 127K.
" " " Bur. Mines, Ont., Rep. 1904, pt. ii, p. 38.

Frontenac.

Barrie, Lots 27, 28, 29, Cons. IX and X.—Geol. Sur. Can., Rep. 1863, p. 882.
" Geol. Sur. Can., Rep. 1870–71, p. 315.
" Geol. Sur. Can., Rep. 1872–74, p. 154.
" Geol. Sur. Can., Rep. Royal Com., pp. 69, 80, 235.
" Bur. Mines, Ont., Rep. 1895, p. 220.
" Geol. Sur. Can., Rep. 1888–89, p. 27R.
" Geol. Sur. Can., Rep. 1901, p. 44. J.
" Geol. Sur. Can., Rep. 1896, pp. 55–56 A.
" Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 45, 10.
" Lot 28, Con. IX.—Geol. Sur. Can., Rep. Museum, 1893, p. 117.
Loughborough, Lot 1, Con. X.—Bur. Mines, Ont., Rep. 1904, pt, ii, p. 45.
" Lot 6, Con. X.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 45.
" Lot 1, Con. X.—Geol. Sur. Can., Rep. 1863, pp. 592–3.
" Lot 6, Con. I.—Geol. Sur. Can., Rep. 1863, pp. 592–3.
Palmerston, Dalhousie—Geol. Sur. Can., Rep. 1874–75, p. 132.

Haliburton.

Anson, Lot 12, Con. I.—Geol. Sur. Can., Memoir No. 6, 1910, p. 195.

Glamorgan, Lot 17, Con. I.—Bur. Mines, Ont., Rep. Royal Com., p. 83.

" Lot 17, Con. I.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 57.

" Lots 26, 27, 28, 29, 30, Con. X.—Geol. Sur. Can., Memoir 6, 1910, p. 391.

Glamorgan, Lot 2, Con. VI.—Geol. Sur. Can., Memoir No. 6, pp. 195, 391.

Lutterworth, Lot 19, Cons. IV and V.—Geol. Sur. Can., Rep. 1892–93, p. 8 J. Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 2, 57.

Lutterworth, Lot 20, Con, V.—Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 2, 57. Geol. Sur. Can., Rep. 1892–93, p. 8 J.

Lutterworth, Lot 19, Cons. IV and V.—Geol. Sur. Can., Memoir No. 6, 1910, pp. 391 et seq.

Snowdon, Lot 32, Con. V.—Bur. Mines, Ont., Rep. Royal Com., p. 83.

Snowdon, Lot 32, Con. V.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 57.

Hastings.

Bridgewater village (Actinolite).—Geol. Sur. Can., Rep. 1863–66, pp. 94.

" " Geol. Sur. Can., Rep. 1870–71, p. 315.

" " Bur. Mines, Ont., Rep. Royal Com., 1900, pp. 69, 75, 76, 81, 82.

" " Bur. Mines, Ont., Rep. 1902, pp. 200, 204.

" " Bur. Mines, Ont., Rep. 1904, pt.ii, pp. 62–65.

Dungannon.—Geol. Sur. Can., Memoir 6, 1910, pp. 388–391.

Elzevir.—Geol. Sur. Can., Rep. 1870–71, p. 315.

" Lot 1, Con. VI.—Geol. Sur. Can., Rep. 1863–66, p. 107.

" Bur. Mines, Ont., Rep. 1904, pt. ii, p. 62.

" Geol. Sur. Can., Rep. 1863, pp. 822–23.

" Geol. Sur. Can., Rep. Mus., 1893, pp. 114, 116.

Faraday, Lots 1 and 2, Con. XII.—Geol. Sur. Can., Memoir No. 6, 1910, p. 389.

Faraday, Lots 41 and 42, Hastings road.—Geol. Sur. Can., Memoir No. 6, 1910, p. 389, 390.

Faraday, Lots 1 and 2, Con. XII.—Bur. Mines, Ont., Rep. 1906, p. 107. Bur. Mines, Ont., Rep. 1907, p. 82. Bur. Mines, Ont., Rep. 1908, p. 93.

Madoc, Lot 13, Cons. VII and VIII.—Geol. Sur. Can., Rep. 1863, pp. 593, 822-3.

" Lot 13, Cons. VII and VIII.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 62.

" Lot 1, Con. VIII.—Geol. Sur. Can., Rep. Museum, 1893, p. 118.

" Geol. Sur. Can., Rep. 1870–71, p. 315.

" Lot 1, Con. VI.—Geol. Sur. Can., Rep. 1863–66, p. 107.

" village.—Geol. Sur. Can., Rep. 1863, p. 593.

" " Geol. Sur. Can., Rep. 1866–69, p. 154.

" " Bur. Mines, Ont., Rep. Royal Com., 1900, pp. 75, 76, 80.

Madoc village.—Bur. Mines, Ont., Rep. 1902, p. 204.
" " Bur. Mines, Ont., Rep. 1904, pt. 11, pp. 61, 62, 65.

Marmora, Lot 16, Con. XI.—Geol. Sur. Can., Rep. 1866–69, p. 155; Rep. 1863–66, p. 107.

Marmora.—Geol. Sur. Can., Rep. 1863, pp. 822–3.
" Geol. Sur. Can., Rep. 1870–71, p. 315.
" Bur. Mines, Ont., Rep. 1904, pt. ii, p. 62.

Tudor, Lots 41 and 42, Hastings road—information.

Lanark.

Lanark, Lot 22, Con. VIII.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 71.
" Lot 24, Con. IX.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 70.
" Lot 21, Con. X.—Geol. Sur. Can., Rep. Mus., 1893, p. 118.

Leeds.

Bastard, Beverley.—Geol. Sur. Can., Rep. 1863, p. 822.
" " Bur. Mines, Ont. Rep. 1904, pt. ii, p. 72.

Lansdowne, N. side Charleston Lake.—Geol. Sur. Can., Rep. 1863, p. 822.

South Elmsley.—Geol. Sur. Can., Rep. 1897, p. 60A.

South Crosby.—Geol. Sur. Can., Rep. 1863, p. 31.

Peterborough.

Cardiff, Lot 29, Con. XI.—Geol. Sur. Can., Memoir 6, 1910, p. 195.
" Geol. Sur. Can., Rep. 1892–3, p. 4 J.

Cavendish, Cons. XIII and XIV, Deer Lake.—Geol. Sur. Can., Memoir 6 1910, p. 195.

Methuen, northern, Jack Lake.—Geol. Sur. Can., Memoir 6, 1910, p. 195.

Renfrew.

Arnprior, town.—Geol. Sur. Can., Rep. 1863, p. 822.
" " Geol. Sur. Can., Rep. 1895, p. 67 A.
" " Geol. Sur. Can., Rep. 977, 1907, p. 45.
" " Bur. Mines, Ont., Rep. Royal Com., 1900, pp. 69, 76, 82.
" " Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 101–103.

Horton, Lot 11, Con. II.—Geol. Sur. Can., Cat. Mus., 1893, p. 114.

Lynedoch, Lot 12, Con. XII.—Geol. Sur. Can., Rep. 1901, p. 36 J.

McNab, Lot 15, Con. II.—Geol. Sur. Can., Cat. Mus., 1893, p. 163.

Renfrew, town.—Bur. Mines, Ont., Rep. 1904, pt. ii, pp. 11, 101, 102.
" " Bur. Mines, Ont., Rep. Royal Com., 1900, pp. 76, 84.

Ross, Lot 22, Con. IV.—Geol. Sur. Can., Rep. 1882–3–4, p. 15 L.
" Lot 22, Con. IV.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 103.
" Lot 19, Con. VI.—Geol. Sur. Can., Rep. 1895, pp. 66–67 A. Geol. Sur. Can., Pub. No. 977, 1907, p. 45.

Victoria.

Somerville, Lot 8, Con. XI.—Bur. Mines, Ont., Rep. 1904, pt. ii, p. 114.

Reported Occurrences of Serpentine and Serpentine-Marble in Lower Ontario.

Addington.

Kaladar.—Bur. Mines, Ont., Rep. 1893, p. 91.

Frontenac.

Bedford, Lot 6, Con. III.—Bur. Mines, Ont., Rep. 1900, p. 209. Geol. Sur. Can., Cat. Mus. 1895, p. 24.

Haliburton.

Anson, Lot 11, Con. II—Geol. Sur. Can., Memoir 6, 1910, p. 212.
" Lot 11, Con. III—*ibid*, p. 213.
Harburn, Lot 5, Con. I—*ibid*, p. 212.
Lutterworth, Lot 13, Con. XIV—*ibid*, p. 213, p. 391.
Minden, Lot 10, Con. III—*ibid*, p. 212.

Hastings.

Elzevir, Lots 7 and 8, Con. XI.—Geol. Sur. Can., 1894, p. 14 S.
" Lots 7 and 8, Con. XI.—Bur. Mines, Ont., Rep. 1893, p. 91.
Grimsthorpe—*ibid*, p. 91.
Hungerford—*ibid*, p. 91.
Marmora, Lot 13, Con. IX.—Bur. Mines, Ont., Rep. 1900, p. 209.
" Lots 10 and 11, Con. III—information.

Lanark.

Burgess.—Geol. Sur. Can., Rep. 1863, p. 472, 821, 823.
" North—Geol. Sur. Can., Rep. 1863–66, p. 204.
" " Geol. Sur. Can., Rep. 1888–89, p. 57 T.
" " Lot 2, Con. VIII.—Bur. Mines, Ont., Rep. 1900, p. 209.
Dalhousie.—Geol. Sur. Can., Rep. 1876–77, p. 266, 253.
" Lots 23 and 24, Con. III.—Geol. Sur. Can., Rep. 1874–75, p. 138.
Darling.—Geol. Sur. Can., Rep. 1876–77, pp. 253, 266.
" Bur. Mines, Ont., Rep. Royal Com., 1900, p. 83.
Lanark, Lot 8, Con. XI.—Geol. Sur. Can., Rep. 1874–75, p. 155.
Ramsay, Lot 9, Con. X; Lot 3, Con. I.—Geol. Sur. Can., Rep. 1874–75, p. 155.
Sherbrooke, South, Maberley—*ibid*, p. 155.

Peterborough.

Belmont.—Geol. Sur. Can., Rep. 1873–74, p. 204.
" Bur. Mines, Ont., Rep. 1900, p. 209.

Leeds.

Leeds.—Bur. Mines, Ont., Rep. 1902, p. 297.

Nipissing.

Lake Talon.—Geol. Sur. Can., Rep. 1876–77, p. 207.

Parry Sound.

Hagerman, Lot 32, Con. A.—Geol. Sur. Can. Rep. 1876–77, p. 204.

Renfrew.

Horton.—Geol. Sur. Can., Rep. 1876–77, p. 262.
Ross.—*ibid*, p. 262.

Although many different varieties are presented by the occurrences given above, the Ontario marbles may be conveniently arranged in the following manner:—

I. White marbles, *e.g.*
  - McGinn, Haleys, Renfrew.
  - Sanford, township of Barrie, Frontenac.
  - Central Ontario Ry., Faraday, Hastings.

II. Variegated marbles.
  - (a) Coloured, *e.g.*
    - Ontario Marble Co., Bancroft, Hastings.
  - (b) Blue or black clouded, *e.g.*
    - i. Very delicate clouds—
      Legris, Calabogie, Blithfield, Renfrew.
    - ii. Coarser clouds, light—
      Jamieson, Renfrew, Renfrew.
      Fitzroy Harbour, Fitzroy, Carleton.
    - iii. Coarse clouds, dark—
      Old Arnprior quarry, McNab, Renfrew.
    - iv. Uniform bluish grey—
      Clue, Actinolite, Elzevir, Hastings; Lanark village, Lanark.
    - v. Very dark (black marble)—
      Ellis, Madoc, Hastings.

III. Serpentine marble.
  - North Lanark Marble Co., Darling, Lanark.

THE WHITE MARBLES.

Mrs. Robert McGinn, Haleys, S. half of E. half of Lot 19, *Con. VI, Ross, Renfrew county.*

From this property has been obtained some of the finest white marble quarried in the province. The quarry was first opened ten years ago, but there has been no production for the last four years.

The formation consists of a belt, several hundred feet wide, striking from 7° to 20° E. of N. and dipping east at 60°. Bedding, as shown by any pronounced difference in the rock, is not apparent, but joints running with the strike and dip divide the formation into sheets. These joints are from 5 to 10 feet apart and usually show needles of tremolite on the joint planes. A second set of joints cuts the formation vertically with a strike of 15° S. of E.: these occur at intervals of 8 feet or more. Horizontal joints occur in an irregular manner but they are not sufficiently close together to interfere with the extraction of large stone. Another set of joints, running with the strike of the formation but dipping the opposite way—60° west—is seen in certain parts of the quarry. The work hitherto done is of a shallow character, several openings having been made and the adjoining rock shattered by the use of explosives.

Much of the stone is white, even in grain and free from impurities of any kind. In places, spangles of tremolite occur; these are scarcely perceptible in the fresh stone but they turn brown on exposure and give the product a blotched appearance. This objectionable feature is seen only towards the east of the exposure where the formation gradates into an amphibolitic band. Certain parts of the belt, while similar to the white stone in other respects, show a slight yellow discolouration which deepen on weathering (259). This yellow appearance is noticeable in some of the structures made from the stone of this quarry.

The stone: No. 258.—This stone must be regarded as the best example of the white coarsely crystalline limestones. The crystals average one-fourth of an inch in diameter and in consequence the polished surface presents a sheen due to the different ways the crystals are cut. Although this stone would be called white, it nevertheless possesses a slightly creamy shade. The stone is dolomitic in composition, as the analysis below indicates. In the best parts of the quarry no impurities are present except an occasional grain of chondrodite. The product of these quarries must be regarded as an extremely desirable material.

Specific gravity	2·878
Weight per cubic foot, lbs.	179·347
Pore space, per cent	0·149
Ratio of absorption, per cent	0·052
Coefficient of saturation	0·9
Crushing strength, lbs. per square inch	22595·
Crushing strength after freezing, lbs. per square inch	20219·
Loss on freezing, per cent	0·012
Loss on treatment with carbonic acid, grams per square inch	0·00196
Transverse strength, lbs. per square inch	1745·
Chiselling factor	2·3

It should be observed that this stone is much harder to cut than the softer sedimentary limestone and that it stands within the danger line of injury by frost.

An analysis by Mr. Leverin shows the stone to be highly dolomitic and practically free from impurities.

Insoluble matter	0·16
Ferrous oxide	0·33
Ferric oxide and alumina	0·35
Iron sulphide	0·025
Calcium carbonate	55·62
Magnesium carbonate	43·90

No. 259.—This stone does not differ from No. 258 except that the creamy colour gives place to a distinctly yellow tint, which is probably due to the oxidation of the iron.

At the time the property was worked, 20 cts. per cubic foot was charged for rough blocks at the quarry. The haul to Haleys station added $1 per load to the cost of the stone.

Among the pure white marbles of Ontario the product of this quarry ranks high. While much coarser in grain than the Barrie marble, it is free, in large part, from disfiguring needles of tremolite and the highly objectionable crystals of pyrite. The stone is too coarse in grain for fine carved work, but as a structural material, its strength, durability and appearance are of high order.

Shipments have been made to Pembroke, Ottawa, Calgary, Sault Ste. Marie, Cobden, Douglas, and other places. Good examples may be seen in the Monroe block at Pembroke, in a school at Sault Ste. Marie, and in the Roman Catholic church at Douglas.

A. G. Gould, Haleys, Lot 20, Con. V, Ross, Renfrew county.

The exposure on this property is of considerable extent, but as no work has been done it is difficult to arrive at conclusions as to the value of the deposit. The surface presents a coarse granular and broken stone, particularly towards the north, where weathering has affected the rock to such a depth that it is impossible to determine its true character. At the south end, however, the rock is solid and shows a strike of 10° E. of N. and a dip of 45° to the east. Irregular jointing is present at 5° N. of E. and 10° W. of N. The stone here is pure white and rivals that from McGinn's quarry (260). The broken character of much of the exposure is due to surface effects alone and it is not to be inferred that good stone may not be procured at a reasonable depth. It is highly probable that a large body of pure white marble is available on this property.

The stone: No. 260.—This example is of the same grain and purity as McGinn's. It is, however, of a dazzling white colour, which, in contrast to the white stone from McGinn's, has a slightly blue cast.

James Cook, Haleys, West half Lot 20, Con. VI, Ross, Renfrew county.

On this property pure white marble of similar character to that described above is obtainable. Little or no work has been done.

A very large amount of crystalline limestone is exposed along the railway from Renfrew to Haleys station and northward from that point. Much of the stone is thin, grey in colour and interstratified with rusty gneisses; but pure white marble, rather coarse in grain, but otherwise highly desirable is obtained at several points. It is reasonable to assume that much of this handsome stone would be revealed by careful prospecting.

The occurrence of a wide and continuous belt of crystalline limestone in the township of Barrie, Frontenac, has long been known. "A fine white marble is found in the township of Barrie, where the Laurentian limestones are said to be extensively developed on the 27th, 28th and 29th lots of the ninth and tenth ranges. Blocks of considerable size have been brought from this locality, and show a fineness of grain and strength equal to the best foreign statuary marbles. Grains and spots of tremolite and more rarely of quartz, are however disseminated through this marble and detract from its value. Specimens of an equally fine grained marble from this locality have a uniform pink or rose tint and others are of a dove grey colour. Besides these, variegated marbles of blue and white, and of purple and brown colours are said to be found here, which appear to be more free from foreign minerals and may possible yield abundance of coloured marbles for the purpose of interior decoration." [1]

For a detailed description of the geology of the region and of the general extent and character of the crystalline limestone bands and the associated rocks, the reader is referred to the report of Dr. R. W. Ells, in the Annual Report of the Geological Survey for 1901 (Vol. XIV).

In the immediate vicinity of the quarry described below the main belt is a greyish crystalline limestone interbanded with coarse basic eruptives and bordered by fine black micaceous schists and altered eruptives. Parts of this grey limestone are free from foreign minerals, but much of it is filled with tremolite, which becomes so abundant in places that it constitutes the greater part of the rock—192.

Sanford Estate, Hamilton, Ont., Lot 27, Con. VIII, Lot 28, Con. IX, and Lot 29, Con. X, Barrie, Frontenac county.

A quarry was opened on one of the fine grained white belts of marble about 40 years ago and a small quantity was shipped for monumental use. At a later date some specimens were taken out for exhibition purposes. The opening is of crescentic shape, about 50 feet wide, and exposes a face of 15 feet. Horizontal bedding divides the face into layers of 4 feet, 2 feet, 1 foot, 2 feet, and 3 feet in thickness. The main joints strike S. 30° W. and dip 80° to the northwest. A second set of joints strikes 5° S. of E. The general

[1] Geol. Sur. Can., 1863, p. 823.

strike of the formation and the lamination of the marble correspond to the southwest jointing. The extent of the fine grained belt could not be determined, owing to overburden, but there is undoubtedly a very large amount available. I see no reason why very large blocks could not be obtained, in fact there are some pieces already quarried measuring 3 feet by 3 feet by 6 feet.

To the south of the deposit there is a large mass of greyish coarse grained crystalline limestone, which also occurs on the lake shore to the northward—190.

The marble of the three beds is not very different; an example of the best stone available on the dump is described below as No. 191.

The marketing of any of the stone is at present almost impossible, owing to the 17 miles haul to the rail.

The stone: No. 191.—The base of this stone is pure white and finely crystalline, the individuals being about one-fourth of a mm. in diameter. This degree of fineness is not sufficient to give the dull effect of the finest statuary marble, as the stone presents minute glistening facets to the eye. The grain is coarser than in the Calabogie marble. (See page 327). Elongated crystals of tremolite, sometimes more than an inch in length, are scattered throughout the whole mass of the rock. On fresh fracture, these crystals are not so disfiguring, but on short exposure they turn brown and seriously detract from the value of the stone. Should further prospecting reveal parts of this band free from tremolite, the township of Barrie would undoubtedly furnish the finest white marble hitherto found in the province.

As the Barrie marble has so often been referred to in the literature of the subject all the ordinary tests were applied with the results given below:—

Specific gravity	2·846
Weight per cubic foot, lbs	179·224
Pore space, per cent	0·22
Ratio of absorption, per cent	0·08
Coefficient of saturation	0·94
Crushing strength, lbs. per square inch	25018·
Crushing strength after freezing, lbs. per square inch	21737·
Loss on freezing, per cent	0·016
Loss on treatment with carbonic acid, grams per square inch	0·0223
Transverse strength, lbs. per square inch	1858·
Chiselling factor	0·6

It will be observed that the stone is hard to cut and that it stands within the danger zone of injury by frost.

An analysis to determine the dangerous stain-producing ingredients gave Mr. Leverin 0·95 per cent of ferrous oxide and 0·086 per cent of ferric sulphide (pyrite).

No. 190.—A comparatively coarse grained crystalline limestone of fairly uniform structure and light greyish blue colour. It appears to disintegrate rapidly and to assume a granular condition on exposure to the weather.

No. 192.—Hard amphibolitic limestone with large blades of amphibole arranged in a radiating manner in the stone. Some parts are so full of amphibole that the rock would be described as an amphibolite rather than as a limestone. This material is of no economic importance.

Central Ontario Railway, S. half Lots 1 and 2, Con. XII, Faraday, Hastings county.

This quarry was opened by a company of which D. Ritchie, Esq., of the Central Ontario railway, was president, but, after somewhat extensive quarrying had been done, the workings were abandoned. The quarry is situated on the Goebel farm to the southwest of Bancroft, and was formerly connected by a spur 1½ miles long with the Central Ontario railway.

The rock formation runs in a general northeasterly direction with a somewhat variable strike. Towards the south of the property, a dark, grey mica schist with an almost vertical dip occurs; this is followed by crystalline limestone with amphibolite bands, the belt being 150 feet wide. The stone is finer in grain than at the quarry and is apparently more free from pyrite. North of this limestone is a belt of fine grained reddish contorted gneiss and mica schist. The quarry belt of crystalline limestone succeeds the gneiss with a width of about 300 feet. The bedding planes are almost vertical with a strike varying from 50° to 70° E. of N. The rock consists of bands of rather coarse grained, but pure white crystalline limestone interbanded with light coloured amphibolitic portions. Associated with the latter material is some black mica and an unfortunate amount of pyrite which is also universally distributed through the white marble. The quarry is about 50 feet square and has been sunk by channelling machines to a depth of 10 feet at one end and 4 feet at the other. A prominent joint runs along the strike in the middle of the quarry. Irregular vertical and horizontal cracks are frequent, but these would probably disappear with depth. The jointing has not interfered with the production of blocks 4 feet by 4 feet by 6 feet. Few of these are, however, free from flaws, but slabs of the full size indicated could readily be sawn from them.

The stone: No. 292, 293.—While pure white in part, the best shows grey bands in the amphibolitic portions, and the stone is marred by universally disseminated small crystals of pyrite, the weathering of which is conspicuous on all the blocks now lying in the quarry. Grains of brownish mica are likewise present which give a dotted aspect to the stone. The grain is about the same as in the white marble from Haleys station and from Portage du

Fort. The stone is much too coarse for interior use and its value for structural purposes is lowered by the presence of pyrite, which as above stated is disastrous in a white stone intended for exterior construction.

On the property are three buildings in good repair, a boiler and engine, hoist and derrick, and channelling machines. All work has been suspended and the track has been removed from the spur.

T. C. McConnell, Bancroft.

Mr. McConnell has drawn the attention of the writer to several prospects in the vicinity of Bancroft. These properties are placed under his name, although the extent of his financial interest in them is not stated.

N. half Lots 1 and 2, Con. XII, Faraday, Hastings county.

North of the exposure of marble on the Ritchie property is a deep ravine beyond which the country rises to a considerable hill on the northern half of the lots. The top of this hill consists of schists with many coarse basic intrusions. A marble band extends along the side of the hill at an elevation of 200 feet from the bottom of the ravine and 150 feet from the summit. The stone is rather finer in grain than that of Ritchie's quarry and shows, in places, purplish and salmon coloured tints (165). A coarse pink variety occurs farther west along the same band (167) and at the western edge of lot 2 the stone is blue and of a banded character (166). At the foot of the ridge a fine grained blue variety is seen. The whole series is doubtless the northern margin of the same formation on which Ritchie's quarry is opened. The marble bands are more intermingled with other rocks, show more variation in colour and texture and are apparently more free from pyrite. The rock is extensively covered, and as no work has been done, little can be said as to the possibilities of economic production.

Lots 24 and 25, Con. X, Dungannon, Haliburton.

South of the road and south of a belt of gneiss on the above lots is a coarse white crystalline limestone, coloured pinkish in part, but apparently free from pyrite (295). Eastward, this belt crosses the road between Bronson and Bronson Station and shows a considerable exposure of a greenish tint (296). South and east of this belt gneisses again occur in a large mass and a second narrow belt of marble comes out just north of Bronson Station in the side of the hill. The stone is here very coarse and of a pink colour (297); it is associated with fine pink and white sugary quartzites.

The stone: No. 165.—Coarse white crystalline limestone, resembling Ritchie's, but somewhat finer.

No. 166.—Coarse blue and white banded crystalline limestone with much pyrite.

No. 167.—Very coarse pink crystalline limestone of friable character.

No. 295.—Dove coloured, medium grained crystallized limestone with numerous specks of pyrite and glistening mica.

No. 296.—Coarse crystalline, bluish stone with micaeous and tremolitic spots.

No. 297.—Very coarse, pink crystalline limestone with individual calcite crystals of over one inch diameter.

A. Curry, Maxwells, Ont., Lot 2, Con. V, Glamorgan, Haliburton county.

Stone from this quarry was obtained over 20 years ago for monumental purposes, but the output was very limited in amount. The marble occurs along the north edge of a gneissoid hill and is exposed on the river for a short distance only. The strike of the formation is 10° S. of E. and the dip southwards at 30°. The belt is only about 20 feet wide. The under side is laminated and greenish (25) with a large amount of glistening mica and is too thin bedded for economic purposes.

The upper part is thicker, but the stone is coarse and shows yellowish spots (24). The deposit may be somewhat wider than stated above as the southern contact is hidden; there can, however, be no considerable amount of valuable material.

The stone: No. 25.—A white crystalline dolomite of schistose structure. The calcite grains are mingled with flakes of talc or sericitic mica. On the parting planes these glistening flakes are very apparent.

No. 24.—A very coarse grained white dolomite with a considerable quantity of disseminated brown matter which gives the stone a dirty appearance.

P. A. Barr, Maxwells.

The marble on this property forms a belt about 30 feet wide, striking 10° S. of E. and dipping south at an angle of 15°. On the north side is a fine grained evenly banded gneiss and on the other contact a decomposed micaeous gneiss of somewhat similar character.

The stone: No. 23.—A coarse grained crystalline dolomite, normally white but much stained and dotted with small crystals of foreign minerals.

At Furnace Falls a greenish pyritic marble is seen, and along the road between Maxwells and Furnace Falls a thin bedded white crystalline limestone is interlaminated with rusty gneisses. West of Irondale, a pink banded variety is seen in the railway cut. None of these occurrences appear to be of economic importance.

John Grant, 58 Tranby Ave., Toronto, S. W. quarter Lot 11, *Con. XIV, Hungerford, Hastings county.*

This property, known as the Hungerford quarry, is close to the village of Actinolite and is connected by a spur with the Bay of Quinte railway. "The strike of the band is north and south, dipping slightly eastward from the vertical. On the east is a quartzose rock with large masses of quartz and feldspar, immediately followed by a close grained pink coloured syenite. On the west side is a highly altered shale dipping at a high angle. This band of marble is some 500 feet wide, and curves around from north to south 30° east. Where an opening has been made, it is observed that the joints are at right angles to the strike and running with the dip, and are four to forty or fifty feet apart. The open floors are two feet to ten and twelve feet apart. The seams vary from six inches to ten or twelve feet apart, the average being about two feet."[1]

The surface stone seems to be very much fractured by joints, of which the main series strikes southwest and a less pronounced series at right angles to this direction. Horizontal joints (floors) are also close together near the surface. All of these joints become less frequent with depth. In the present condition of the quarry, owing to the use of dynamite, it is almost impossible to speak of the possibility of obtaining large block. Stone 2 feet by 2 feet by 4 feet could be obtained without difficulty, but there would be considerable waste.

The opening is about 120 feet by 40 feet with a depth of 25 feet. The equipment consists of a 15 horse-power gasoline engine, by Sylvester, Lindsay, an Ingersoll-Sergeant compressor delivering air at 60-80 lbs., and a hand derrick. Sullivan hand rock drills are used and are equipped with steel in which a central perforation allows of the exhaust being made at the apex whereby the hole is kept free of debris. One and three quarter inch starters are used followed by 1½ and 1¼ inch bits. Four feet holes are made and the rock removed by dynamite. Seven men are employed.

The total product is shipped to the Roman Stone Co., Toronto. No dimension or other building stone is being quarried.

The great mass of stone is a very coarse grained but compact white crystalline limestone with grey and green bands in places—195.

At the south end of the quarry salmon pink bands are encountered, but it is questionable if economic quantities of this variety could be obtained. Towards the north end a large mass of much finer grained material of a light sea green colour occurs. This belt is exposed for 25 feet with a width of from 4 to 6 feet—196.

The stone: No. 195.—A very coarse white crystalline limestone which seems to be free from any considerable amount of impurity of any kind. In parts, a light dove-coloured tint appears as well as an occasional speck of shining mica.

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[1] Rep. Royal Com., Min. Res. Ont., 1900, p. 75.

Crystalline Limestone. Old Church at Actinolite, Ont.

Plate LXV.

Crystalline Limestone. New Roman Catholic Church, Lanark, Ont.

Miller [1] gives the following analysis of a specimen from "Ellis' quarry, on the Bay of Quinte railway, a short distance south of Actinolite." As this quarry is in all probability the one under review, the analysis is given herewith:—

Insoluble residue, per cent	2·54
Ferric oxide and alumina, per cent	·34
Lime	53·64
Magnesia	·99
Sulphur trioxide	·34
Carbonic acid	42·92
Alkalies	·25

No. 196.—This variety has a uniform light sea-green colour. The grain is very much finer than that of No. 195 and it appears to be practically free from impurities. If this material can be obtained in sufficient quantity it should prove a valuable product.

The popular impression that these coarse crystalline limestones are unsuitable for building purposes is entirely disproved by the present condition of a church built in Actinolite 45 years ago, which, despite the fact that it was burnt in 1889, still shows sharp angles and the original chisel marks. Bad masonry and the lack of selection in the stone detracts seriously from the appearance of the edifice. The stone for this structure was quarried, not from the property described, but from behind the building itself, where the belt is 300 feet wide and shows a pronounced banded structure with much white mica throughout the rock. In the walls of the building this mica is in places very apparent as glistening flakes. (Plate LXIV.) The stone makes good lime and several small kilns have been in operation at different times. The belt is said to extend, with scattered outcrops, for a distance of 35 miles.

THE VARIEGATED MARBLES.

The Ontario Marble Quarries, Limited, John Hoidge, president, Toronto; Thomas Morrison, manager, Bancroft, Lots 27, 28, 29 and 30, Con. X, Dungannon, Hastings county; Lots 41 and 42, Hastings Road, Faraday.

At the present time the main working and mills are on the Dungannon property not more than quarter of a mile from the line of the Central Ontario railway. Surveys for a spur have already been made. An extension of this spur for rather more than half a mile will be required to connect the Faraday deposits.

The deposits on which most work have been done are on lots 29 and 30 of Dungannon; here the marble is exposed on a hill standing about 50 feet above the general level of the country.

The general strike of the belt is N. 70° E., in which direction the continuity of the deposit has been proved by test pits for at least 1,000 feet. The

[1] Bur. Mines, Ont., Rep 1904, pt. 2, p. 65.

width is stated by Mr. Morrison to be 1,000 feet, but owing to the overburden, it is not easily ascertained.

Different types of marble are arranged in bands parallel to the strike. From the north to the south the following varieties are recognized:—

(1) A laminated green variety—280.

(2) A green variety with broad bands and clouds of white and pink—281.

(3) A light green marble with bands of white—282.

(4) A light cream ground with green bands and cloudings—283.

(5) A pink ground with green, blue and white foliated bands—284.

(6) A blue variety with very fine white veins—285.

The deposit, as exposed on the hills near the mill, is remarkably free from surface cracking and weathering, which argues well for the durability of the stone. The surface alteration is so insignificant that large blocks with the adhering earth go directly to the mill and result in an entirely satisfactory product.

Clean vertical joints striking S. 20° E. cut the deposit at an average distance apart of 20 feet. There is very little minor jointing. Blocks 25 feet square could be obtained and several 4 by 5 by 10 have already been quarried. Horizontal partings (floors) occur at intervals of 10 or 12 feet.

At a distance of about a half mile to the southward of the main openings and mill, the company has conducted exploratory work on a series of marbles of very different character. These deposits occur on lots 41 and 42, Hastings Road, Faraday.

Insufficient stripping has been done to make perfectly clear the geological relationship of the different types of marble; it would appear however that a broad belt of at least 250 feet in width passes across the property in a direction a little south of west. This belt is composed of a striking variegated variety, known to the company as Rose fantasia, and of which there is a large amount available—305.

To the northward of the Rose fantasia lies a deposit of unknown extent of a fine blue variety resembling No. 285 from the northern workings, but without the fine white veining characteristic of the latter.

The most beautiful and delicate marbles of this property apparently occur at a higher level and are exposed along the brow of a considerable hill running north and south towards the eastern border of the lots. Without considerable stripping and a longer time for careful examination, it is impossible to discuss the relation of these marbles to those already described. The upper 50 feet of the bluff consists of the marbles about to be described, but whether these extend to greater depths or whether they overlie the Rose fantasia I am unable at the present time to say.

The general strike of these deposits is 5° S. of E. and the dip 80° to the north. Beginning at the south the first belt is about 100 feet wide and consists of a beautiful fine grained semi-translucent base with brown and green bands and contorted stripes—304.


PLAN
-of-
ONTARIO MARBLE QUARRIES
-ON-
HASTINGS-ROAD LOTS Nos 41 & 42
FARADAY TP.
1908
OLD HASTINGS ROAD
LINE AT NORTH SIDE OF QUARRY PROPERTY
SPRING
N
S.
W
E
LOT 42
BROOK
MARBLE
311
ST A
285
LAURENTIAN
BLUE
High
Ridge
285
ROSE
FANTASIA
ST E
305
305
305
310
ST B
307
ST D
306
304
ST H
ST C
LIGHT & DARK BRECHE-LAURENTIAN
BROAD BOTTOM LEADING TO LAKE LAMABLE
LOT 41
OLD FENCE LINE AT SOUTH SIDE OF QUARRY PROPERTY

Fig 21

Towards the north this band is less prominently marked and presents the same base with much fainter cloudings. Then follows a narrow dyke of basic eruptive, north of which the Rose fantasia rises to a higher level and is succeeded by 150 feet of beautiful brecciated varieties, the chief of which are described as Nos. 306 and 308.

This brecciated zone is followed by about 200 feet of a fine grained, delicate pink variety with black bands and clouds—307.

A brown veined partly brecciated variety follows—309 and 310.

The continuity of the exposure is interrupted at this point for a considerable distance, but another opening 750 feet from the southern limit shows a large body of a brown and red veined variety—311.

The accompanying sketch shows the relative position of the various marbles exposed on this property. (Fig. 21).

The stone: No. 280.—A fine grained, laminated rock consisting of white and green calcite crystals, intimately associated with fine amphibolitic matter. On the planes of parting much secondary mica appears. Little work has been done on this belt and I have seen surface examples only.

No. 281.—The base of this specimen is the same as No. 280, but it is without the distinct lamination. The green calcite mass is banded with pink and with white varieties in irregular belts of one inch or more in width. The pink and the white belts show a somewhat coarser grain than the green base. When sawn parallel to the bedding very handsome clouded effects are produced. This belt shows very little actinolite of sufficient size to attract the eye to the individual crystal, in this respect it differs from No. 282 about to be described.

No. 282.—This stone may be considered as a typical example of the greenish, amphibolitic marbles. It consists of a white crystalline groundmass of calcite in which occur bands of acicular light green actinolite in crystals up to 1 inch in length. Under the microscope the calcite crystals are seen to have a diameter of from 1 to 1½ mm. Besides the needles of actinolite, a few grains of secondary quartz appear, as well as a few scattered crystals of pyrite and other minerals. This was the only example submitted to physical tests, the results of which are shown below:—

Specific gravity	2·91
Weight per cubic foot, lbs.	179·706
Pore space, per cent.	0·224
Ratio of absorption, per cent.	0·077
Coefficient of saturation.	0·68
Crushing strength, lbs. per square inch	22065·
Loss on freezing, per cent.	0·008
Loss on treatment with carbonic acid, grams per square inch	0·001
Transverse strength, lbs. per square inch	3734·
Chiselling factor	0·2

Analysis: H. A. Leverin, Mines Branch laboratory:—

Ferrous oxide.	1·60
Ferric sulphide (pyrite).	·044

As this percentage of ferrous oxide is high, the stone would be liable to discolour on exposure. Mr. Morrison considers that this stone resembles the Greek Cippilino, but that it possesses a lighter ground.

No. 283.—In this example the base is white or slightly cream coloured. Roughly parallel with the bedding, bands of feathery very light green actinolite traverse the mass. The bands are irregular in their course and have a width of about 1 inch. Slabs show delicate greenish cloudings on a broad scale. Considerable pyrite is present in parts of the belt.

No. 285.—This stone is of medium fine grain and possesses a dark bluish grey colour. Fine veinlets of white calcite run irregularly through the mass.

No. 284.—This stone is of medium fine grain and uniform structure; it shows broad cloudings in green and pink, the colours being very light. The pink portions seem to owe their colour to scattered flakes of brownish glistening mica. Occasional bands of light greenish actinolite of a feathery form traverse the stone. When perfectly fresh, the amphibolitic bands do not differ in colour from the greenish calcite base.

No. 304.—This is a very handsome variety, with broad cloudings of delicate brown and green. The groundmass is medium fine grained. The brown colourings are due very largely to the presence of mica, while the greenish tints are due, as usual, to actinolite.

No. 305.—A very striking and highly coloured marble, showing large and small patches of bright red, salmon-coloured and otherwise tinted calcite imbedded in a matrix of darker micaeous material. Green bands are frequent and often appear as rings around the highly coloured centres. On the whole, this marble is very brilliant, perhaps too brilliant for most purposes, and is well described by the name *Rose fantasia* which has been given to it by Mr. Morrison.

No. 306.—This marble is a true breccia, consisting of angular fragments of fine grained calcite imbedded in a groundmass of which brown mica is the chief constituent.

No. 308.—Like 306 but with less groundmass. The fragments are, in themselves, clouded with green, and the brown cementing material is less abundant than in No. 306. This example is shown in Plate LXXIV.

No. 307.—A medium grained marble of a pink, or pink and white colour, delicately veined and banded with dark brown. The brown is as usual due to the presence of mica. This should prove a very valuable stone for the finer types of interior decoration.

Nos. 309 and 310.—Brown veined, partly brecciated types, which, owing to a brownish tint throughout the calcite, are not so clear and brilliant as the other brown veined varieties.

No. 311.—A medium fine grained marble resembling No. 304; it is distinguished from that variety, however, by the presence of fine veinlets and points of bright red calcite.

Two heavy Sullivan quarry bars, and one of medium weight, which also serves as a gadder, are employed to cut and raise the blocks. Mr. Morrison prefers a single-bit drill and uses a 2 inch starter for the heavy bars and a $1\frac{3}{4}$ inch starter for the lighter machine. After gadding, the blocks are raised by shims and wedges and are handled by an excellent 25 ton derrick by the Robertson Machinery Co., of Welland. Directly from the quarry, the blocks are loaded on small flat cars which pass down the grade to a track lying along the front of the mill. On this track a larger "transfer" car receives the smaller car and its load and transfers them to a point directly in front of the saw. The smaller car is then pushed into position under the saw on a track provided for the purpose, so that the operation of sawing is conducted directly on the car which first received the block from the quarry. A 12 ton derrick is being erected to handle the slabs as they come from the mill.

The mill is a substantial building 78 feet by 48 feet, and is equipped with a 100 horse-power boiler and a 75 horse-power engine, both by the Robertson Machinery Co. Two gang saws, by the Patch Manufacturing Co., of Rutland, Vt., are installed. One of these saws will carry 70 blades for ordinary slab work and it is capable of handling a block 10 feet by 7 feet by 7 feet. The other carries 60 blades and will operate on a block 12 feet by 6 feet by 6 feet. Beneath the track carrying the car and block is a hopper-shaped depression for the collecting of the sand and water, which is removed by a centrifugal sand pump and redistributed.

An excellent quality of sharp quartzose sand is found in close proximity to the mill.

A seven kilowatt generator is about to be installed and I believe it is the ultimate intention of the company to electrify the whole system.

At the time of my visit, June 1910, 30 men were employed.

There is no doubt that this property contains large amounts of exceedingly handsome variegated marbles, and it is further reasonably certain that no difficulty will be experienced in quarrying large blocks, as there is little evidence, even on the surface, of an undue amount of fracturing. Some of the exposures already stripped show no signs of flaws, and I have little doubt that a channelling machine could be put to work and marketable stock produced from the very surface.

The Canadian Marble Co., Limited, 18 Toronto St., Toronto, Ont.

This company, which has recently been incorporated, has acquired a considerable acreage of marble lands in the vicinity of Bancroft. In the spring of 1912, when the properties were visited, very little work had been done beyond the sinking of a few test pits. It was apparent, however, that the company possesses deposits of marble of different colours, among which may be mentioned white, green veined, pink, and brown clouded types. The last variety is very similar to the brown veined marble of the Ontario Marble Company. I am informed by the management that it is intended to actively exploit this deposit, which occurs on the Winfield farm.

The properties held by the company are as follows:—

Walker farm, lots 26 and 27, con. X, Dungannon.
Bowers farm, lots 41 and 42, con. IX, Dungannon.
Stoughton farm, lots 29 and 30, con. XI, Dungannon.
Part of lots 24 and 25, con. X, Dungannon.
Winfield farm, lot 40, con. VII, Faraday.
Harling farm, lots 38 and 39, con. VIII, Faraday.
North half of lots 1 and 2, con. XII, Faraday.
North half of lots 14 and 15, con. VII, Mayo.

James Legris, Calabogie, Lots 17, 18, *and* 19, *Con. III, Blithfield, Renfrew county.*

A prominent ridge of rock extends in a northwesterly direction across the three lots and beyond. The northeast side of the ridge is composed of fine grained, reddish gneiss, while the base of the hill on the southwest side shows a dark mica schist. Between these two rock formations is a band of crystalline limestone of variable width, in places reaching an extent of 300 feet. These formations all dip northeast at angles varying from 40° to 80°. Between the limestone and the underlying mica schist there is exposed in places a dyke of dark coloured diabase, but whether this dyke is continuous along the contact it is impossible to say. Wherever the limestone is in contact with this dyke it is converted into a beautiful, fine grained, grey clouded marble for a distance of about 10 feet. Passing northeast across the strike there is encountered a blue-banded somewhat coarser type, followed by very coarse greyish crystalline limestone to the contact with the gneiss. The country is very rough, no work has been done and actual exposures are isolated, so that it is impossible to state that the above succession holds throughout, although it seems to be a reasonable deduction from the facts observed.

At the northwest end of the ridge, on lot 19, the fine grained type is observed in a small exposure where the formation seems to stand vertically with a strike of 10° W. of S.—168.

Passing southeast the next exposure, at a higher level, shows the blue banded variety (159). Near the line between lots 18 and 19 the diabase dyke is exposed with the fine grained marble in contact with it. The dip here is 85° to the southeast. The coarse grained limestone is exposed at a short distance across the strike—157.

Near the northern line of lot 18, the fine grained type is again exposed and shows blebs of diabase included in the delicately clouded marble (156). At this point, 250 feet of coarse crystalline limestone are exposed towards the contact with the gneiss.

At the line between lots 17 and 18, a cliff exposes the coarse type, with some of the medium grained blue banded variety (159). Towards the southern side of lot 16, the fine grained marble is seen in an exposure about 50 feet wide (164). Here it seems to overlie a coarse amphibolitic type which is exposed in great masses farther to the south. The diabase dyke was not observed at this point.

The stone: No. 164.—An extremely fine grained white marble, lined and mottled with grey. A few tests of this stone were made and are given below:—

Specific gravity	2·744
Weight per cubic foot, lbs.	179·347
Pore space, per cent	0·342
Ratio of absorption, per cent	0·125
Crushing strength, lbs. per square inch	24456·

Analysis: H. A. Leverin, Mines Branch laboratory:—

Insoluble matter	·20
Ferrous oxide	·24
Ferric oxide and alumina	·13
Ferric sulphide (pyrite)	·020
Calcium carbonate	90·69
Magnesium carbonate	6·80

The fine grained marble described above is an extremely handsome and delicate material, and if it could be secured in blocks of sufficient size would constitute one of the most artistic marbles of the province. As far as could be observed this fine variety occurs in a bed, not over 10 feet wide, dipping to the northeast under the coarser types. Where seen, it is marred by two imperfections, first, the inclusions of blebs of the diabase, and second, a thin bedded arrangement parallel to the strike. In the present state of the property it is impossible to say to what extent these imperfections may prevent the obtaining of large blocks.

The blue variety is of medium grain and is susceptible of a good polish; it could be employed as a decorative material or as structural stone. In places, the banding is irregular but in others it is shown in a fine laminated structure. The white layers in this stone show a tendency to become pink on weathering.

No. 157.—A very coarse grained, greyish friable stone.

No. 159.—A medium grained, blue banded stone.

No. 156.—Like 164, but contains blebs of diabase.

A marble exactly the same as the fine variety on Legris' property is said to occur farther north on the property of Thomas Quilte, near Ashdod station.

J. A. Jamieson, Renfrew.

Mr. Jamieson works three quarries in the grey banded crystalline limestone in the vicinity of Renfrew. The rock is mostly converted into lime but it likewise constitutes an excellent building material. One quarry is situated about two miles west of the town and will be referred to as the western quarry; the second is behind the Catholic church in the town and will be called the lime-kiln quarry; the third is east of the town, on lot 9, Con. II of Horton, and will be called the eastern quarry.

The Western Quarry. The opening has been made along the brow of a hill in a direction a little north of east for a distance of 500 feet. The strike of the formation is 30° S. of E. and the dip, while very irregular, is northeasterly at about 40°. There is a strong vertical jointing 15° S. of W. and a very irregular series in a direction at right angles to this. The bedding divides the formation into layers about 4 feet thick, and, as the major joints are about the same distance apart, no difficulty is experienced in obtaining blocks 4 feet square. The opening is about 500 feet by 50 feet, with an average depth of 8 feet on the face. An immense amount of material is available—253.

The Lime-kiln Quarry. This quarry is about 200 feet by 200 feet in extent with a depth of 25 feet. As the opening has advanced practically to the limit of the property, further extension must be in a downward direction. The formation is well jointed, with one series striking 15° N. of W. and dipping 80° to the S.W., and the other striking 10° W. of S. with a dip of 85° to the west. The bedding strikes 15° N. of W. and dips 10° to the north. The major joints are 10 feet apart, but an irregular series of horizontal fissures prevents the quarrying of very large blocks, although some large pieces are obtainable.

The stone is quarried by the use of steam drills and dynamite. Building stone is squared by plug and feathers. Much of the output is made into lime, but some building and monumental material has been produced from this quarry. It is said that a bore hole in Renfrew shows the thickness of the limestone to be 700 feet. The mass is not continuous but is divided into two by 10 feet of black mica schist at a depth of 230 feet.

The Eastern Quarry. This quarry, while the smallest of the three, is perhaps the most important from the present point of view as its output is used more particularly for building and monumental purposes. The strike of the rock is 35° S. of E. and the dip is 40° to the northeast. The stone is coarse in grain and heavily bedded, with joints running 10° W. of S. vertically, and 10° S. of E. dipping

80° to the south. Horizontal jointing is also irregularly developed. The major set of joints is that with a north and south direction, which cuts the rock into blocks varying from 2 to 10 feet in thickness. The rock splits easily along the bedding and also across it, but not so well on the dip.

In places the formation contains bands of greenish crystalline actinolite.

The stone: No. 250.—This is a coarse grained crystalline limestone with some of the calcite individuals one-fourth of an inch in diameter. The stone has been selected for complete examination as being typical of that class of crystalline limestone which is dotted rather than clouded with grey. This effect is in part owing to some of the crystals being clear while others are milky, and in part to the presence of very fine graphite crystals which may be irregularly disposed or may run in fine lines through the stone. These little specks seen through the transparent crystals give the grey effect. As the analysis shows, this stone is dolomitic, and it is likely that the distinction between the two kinds of crystals depends on their composition—the one set being pure dolomite and the other pure calcite. Treatment with carbonic acid brings out more strongly the difference between the two sets of crystals and enhances the spotted effect. It is clearly seen that the clear crystals are much less soluble and therefore represent the dolomite individuals.

Specific gravity	2·758
Weight per cubic foot, lbs.	171·85
Pore space, per cent	0·016
Ratio of absorption, per cent	0·0057
Coefficient of saturation	0·58
Crushing strength, lbs. per square inch	14562·
Crushing strength after freezing, lbs. per square inch	14560·
Loss on freezing, per cent	0·0425
Loss on treatment with carbonic acid, grams per square inch	0·0877
Transverse strength, lbs. per square inch	2090·
Chiselling factor	2·2

Analysis by H. A. Leverin gives:—[1]

Ferrous oxide	2·07%
Ferric sulphide	·02%

No. 253.—In general character this example is quite comparable with No. 250. It presents a more banded aspect with the dark stripes very narrow and close together. The graphite grains are of greater size and are accompanied by glistening greenish yellow mica, which gives a spangled appearance to the stone.

[1] Miller gives several analyses in the Report of the Ontario Bureau of Mines for 1904. pt. ii, p. 106.

No. 251.—This example also is essentially the same as No. 250. The general groundmass is very coarse and is slightly blue-grey in colour, owing to disseminated graphite. At intervals of from 1 to 3 inches distinct dark bands occur owing to the concentration of the graphite. A small amount of finely divided pyrite is present but very little of the shining mica.

The Renfrew stone, as exhibited by these three quarries, is coarse in grain and possessed of a distinct grey banding; it is soft enough to chisel with facility and is said to be very easy on steel. While too coarse for most ornamental purposes, it polishes well and is quite suitable for certain types of monumental work. As a structural stone it is of exceptional value and presents a fine appearance in rock face work. The new post-office in Renfrew is a good sample of the use of this stone for structural purposes. It may also be seen in the Roman Catholic church at Renfrew, and in the pulp mill at Sturgeon Falls, Plate LXVII.

Mr. Jamieson has furnished the following scale of prices:—

Cost of quarrying, $2 to $3 per cord.

Rough block stone, $5 a cord in quarry.

Coursing stone, squared by plug and feathers, $10 per cord.

Sills, rough, 40 cents per running foot.

Sills, bush-hammered top and bottom, rock face, 75 cents per running foot.

C. J. Scott, Renfrew, Lot 14, *Con. I, Horton, Renfrew county.*

This quarry is near Jamieson's western property and is opened at several places on the flanks of a ridge which crosses the lot. The beds strike 5° W. of S. and dip east at an angle of 30°. There is only one pronounced set of vertical joints, which cuts the formation 15° N. of W. Horizontal joints occur at intervals of about 4 feet and necessarily cut the bedding planes at an angle so that the blocks possess a distinct lamination oblique to their faces; this renders subsequent work necessary in order to reduce them to a proper condition for structural work. The product is used locally for building and has also been employed for lime-making—252.

The stone: No. 252.—This example is very like the stone from Jamieson's quarry, but it may be distinguished by the more uniform colour, which is a somewhat mottled light blue-grey. The graphite scales are not aggregated into pronounced bands, but are scattered through the stone, together with small crystals of glistening mica.

Miller gives the following analysis of this stone:—[1]

Insoluble matter	2·28
Lime	49·62
Magnesia	4·17
Alumina	trace

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 106.

Ferric oxide	·50
Carbon dioxide	43·44
Sulphur trioxide	·06

Some other small quarries have been operated near Renfrew, notably on lot 13, con. III of Horton, from which some large blocks are said to have been obtained.

Lanark village.

Crystalline limestone has been employed for building purposes in Lanark to a considerable extent. The buildings now standing afford valuable evidence as to the durability of the stone. Two varieties are obtained in the vicinity; that immediately at the village is white, while a pronounced blue type is obtained at a short distance.

The local stone occurs in a formation which strikes 30° W. of N. and dips at an angle of about 15° to the eastward. The stone is banded in white and grey parallel to the strike and can easily be obtained in thicknesses up to two feet. There is an unlimited amount available—313.

The blue stone (314) is obtained to the eastward of Lanark at several points, particularly on the farm of Wm. Stead, and has been largely used for buildings of more recent date, *e.g.* the Congregational church, 1902, and the Roman Catholic church, 1903. (Plate LXV.)

The stone: No. 313.—This example is comparable with the Renfrew stone and strongly resembles the more banded types from that locality. The black specks in this instance seem to consist of grains of graphite almost entirely. The physical properties are as follows:—

Specific gravity	2·772
Weight per cubic foot, lbs.	169·45
Pore space, per cent	0·519
Ratio of absorption, per cent	0·18
Coefficient of saturation	0·44
Crushing strength, lbs. per square inch	15343·
Crushing strength after freezing, lbs. per square inch.	14565·
Loss on freezing, per cent	0·025
Loss on treatment with carbonic acid, grams per square inch	0·2015
Transverse strength, lbs. per square inch	1394·
Chiselling factor	4·5

It will be observed that this stone is softer and less dolomitic than many of the crystalline limestones.

No. 314.—A coarse grained crystalline limestone of distinctly blue appearance. The colour may be uniform through a thickness of several inches, but usually a narrower banding is apparent. Under the microscope the crystals are seen to vary greatly in size, some being only a fraction of mm. in length while others extend for several mm. Occasional grains of quartz are present, and numerous minute black dots which are probably of a graphitic nature and to the presence of which the dark blue colour is due. The stone is comparatively soft and should work with ease.

An analysis of a sample from lot 22, concession VIII of Lanark, is given in the Report of the Geological Survey for 1874-75, p. 141, as follows:—

Insoluble matter	5·78
Carbonate of lime	52·12
Carbonate of magnesia	42·10
Carbonate of iron	·80

Miller gives the following analysis of the Lanark village stone:—[1]

	Light	Dark
Insoluble matter	3·06	1·12
Lime	49·86	51·20
Magnesia	3·36	2·28
Ferric oxide and alumina	·46	·38
Carbon dioxide	42·69	45·50
Sulphur trioxide	·28	·32
Water	....	·08
Loss	·31	...

The old Fitzroy Harbour quarry, H. K. Egan, Ottawa.

This old quarry, long since abandoned, was opened close to the river at Fitzroy Harbour. The excavation is about 40 feet by 50 feet, with a depth of 10 feet. The bedding planes strike 30° W. of N. and dip 45° to the northeast. Two sets of joints cut the formation at 25° W. of N. and 20° N. of E. A third set of joints striking 40° N. of W. cuts up the formation to some extent, but large blocks can be obtained as the major joints are usually 10 feet or more apart. The southwest or lower beds are white and grey banded; the northeast or upper beds are whiter but shows specks of impurities and tremolite bands in places. Large blocks of this upper white portion could easily be obtained. Specimen 243 described below is a good average sample of the product of this quarry.

The stone: No. 243.—For a description of this type the reader is referred to the account of the Renfrew marbles. It is very similar to the variety with a white base and ill defined black clouds and bands. This stone is much lighter than the Arnprior marble. The weather-resisting properties may be judged from the fact that Mr. Leverin finds the amount of ferrous oxide to be 0·4 per cent and of pyrite to be 0·012 per cent.

Material from this quarry was used in the construction of the parliament buildings at Ottawa. Like the marble from Arnprior and from Renfrew it

[1] Bur. Mines, Ont., Rep. 1904, pt. ii, p. 70.

is too coarse in grain for fine carved work, but it takes a good polish and is suitable for panelling that is not exposed to the weather. For exterior work it should not be polished as the weather soon removes the lustre.

A great quantity of this stone is easily to be procured in the vicinity, and on an island in the river, a better bedded deposit is said to occur; this is the property of G. B. Brophy of Ottawa.

The Old Arnprior quarry.

This quarry was opened many years ago in the side of a ravine east of Arnprior. The limestone beds strike northeast and dip southeast at an angle of 30°. Parallel to this direction, the stone is banded in white and greenish-grey layers. In places the banding is irregular so as to constitute clouds rather than bands, in others the grey material is in excess so that it forms the base rather than the white part, which then appears as irregular clouds, in still other parts the two colours are mixed so as to give a "pepper and salt" effect. In descending order the following beds are seen:—3 feet, 3 feet, 4 feet, 3 feet, 18 inches, 18 inches, 4 feet (thin bedded), 3 feet, 2 feet (thin bedded), 6 feet, 2 feet, 12 feet, 4 feet. Strong joints cut these beds in a northwesterly direction; they are close together for 2 or 3 feet, with undisturbed intervals of 8 or 10 feet between. A less pronounced series of joints runs in a easterly direction across the formation. The major joints are clean cut and provide an excellent working face.

The stone: No. 242.—This example is selected as typical of that class of crystalline limestone which is strongly clouded with bluish grey. The appearance of the polished material is very striking and handsome and may be seen in Plate LXXII. The grain is finer than that of the Renfrew stone, but it is coarse enough to cause the stone to be classified as a coarse grained marble. As in the Renfrew stone, the clouding seems to be due to the differentiation of calcite and dolomite crystals. The latter are clear and absorb the light, whereas it is reflected from the milky white calcite crystals. The dark effect is assisted by the association with the dolomitic bands of extremely finely divided grains of graphite as well as occasional specks of mica and other minerals. The polished stone should not be employed for exterior work as the more pronounced effect of the carbonic acid of the atmosphere on the calcite portion of the stone is sure to render the surface rough within a short time.

Specific gravity	2·741
Weight per cubic foot, lbs.	170·634
Pore space, per cent	0·252
Ratio of absorption, per cent	0·092
Coefficient of saturation	0·76
Crushing strength, lbs. per square inch	15100·
Crushing strength after freezing, lbs. per square inch	14347·
Loss on freezing, per cent	0·0305

Loss on treatment with carbonic acid, grams per square inch	0·162
Transverse strength, lbs. per square inch	1677·
Chiselling factor	3·2

Analysis:—H. A. Leverin, Mines Branch laboratory:—

Ferrous oxide	1·31
Ferric sulphide (pyrite)	·016

Stone from this quarry was employed in the construction of the parliament buildings at Ottawa and has often been referred to in the literature of the subject.

Corporation quarry, Arnprior.

A short distance west of the village the corporation has quarried crystalline limestone for rough use. The stone is quite similar to parts of the old quarry and shows even-banded grey and white types with lenticular patches of either colour scattered through the mass. The formation strikes 15° N. of W. and dips from 70° to 90° to the south. The rock is rather thin bedded but material of sufficient size for the making of coursing stone is easily procured.

Joseph Clue, Actinolite, Lot 3, Con. V, Elzevir, Hastings county.

A short distance northeast of Actinolite is an exposure of blue marble, from which a small quantity was quarried about 20 years ago. The deposit is distinctly banded and strikes north and south with a vertical dip. Although the actual exposure is small there is said to be a large quantity of this material under the sand which has drifted over the old workings.

The stone: No. 197.—This marble, which is said to resemble the Gouverneur, appears to be somewhat bleby on the exposed surface and has a tendency to split along the planes of banding. In structure, colour and general appearance it is almost identical with the blue marble from Lanark village, which has been employed for building purposes with a large measure of success. (See No. 314, p. 331). It bears a strong resemblance to the Gouverneur marble from the State of New York. The present deposit has the great advantage of immediate proximity to a railway.

R. Y. Ellis, 410 *Sherbourne St., Toronto.*

The famous Madoc black marble quarry is situated close to the village on the south side; it is opened on a belt about 900 feet wide which extends into the village. An enormous amount of the material is therefore available. The weathered surface shows distinct evidence of differential weathering, and reveals a north and south strike with a dip of about 80° to the west. The whole mass is distinctly laminated, showing grey and whitish bands, as well as lenticular blotches. Some of the bands are coarsely crystalline, some are very fine and others appear almost devoid of crystallization. Considerable pyrite was observed in nearly all the specimens examined. Owing to the quarry being full of water and to the fact that natural exposures are of a very limited extent it is impossible to speak of the amount of jointing. Some old blocks about 4 feet square are on the dump, but these are by no means flawless. "Checks or joints occur here and there near the surface but are said to become less frequent as the band is sunk on . . . . . We were informed that a depth of 38 feet had been attained, and that at that depth the open floors were 6 to 8 feet apart. The machinery on the ground consists of 35 horse-power portable boiler, two steam pumps, an Ingersoll gadder, a diamond drill, a channel machine, a 30 ton derrick, and necessary tools."[1]

The opening is about 50 feet square and is now full of water. Of the machinery mentioned above the boiler and derrick alone remain.

In view of the large quantity available and the very unique character of this marble, it is rather remarkable that operations ceased many years ago (about 25). I have been informed that the cessation of work was due to the difficulty experienced in obtaining large pieces, and to the fact that the stone does not retain its polish. The first of these statements I am unable to verify, and judging from some roughly handled specimens that I have seen, it is doubtful if the latter statement is true.

The stone: No. 223.—The general appearance of this so-called black marble is decidedly attractive. It is a distinctly banded stone, not only in the rough, but in its microscopic structure. The crystals of which it is composed are all elongated in one direction, having a width of about one-fiftieth of a mm. and a length of over one mm. The black colour is apparently due to the same cause as in the Renfrew and Arnprior stone, *i.e.*, it is caused by the presence of clear crystals of dolomite interlaminated with milky crystals of calcite and enhanced by the presence of minute grains of graphite. Under the microscope, there is no black appearance, but the field is dotted by minute black specks which are more apparent in some bands than in others. These grains are too small for their exact nature to be determined by the microscope, but it is a reasonable inference that they consist of graphite. Small crystals of pyrite may also be seen.

On treatment with carbonic acid the stone becomes dull and grey in appearance, and the smooth surface assumes a rough feel. This effect is doubtless due to the acid dissolving the calcite crystals and leaving the dolomite individuals in relief. It is to be inferred that exposure to the weather would produce the same result.

Specific gravity	2·727
Weight per cubic foot, lbs	169·618
Pore space, per cent..	0·336
Ratio of absorption, per cent	0·134

[1] Report of the Royal Commission, Min. Res. Ontario, 1890, p. 75.

Coefficient of saturation	0·58
Crushing strength, lbs. per square inch. . .	12079·
Loss on treatment with carbonic acid, grams per square inch.............	0·0875
Transverse strength, lbs. per square inch..	1666·
Chiselling factor......................	2·95

Analysis: H. A. Leverin, Mines Branch laboratory:—

Ferrous oxide.........................	0·13
Ferric sulphide (pyrite)	0·24

THE SERPENTINE MARBLES.

The North Lanark Granite and Marble Quarries, Limited, W. H. Wylie, president, St. Catharines; James Milne, superintendent. Caldwell's Mills, N.W. quarter Lot 7, Con. IV; East quarter Lot 7, Con. III, Darling, Lanark county.

The main mass of marble extends across both lots for a distance of about one-third of a mile with an average width of 500 feet. This belt strikes about 70° E. of N., and is flanked on the north side by a grey granite, while to the south succeeds a band of common whitish, coarse crystalline limestone of variable width, followed by black hornblendic schists. Towards the north-east corner of the property is a parallel lenticular deposit of clouded blue marble not yet exploited.

The valuable material is a true serpentine marble consisting of a medium-grained white or lavender coloured calcite marked by cloudings of green or buff serpentine. Although different types are recognized, there does not seem to be any distinct banding or arrangement of the various kinds, which appear to fade into one another. Three chief varieties are recognized as follows:—

(1) White base with green cloudings—155.

(2) Lavender base with green cloudings—153.

(3) White base with buff cloudings—154.

The stone: No. 154.—This sample is a true serpentine marble in which the calcite portion is white and the serpentine portion buff coloured. Under the microscope the two minerals, calcite and serpentine, are seen to be intimately associated, but while the calcite portions are practically free from serpentine, the serpentine masses are invaded by calcite which is seen in small patches throughout the serpentinous parts. Treatment with carbonic acid etches out the calcite and leaves the serpentine standing in relief; the colour of the latter mineral is rendered a more pronounced yellow by the treatment.

Serpentine Marble. Quarry of the North Lanark Marble Co.

Crystalline Limestone. New Post-office, Renfrew, Ont.

The tests conducted on this stone resulted as follows:—

Specific gravity	2·662
Weight per cubic foot, lbs	164·38
Pore space, per cent	1·06
Ratio of absorption, per cent	0·406
Coefficient of saturation	0·51
Crushing strength, lbs. per square inch (unsatisfactory test)	16068·
Loss on treatment with carbonic acid, grams per square inch	0·158
Transverse strength, lbs. per square inch	1091·
Chiselling factor	5·

It is important to note that the chiselling factor of this stone is the highest obtained for any of the crystalline limestones or marbles.

Of the dangerous materials, ferrous oxide and pyrite, Mr. H. A. Leverin found the samples to contain:—

Ferrous oxide	0·20
Ferrico sulphide (pyrite)	·010

No. 153.—This sample is quite similar to the above except that the calcite portion has a lavender colour and that the serpentine is for the most part green. Much better than a description is the representation given in Plate LXXI.

No. 155.—The structure of this stone is similar to the others.

The surface of the deposit where no work has been done shows a discouraging amount of irregular fracturing, but at a very limited depth this disappears and a comparatively strong series of joints parallel to the strike of the deposit is encountered. Somewhat irregular cross joints also occur, but there is no difficulty in quarrying large blocks without flaws. Many pieces 3 feet by 3 feet by 6 feet have already been shipped to Clyde Forks.

Modern quarrying methods are being applied to the exploitation of the property; this fact together with the excellent character of the material argues well for the ultimate success of the company.

The present equipment consists of the following appliances: One Sullivan steam channeller, three heavy quarry bars, one light quarry bar, one 20 ton derrick, one 30 horse-power boiler, one 60 horse-power boiler, one steam hoist by Beattie, Welland.

The quarry bars are equipped with Rand drills. It is Mr. Milne's practice to employ rose drills of $2\frac{1}{4}$ inches diameter for channelling and $1\frac{3}{4}$ inches for plug and feathers work and for gadding.

The company proposes to saw the product at the quarry and have ordered two gang saws by Anderson, Carnoustie, Scotland. Serviceable buildings for the accommodation of the men and for the protection of the machinery have been erected.

Twenty men were employed at the time of my visit. The scale of wages is indicated below:

Channellers, $3.
Blacksmith, $3.
Drillers, $2.
Labourers, $1.50.
Engineer, $2.50.
Estimated cost of quarrying, 50 cents per cubic foot.

The nearest railway station is Clyde Forks on the K. and P. railway at a distance of ten miles. The difficulty and expense of transportation is, however, lessened by making use of the lakes in the winter. About 5,000 cubic feet in blocks of large size were hauled to Clyde Forks in the winter of 1909–10 at a cost of $1.50 per ton. In June of 1910, 80 such blocks were at the forks and 30 at the quarry. Three car loads have been shipped at $3.50 per cubic foot, f.o.b. Clyde Forks.

North Lanark marble has been employed in the residence of J. R. Booth, Ottawa, in the members' private post-office, Ottawa, and in certain places of business in Toronto.

The property described above is the only one in the province now being worked for the production of this kind of material. The numerous localities already mentioned (page 311) show however that further development may be expected in the production of this type of stone.

Serpentine has been worked at a point 2½ miles west of Gananoque in Leeds county, but the product was all crushed for other than decorative purposes.[1] Some parts of the deposit however show bright green serpentine in masses of about ¼ to ½ inch in diameter embedded in a lesser amount of bluish white calcite. This constitutes a handsome decorative stone.

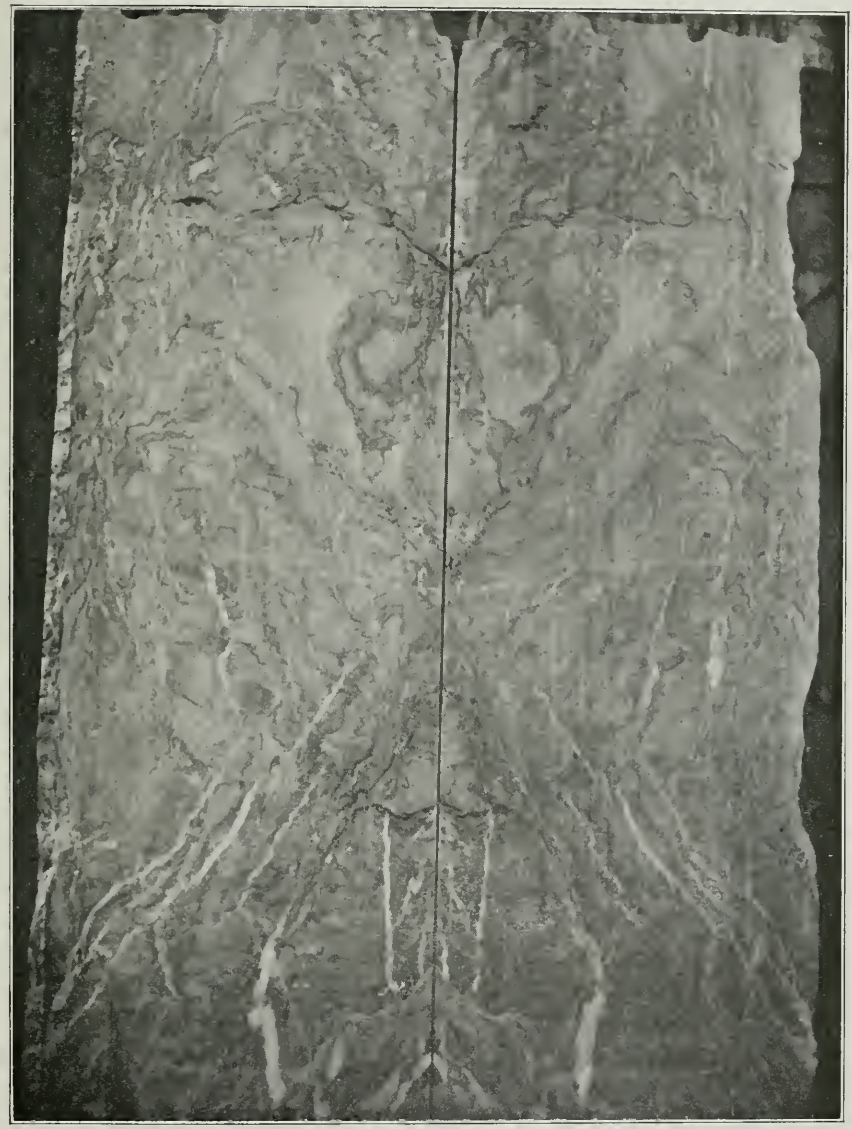
A deposit similar to that of the North Lanark Co. occurs to the east of Flower station on the K. and P. railway. For a description of this occurrence see page 343.

Summary—Crystalline Limestone and Marbles.

For a general account of the crystalline limestones, marbles, and serpentines of Ontario, and an extended list of references, see the introduction to this chapter, page 307 et seq.

[1] Bur. Mines, Ont., Rep. 1902, p. 297; Rep. 1904, pt. i, p. 13.

Plate LXVIII.



Matched Slabs of Marble, Ontario Marble Co., Bancroft, Ont.

CHAPTER VI.

Miscellaneous Ornamental Materials.

Of the decorative materials, other than marble and serpentine, the following are known to occur in the part of Ontario under review:—

Feldspars, common and iridescent.
Sodalite and detroite.
Talc.
Tourmaline in rock.
Starry amphibolite.
Garnet in rock.
Graphic granite.

With the exception of the sodalite, none of these substances have been exploited on a commercial scale for decorative purposes, but, as they constitute possible future sources of supply, they will be briefly reviewed here.

As most of the localities of occurrence are difficult of access and as no work has been done on the properties, it was not thought advisable to visit them. Besides, little could be learned from entirely undeveloped prospects beyond the facts already ascertained and published.

IRIDESCENT AND OTHER FELDSPAR.

Common white or red feldspar is by no means to be despised as a decorative material. It is capable of a high polish and its superior hardness makes it valuable for certain purposes. The mining of feldspar has not been carried on for the production of decorative material but for use as a flux and in the pottery industry. Nevertheless some of the output of these mines has found its way into decorative work.

The most important region for feldspar mining is on the Kingston and Pembroke railway in southern Frontenac, in the townships of Bedford, Oso and Portland. At least two properties have been worked extensively; they are described below.

Kingston Feldspar Mining Co., Richardson mine, Lot 2, Con. II, Bedford, Frontenac county, M. J. Flynn, local manager.

"The feldspar is mined from a large open cut and is hoisted to the top of the hill, a distance of 50 feet, in two ton buckets. These loaded buckets are conveyed on wagons to pontoons on Thirteen Island lake, on which the ore is loaded. It is then taken by tug across the lake to a portage, placed on cars and drawn across to Thirty Island lake. From there it is taken by tug and pontoon to a spur of the Kingston and Pembroke railway at Glendower, where by means of a steam hoist, the ore is loaded directly on to the cars or into a pocket.

"The quarry is divided into two openings, No. 1 or southwest pit and No. 2 or northeast pit.

"No. 1 is at a depth of 50 feet and has an area of 250 feet long by 50 feet wide. No. 2 is the same depth and is 300 feet long by 30 feet wide.

"The two pits or open cuts, while coming together on the eastern side, are separated on the western side by a large mass of quartz which intrudes into the feldspar. A very perfect separation of the quartz and feldspar is here seen, the quartz having crystallized out in large masses and overlying the feldspar on the west side of pit No. 2."[1]

At the present time, these pits as described above have been greatly extended and they are now practically confluent. The line of demarkation between the overlying quartz and the underlying feldspar is sharply shown.

The feldspar is of a flesh red colour and can be obtained in pieces of sufficient size for decorative work. Pieces measuring 18 inches by 12 by 12 are common and much larger masses have been obtained.

At present 50 men are employed and the output averages 130 tons per day.

Verona Mining Co., Lot 5, Con. XII, Portland, Frontenac county.

For the purposes of the present report the feldspar is of interest only as a decorative material and in consequence it will suffice to state that the average run of the quarry is of too small a size to be of value. It should be noted, however, that occasionally good examples of iridescent types of feldspar are obtained.

In this region pits have been opened in several other places, particularly on lot 3, con. III, Bedford; lot 5, con. IV, Bedford; and lot 10, con. V, Oso.

The so called iridescent feldspars are represented by several varieties in Ontario and although small quantities have been obtained there is no output. Most of the samples have been converted into small objects for exhibition purposes or have found their way into museums. The chief localities of the different types are indicated below, with a reference to the original description.

Sunstone.—A flesh red feldspar shining with golden points; it occurs in a large granite vein traversing gneiss on the northeast shore of Lake Huron, 20 miles east of the French river.—Geol. Sur. Can., Rep. 1863, p. 475; *ibid*, Rep. 1887–88, p. 75 S. Sunstone also occurs in the township of Sebastopol in Renfrew. The nepheline syenite in Dungannon township in northern Hastings shows this beautiful material in small crystals. As the rock also carries the blue sodalite, selected pieces should be valuable for small articles of adornment.—Geol. Sur. Can., Memoir 6, 1910, p. 392.

Peristerite.—A variety of albite or soda-feldspar which has a pronounced bluish opalescence. Some fine examples have been obtained in the township of Bathurst, (lot 19, con. IX) where it occurs " in large cleavable masses

[1] Bur. Mines, Ont., Rep. 1905, pt. i, pp. 81–82.

with quartz in veins." It also occurs in the township of Burleigh, on Stony Lake, near the mouth of Eel creek.—Geol. Sur. Can., Rep. 1887–88, p. 75, S; *ibid*, Rep. 1888–89, p. 51 T; *ibid*, Rep. 1863, p. 477, p. 833.

Perthite.—"Perthite occurs in large cleavable masses in thick pegmatite veins, cutting the Laurentian strata, and is often made up of flesh-red and reddish-brown bands of orthoclase and albite, interlaminated. When cut in certain directions it shows beautiful golden reflections like aventurine, and being susceptible of a high polish, is adapted for an ornamental stone or for use in jewellery. It is also found in considerable quantity in Burgess, Ont., about seven miles southwest of the town of Perth, and near Little Adams lake on what was formerly called Dobey farm."—Geol. Sur. Can. Rep. 1887, p. 75 S.

Microcline.—The green variety of this type of feldspar is known as "amazon stone" and constitutes a handsome decorative substance. This stone is reported by Dr. Barlow from lot 7, concession B of Cameron in Nipissing (Geol. Sur. Can., Rep. 1892–93, p. 70 AA.).

A deposit of quartz, microcline and albite occurs on lot 6, con. II, March, Carleton county (Geol. Sur. Can., Rep. 1897, p. 220 S). It is also reported from the township of Sebastopol in Renfrew.[1]

Labradorite.—A beautiful iridescent variety of feldspar which occurs in some abundance in Labrador, whence its name. I am not aware of any localities in Ontario which have produced valuable material, but references to its occurrence may be found in the Report of the Geol. Sur. for 1876–77, pp. 256 and 261; also in the report for 1874–75, p. 316.

SODALITE.

This beautiful blue mineral, which has already been described, may be regarded as peculiar to the province of Ontario; not that it occurs here only but that the Ontario deposits are the only ones large enough to constitute economic occurrences.

Although this mineral is known to occur at several points in the belts of nepheline syenite in the Haliburton district, the only properties on which development has been done are situated in concessions XIII and XIV of Dungannon in northern Hastings.

Michael Walker, Bancroft, Lot 24, Con. XIV, Dungannon, Hastings county.

The sodalite occurs as segregations in a belt of nepheline syenite, which shows a distinctly banded or gneissoid structure, with a strike of 30° W. of N., and a dip of a few degrees only to the southwest. The formation is strongly jointed, with one set striking 35° W. of S. and dipping northwest at an angle of 60°; the parting planes are from 3 to 8 feet apart. Along these joints occur veins of brown crystalline calcite, with crystals of black

[1] Since writing the above I have visited a deposit of fine green microline in the township of Mayo, about two miles east of Bessemer.

biotite, sometimes 2 or 3 inches in diameter. In these veins also are large crystals of green apatite which sometimes reach a length of 8 inches. From the nepheline syenite, crystals of nepheline extend into the calcite veins, and between this line of nepheline crystals and the syenite proper are crystals of pink orthoclase which become mixed with sodalite and fade away into the syenite mass. Besides occurring in this way, the sodalite is found scattered through the syenite in bands parallel to the foliation of the rock. This impregnated rock, *detroite,* is a beautiful material in itself and could be procured in pieces of considerable size. At another opening on this property, the sodalite-dotted rock could be quarried in blocks at least four feet square. Some of this rock also contains small crystals of sunstone, which would add greatly to the beauty of the polished material. In places along the strike and along the edges of the veins mentioned above, the sodalite occurs pure and can be extracted in irregular sheets of several inches thickness. (Plate LXXIII.)

The Princess quarry, Lot 25, Con. XIV, Dungannon, Hastings county.

On this property the general strike of the rock is almost due north and the dip east at an angle of 45°. Dry joints cross the formation almost vertically in an east and west direction. Very irregular joints also run with the formation, but they do not dip with the rock as their average inclination is 80° to the west. These joints have been filled with vein matter in the same way as at Walker's quarry. Sodalite occurs along these veins, and also as lenticular inclusions with the strike and dip of the rock. A V shaped opening has been made for a distance of about 150 feet along the strike and has been opened to a depth of 10 feet or more. A considerable amount of sodalite is in sight in this cut; the bands being several inches in thickness and extending for some feet. So irregular are these deposits that it is impossible to give exact figures, particularly as the excavation has been made by the use of dynamite which has shattered the rock very badly. The use of explosives in such a property as this, for the winning of a hard and extremely brittle substance like sodalite, seems peculiarly inappropriate.

At the foot of the hill on which the main quarry is opened there is a second pit which shows veins of sodalite running in both directions, *i. e.*, the east and west joints are not dry but are mineralized as on Walker's property. Here, some large masses of sodalite were observed at the intersection of the two sets of joints.

There is a derrick on the property and a good mill building 100 feet by 40 feet in size. The mill now contains a crane by the Smart-Turner Machine Co., Hamilton, and an engine and boiler, by H. W. Petrie, Toronto.

This property has produced a considerable amount of this beautiful mineral. The most important shipment, consisting of 130 tons, was made in 1906. This material was used in the residence of Sir Ernest Cassel, Park Lane, London. I believe that the gross price received was £28 per ton.

It would appear that the cessation of operations was in part due to legal difficulties among the owners and in part to the lack of proper machinery for removing the stone. This deposit should be worked in the same manner as the finer types of granite; the pure sodalite could then be removed without cracking, and sodalite-dotted rock should find a ready market as a decorative substance in itself. Personally I was more impressed by the possibilities of the sodalite-bearing rock as an economic proposition than by the sodalite alone. It is much to be regretted that this unique and beautiful material is not now available for the market.

Directly south of the Princess mine, on lot 25, con. XIII. the continuity of the deposit has been proved by several pits. It is also known to occur to the westward of both these lots. The sodalite must therefore occur over parts of at least five lots. Considering the fact that but little stripping has been done it is reasonably certain that a large amount of sodalite and sodalite rock is available in this locality.

In Memoir No. 6 of the Geological Survey of Canada, Drs. Adams and Barlow mention the occurrence of sodalite at a number of places besides the above, particularly:—

Lot 29, Con. XIII, Dungannon.
Lot 34, Con. V, Brudenell.
Lot 11, Con. VIII, Monmouth.
Lot 32, Con. II, Glamorgan.
Craigmont in Raglan township.

TALC.

The purer and softer varieties of talc are much in demand for the manufacture of lubricants, toilet powders, etc. The more massive types (soapstone) have been employed for the making of electrical switch-boards, laundry-tubs, etc. Occasionally soapstone is uniform enough and at the same time of sufficiently attractive colour to be used for small carvings, clock cases, etc.

The most important talc mine in Ontario is the Henderson mine near Madoc, from which is produced a superior grade of talc for the manufacture of powders. The product is too soft for use as a decorative material. Although the literature contains many references to the occurrence of talc in Ontario, I find little or no comment as to the suitability of the material for decorative purposes. The only deposits of this kind with which I am acquainted is that described below.

T. B. Caldwell, Lanark, E. half Lot 24, Con. III, Lavant, Lanark county.

This deposit is situated close to the line of the Kingston and Pembroke railway north of Flower station. The country rock to the west of the deposit consists of black mica gneiss and schists. Where first encountered, the talcose deposit is seen on the face of a hill striking north and south and rising, at this point, about 25 feet above the general level. The rock here consists of white talc, of compact character, showing in a rough way the crystalline outlines of the original mineral from which it has been derived by metamorphism. The talc is mingled with calcite, which also occurs in the form of veins cutting the deposit. The rock shows a lamination 20° S. of W. and a dip of 45° to the south. A drill hole which was sunk by Mr. Caldwell to a depth of 104 feet at a point 60 feet east of the face showed 20 feet of this white rock, followed by solid talc in shades of pink, green, yellow, and brown to the bottom of the hole. A second hole, 60 feet farther west, revealed the same material throughout. To the westward of this hole the hill falls off and no exposure is seen. It would appear from a cursory examination that a belt of variegated talc, eminently suited to purposes of decoration and having a width of at least 200 feet, crosses the country in a north and south direction. Northeast from the drill holes mentioned, the hill continues at a still higher elevation and at a distance of about 300 yards outcrops of amphibolitic crystalline limestone of a lavender colour are encountered. Just west of this point, green serpentine marble appears, interlaminated with the lavender coloured amphibolitic bands, the whole striking north and south and dipping 50° east. The total width of the serpentine belt is about 50 yards. There is no doubt that a considerable body of handsome serpentine marble, comparable with the product of the North Lanark Co., exists at this point.

Mr. Caldwell has, as yet, done no work beyond the drilling mentioned; he is however contemplating quarrying the talc with the object of applying it to purposes of decoration.

STARRY AMPHIBOLITE.

— *Peebles, Actinolite, Lot* 13, *Con. II, Kaladar, Addington county.*

On this property there occurs a deposit of very unique material which should have a considerable value for interior decoration. The belt strikes N. 80° E. with a vertical dip and has a width of about 50 feet. It is easily traced for a distance of 300 feet. Although the valuable material is not continuous across the 50 feet of width there is enough of it to make up about two-thirds of that distance. The jointing is not excessive and permits of the quarrying of very large blocks, some of which are 6 feet by 4 feet by 4 feet. Granite occurs north of the deposit, and to the south a much stretched and altered conglomerate.

Many years ago considerable work was done on the property by a New York syndicate, resulting in the production of a number of large blocks. Difficulties of transportation to the rail are said to be responsible for the cessation of operations.

The stone consists of a very compact and tough aggregation of blades of actinolite arranged in a radiating manner around centres averaging three-quarter of an inch apart. On polished surfaces the impression is that of a closely apposed series of stars in shades of green. The large size of the blocks which can be obtained, the remarkable uniformity of the structure, and the undoubted beauty of the material must eventually give it a high value as a decorative substance. Unfortunately, it can never be employed for exposed work as it rapidly rusts to a dirty brown colour.

Lot 16, *Con. III, Kaladar.*

A material similar to the above is said to occur on this lot.

RARER DECORATIVE STONES.

Tourmaline rock.—The bright green mineral, tourmaline, occurs in certain of the igneous rocks, in crystalline limestone, and in the matter filling mineral veins. When pure, it is employed as a gem stone and the rock containing it ranks as an ornamental stone. The jewel variety has not been obtained in Ontario and it is questionable if the rock has any economic value. The following occurrences and references may be of interest:—

Lot 25, Con. VI, Kaladar, with kyanite in quartz veins: Bur. Mines, Ont., Rep. 1897, p. 238.

Lot 28, Con. VII, Clarendon, with mispickel in quartz veins: Bur. Mines, Ont., Rep. 1902, p. 203.

Lot 18, Range IV, Bathurst, in white quartz: Geol. Sur. Can; Rep. 1887-88, p. 67 S.

Ross, in granite veins: *ibid.*

Lansdowne, on Charleston lake: *ibid.*

N. Elmsley, Madoc, Elzevir, *ibid.*

Garnet rock.—The red and brown varieties of garnet, of insufficient purity for use as gem stones, occur in many of the gneisses of the Grenville series in the Archæan region of Ontario. The best known localities are in Rawdon and Marmora, where the garnets are embedded in white quartzite. For a further account of garnet as well as other rare substances see Geol. Sur. Can. Rep., 1887-88, pt. S. p. 65 *et seq.*

Graphic granite.—"The pegmatite at Montgomery's clearing on Allumette lake, five mile above Pembroke, Ontario, consisting of a brownish red orthoclase with white quartz, is a beautiful ornamental stone, and admits of a good polish." [1]

[1] Geol. Sur. Can., Rep. 1887–88, p. 75 S.

CHAPTER VII.

The Slate of Southern Ontario.

There is at present no slate produced in Ontario; the only deposit that has ever been worked is situated on lot 5, con. VI, of Madoc.

The belt here seems to have a considerable width and to extend for at least a mile in an east and west direction. The slate is of a good blue grey colour and, judging from the fragments now lying in the old quarry, it is very durable. It would appear that excessive hardness and lack of capital to push the excavation to greater depths were responsible for the cessation of operations. See the report of the Royal Commission on the Mineral Resources of Ontario, 1890, pp. 87–88.

Slates are also known to occur on Calabogie lake[1], in the townships of Horton and Ross[2], and in the township of Lavant[3].

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[1] Geol. Sur. Can. Rep. 1876–77, p. 250.
[2] *Ibid*, pp. 260, 262.
[3] *Ibid*, p. 253.

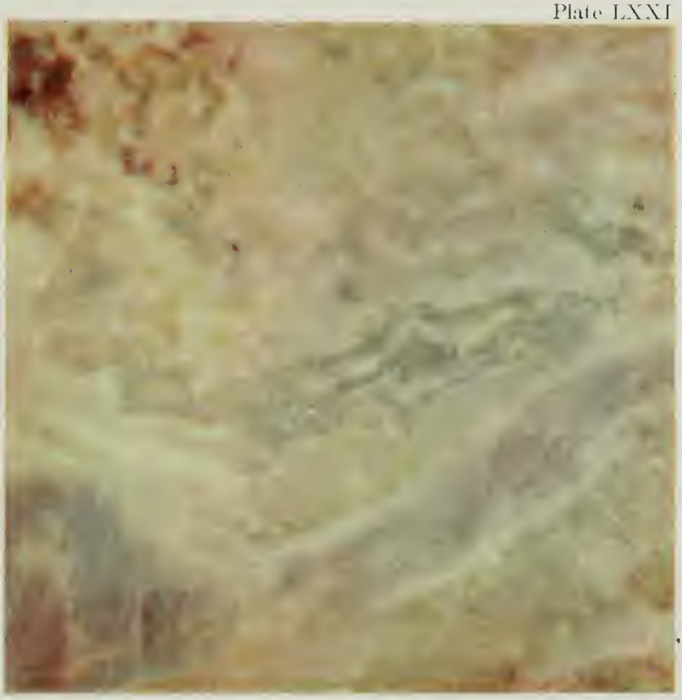
Plate LXIX

Red Limestone, Britnell's Quarry, Burnt River, Ont.

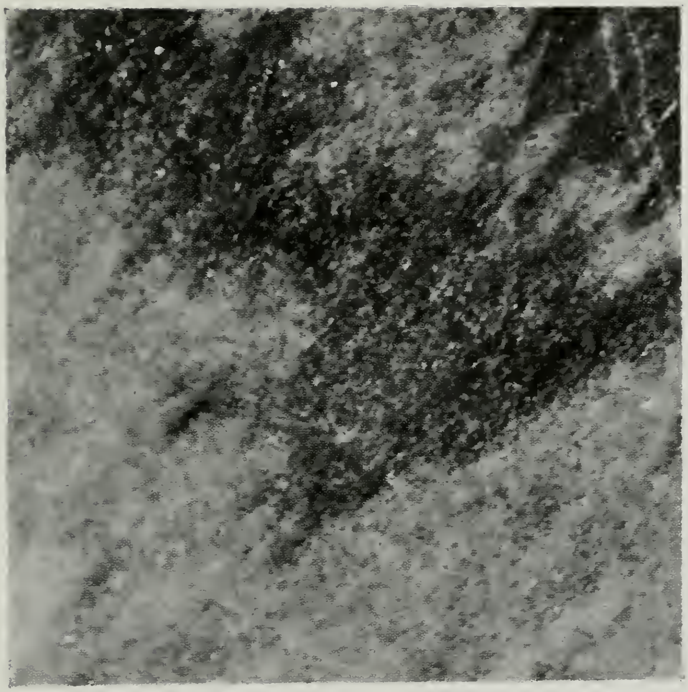
Plate LXX

Gananoque Monumental Syenite

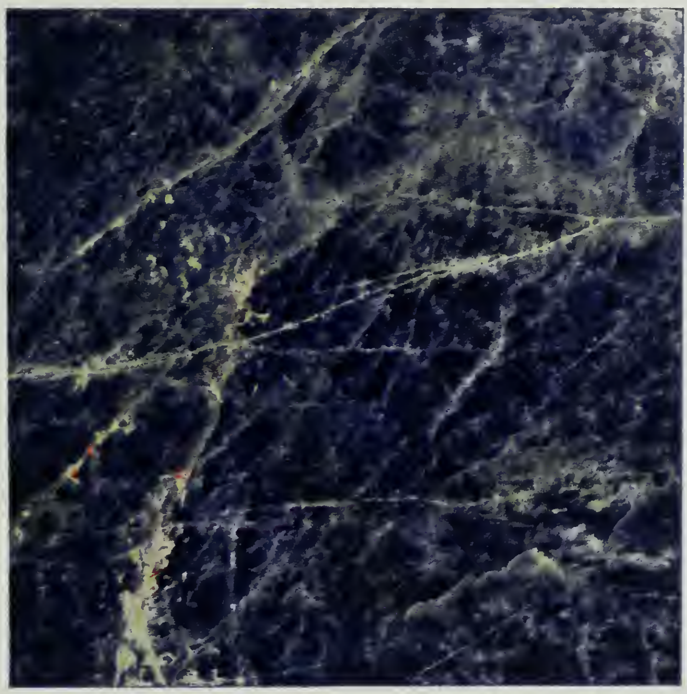
Plate LXXI



Serpentine Marble, North Lanark Marble Co.



Arnprior Marble



Sodalite, Dungannon Township, Ont.

Plate LXXIV.

Brown brecciated Marble, Ontario Marble Co., Bancroft, Ont.

Plate LXXV.

No. 1—Chazy limestone, Marcotte's quarry, Mille Roches (136)
" 2—Black River limestone, Manson's quarry, Mille Roches (135)
" 3—Black River limestone, Wallace's quarry, Kingston (64)
" 4—Black River limestone, Aylesworth's quarry, Newburgh, Ont. (92)
" 5—Black River limestone, Macdonald's quarry, Point Anne, Ont. (112)
" 6—Black River limestone, McPhie's quarry, Glen Robertson, Ont. (107)
" 7—Black River limestone, Longford quarries, top nine inch bed, Longford Mills, Ont (152)
" 8—Niagara limestone, Queenston Quarry Co., blue beds (276)
" 9—Medina grey sandstone, Logan's quarry, Glen William, Ont. (321)
" 10—Trenton or Black River limestone, Quinlan and Robertson's quarry, Crookston, Ont. (239)
" 11—Black River limestone, Brennan's quarry, lower fifteen inch bed, Sand Point, Ont. (246)
" 12—Beekmantown limestone, Mill's quarry, Prescott, Ont. (264)
" 13—Onondaga limestone, twenty-eight inch bed, Thames Quarry Co., St. Marys, Ont. (139)
" 14—Trenton limestone, Thebault's quarry, Ottawa, Ont. (218)
" 15—Onondaga limestone, eight inch bed, Thames Quarry Co., St. Marys, Ont. (138)

Plate LXXV

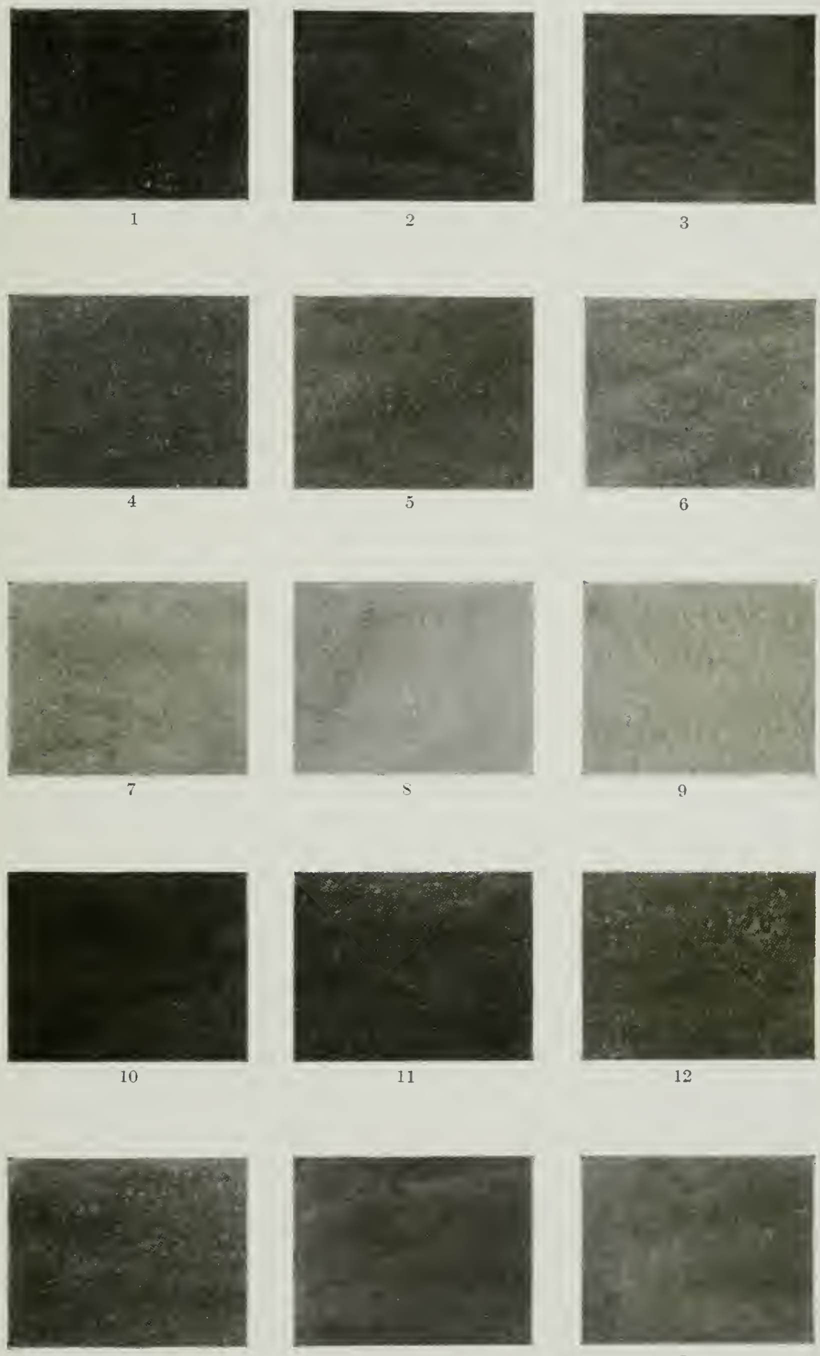


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Plate LXXVI.

No. 1—Beekmantown limestone, McEwen's quarry, Beckwith township, Ont. (254)

" 2—Beekmantown limestone, Dyer's quarry, Brockville, Ont. (52)

" 3—Oriskany sandstone, brown bands, MacDonald's quarry, North Cayuga township (101)

" 4—Niagara dolomitic limestone, Cook's quarry, Wiarton, Ont. (33)

" 5—Niagara dolomitic limestone, light brown coursing stone, Marshall's quarry, Hamilton, Ont. (126)

" 6—Onondaga limestone, McCormick's quarry, Pelee island, Ont. (115)

" 7—Guelph dolomite, Central Prison quarry, Guelph, Ont. (271)

" 8—Black River limestone, bottom fourteen inch bed, Longford quarries, Longford Mills, Ont. (151)

" 9—Potsdam-Beekmantown sandstone, Government quarry, Westport, Ont. (43)

" 10—Guelph dolomite, Ashenhurst's quarry, Brisbane, Ont. (40)

" 11—Potsdam-Beekmantown sandstone, white Nepean stone, Tillson's quarry, Bells Corners, Ont. (216)

" 12—Onondaga (Dundee) dolomite, Solway Process Co., Amherstburg, Ont. (11)

" 13—Niagara limestone, grey beds, Queenston Quarry Co., St. Davids, Ont. (275)

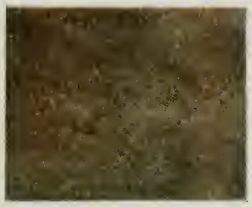
" 14—Niagara limestone, Gibson's quarry, Beamsville, Ont. (119)

" 15—Niagara limestone, Perkins' quarry Owen Sound, Ont. (130)

PLATE LXXVI.

No. 1—Beekmantown limestone, McEwen's quarry, Beckwith township, Ont. (254)
" 2—Beekmantown limestone, Dyer's quarry, Brockville, Ont. (52)
" 3—Oriskany sandstone, brown bands, MacDonald's quarry, North Cayuga township (101)
" 4—Niagara dolomitic limestone, Cook's quarry, Wiarton, Ont. (33)
" 5—Niagara dolomitic limestone, light brown coursing stone, Marshall's quarry, Hamilton, Ont. (126)
" 6—Onondaga limestone, McCormick's quarry, Pelee island, Ont. (115)
" 7—Guelph dolomite, Central Prison quarry, Guelph, Ont. (271)
" 8—Black River limestone, bottom fourteen inch bed, Longford quarries, Longford Mills, Ont. (151)
" 9—Potsdam-Beekmantown sandstone, Government quarry, Westport, Ont. (43)
" 10—Guelph dolomite, Ashenhurst's quarry, Brisbane, Ont. (40)
" 11—Potsdam-Beekmantown sandstone, white Nepean stone, Tillson's quarry, Bells Corners, Ont. (216)
" 12—Onondaga (Dundee) dolomite, Solway Process Co., Amherstburg, Ont. (11)
" 13—Niagara limestone, grey beds, Queenston Quarry Co., St. Davids, Ont. (275)
" 14—Niagara limestone, Gibson's quarry, Beamsville, Ont. (119)
" 15—Niagara limestone, Perkins' quarry, Owen Sound, Ont. (130)

Plate LXXVI



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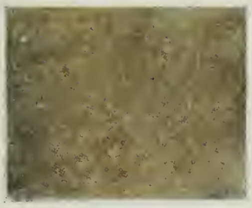

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PLATE LXXVII.

No. 1—Guelph dolomite, Webster's quarry, Galt, Ont. (27)
" 2—Niagara limestone, Walker's quarry, Thorold, Ont. (88)
" 3—Potsdam-Beekmantown sandstone, Wilson's quarry, Perth, Ont. (240)
" 4—Medina mottled sandstone (brown part), Robert Goodall's quarry, Rockway, Ont. (84)
" 5—Black River limestone, lower red beds, Britnell's quarry, Burnt River, Ont. (14)
" 6—Chazy sandstone, Beckett's island, Pembroke, Ont. (169)
" 7—Potsdam-Beekmantown sandstone, Gordon's quarry, Kingston Mills, Ont. (69)
" 8—Potsdam-Beekmantown sandstone, Hughes' quarry, Perth, Ont. (228)
" 9—Chazy limestone, White's quarry, Pembroke, Ont. (170)
" 10—Chazy limestone, Ross' quarry, Little Rideau, Ont. (109)
" 11—Medina grey sandstone, Nicholson's quarry, Orangeville, Ont. (53)
" 12—Beekmantown sandy limestone, Coughlin's quarry, Smiths Falls, Ont. (235)
" 13—Trenton limestone, six inch bed, Robillard's quarry, Ottawa, Ont. (208)
" 14—Chazy limestone, weathered, Marcotte's quarry, Mille Roches, Ont. (136)
" 15—Black River limestone, weathered, Wallace's quarry, Kingston, Ont (64)

PLATE LXXVII.

No. 1—Guelph dolomite, Webster's quarry, Galt, Ont. (27)
" 2—Niagara limestone, Walker's quarry, Thorold, Ont. (88)
" 3—Potsdam-Beekmantown sandstone, Wilson's quarry, Perth, Ont. (240)
" 4—Medina mottled sandstone (brown part), Robert Goodall's quarry, Rockway, Ont. (84)
" 5—Black River limestone, lower red beds, Britnell's quarry, Burnt River, Ont. (14)
" 6—Chazy sandstone, Beckett's island, Pembroke, Ont. (169)
" 7—Potsdam-Beekmantown sandstone, Gordon's quarry, Kingston Mills, Ont. (69)
" 8—Potsdam-Beekmantown sandstone, Hughes' quarry, Perth, Ont. (228)
" 9—Chazy limestone, White's quarry, Pembroke, Ont. (170)
" 10—Chazy limestone, Ross' quarry, Little Rideau, Ont. (109)
" 11—Medina grey sandstone, Nicholson's quarry, Orangeville, Ont. (53)
" 12—Beekmantown sandy limestone, Coughlin's quarry, Smiths Falls, Ont. (235)
" 13—Trenton limestone, six inch bed, Robillard's quarry, Ottawa, Ont. (208)
" 14—Chazy limestone, weathered, Marcotte's quarry, Mille Roches, Ont. (136)
" 15—Black River limestone, weathered, Wallace's quarry, Kingston, Ont (64)

Plate LXXVII


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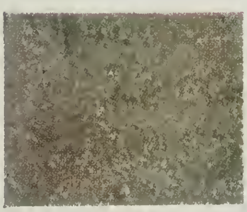
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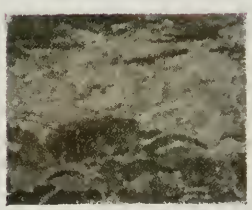
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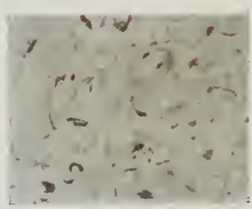
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APPENDIX I.

TABLE I.

The Specific Gravity, Weight Per Cubic Foot, Percentage of Pore Space, and Ratio of Absorption of Ontario Building Stones.

LIMESTONES.

	Formation.	No.	Specific Gravity.	Weight, lbs. per cu. ft.	Pore Space per cent.	Ratio of Absorption.
Ashenhurst, Erin	Guelph	40	2·853	149·78	15·88	5·56
Aylesworth, Newburgh	Black River	92	2·717	169·286	0·166	0·061
Brennan, Sand Point	Black River	246	2·79	171·216	1·67	0·609
Britnell, Burnt river	Black River	14	2·83	175·313	0·74	0·26
Cook, Wiarton	Niagara	33	2·831	158·237	10·44	4·13
Central Prison, Guelph	Guelph	271	2·853	150·309	15·58	6·47
Coughlin, Smith's Falls	Beekmantown.	235	2·73	167·597	1·633	0·608
Dyer, Brockville	Beekmantown.	52	2·821	173·75	1·31	0·472
Gibson, Beamsville	Niagara	119	2·842	153·544	13·427	4·93
Longford Quarry, bottom 14 in. bed	Black River	151	2·71	168·5	0·373	0·13
Longford Quarry, top 9 in. bed	Black River	152	2·701	167·88	0·408	0·152
Macdonald, Point Anne, light blue bed	Black River	112	2·706	168·76	0·07	0·028
McEwen, Carleton Place	Beekmantown.	254	2·836	151·38	12·607	5·09
McPhie, Glen Robertson	Black River	107	2·726	168·633	0·88	0·328
McCormick, Pelee island	Onondaga	115	2·719	151·07	10·98	4·54
Marcotte, Mille Roches	Chazy	136	2·738	170·349	0·31	0·115
Marshall, Hamilton	Niagara	126	2·843	168·512	8·939	3·46
Menard, Embrun	Black River	77	2·714	168·363	0·6	0·222
Mills, Prescott	Beekmantown.	264	2·777	168·598	2·72	1·01
Manson, Mille Roches	Black River	135	2·716	169·335	0·099	0·037
Perkins, Owen Sound	Niagara	130	2·825	157·96	10·4	4·24
Pearce Co., Marmora	Black River	278	2·723	169·827	0·066	0·024
Queenston Quarry Co., blue beds	Niagara	276	2·789	162·015	6·92	2·67
Quinlan and Robertson, Crookston	Black River	239	2·713	168·135	0·699	0·26
Ross, Hawkesbury	Chazy	109	2·718	168·47	0·68	0·255
Solway Process Co., Amherstburg	Onondaga	11	2·773	155·813	9·966	4·00
Thames Quarry Co., 28 in. bed	Onondaga	139	2·715	167·867	0·93	0·34
Thames Quarry Co., 8 in. bed	Onondaga	138	2·709	167·513	0·92	0·34
Thebault, Ottawa	Trenton	218	2·712	168·636	0·366	0·135
Wallace, Kingston, 9 in. bed	Black River	64	2·725	169·766	0·177	0·0651
Walker, Thorold	Niagara	88	2·726	162·653	4·395	1·68
Webster, Galt	Guelph	27	2·837	151·17	14·62	6·05
White, Pembroke	Chazy	170	2·776	171·628	0·936	0·34

SANDSTONES.

	Formation	No.	Specific Gravity	Weight, lbs. per cu. ft.	Pore Space per cent.	Ratio of Absorption
Beckett's island, Pembroke.	Chazy	169	2·657	128·52	17·517	8·01
Gordon, Kingston Mills	Potsdam-Beekmantown	69	2·65	144·861	12·408	5·34
Government quarry, Westport	Potsdam-Beekmantown.	43	2·656	152·103	8·24	3·40
Logan, Georgetown	Medina	321	2·66	146·01	12·04	5·16
MacDonald, Cayuga	Oriskany	100	2·657	154·95	6·55	2·64
Nicholson, Orangeville	Medina	53	2·655	141·06	14·87	6·59
Hughes, MacCue, purple-ribbed	Potsdam-Beekmantown.	228	2·647	150·383	8·969	3·72
Tillson, Bells Corners, hard..	Potsdam-Beekmantown.	217	2·647	155·357	5·958	2·37
Tillson, Bells Corners, soft..	Potsdam-Beekmantown.	216	2·651	153·504	7·22	2·93
Wilson, Perth	Potsdam-Beekmantown.	240	2·631	156·077	4·947	1·98

GRANITES AND GNEISSES.

	Formation	No.	Specific Gravity	Weight lbs per cu. ft.	Pore Space per cent.	Ratio of Absorption
Gananoque, monumental syenite	Laurentian ...	200	2·746	168·82	0·33	0·124
Brockville, dark granite	Laurentian ...	324	2·658	166·647	0·201	0·075
Kingston granite	Laurentian ...	70	2·68	166·72	0·319	0·119
Gneiss, Hall, Parry Sound ..	Grenville	319	2·67	165·588	0·628	0·237

CRYSTALLINE LIMESTONES AND MARBLES.

	Formation	No.	Specific Gravity	Weight, lbs. per cu. ft.	Pore Space per cent.	Ratio of Absorption
Arnprior marble	Grenville....	242	2·741	170·634	0·252	0·092
Ellis, Toronto, Madoc black marble	" ...	223	2·727	169·618	0·336	0·134
Jamieson, Renfrew, lime kiln quarry	" ...	250	2·758	171·85	0·016	0·0051
Lanark village, white marble.	" ...	313	2·772	169·45	0·519	0·018
Legris, Calabogie, white marble	" ...	164	2·744	170·674	0·342	0·125
McGinn, Haleys, white marble	" ...	258	2·878	179·347	0·149	0·052
North Lanark Marble Co., serpentine marble	" ...	154	2·662	164·38	1·06	0·406
Ontario Marble Co., variegated stone..................	" ...	325	2·91	179·706	0·224	0·077
Sanford Estate, Hamilton, Barrie white marble	" ...	191	2·846	179·224	0·22	0·08

TABLE II.

The Crushing Strength of Ontario Building Stones.

(An asterisk * after the number indicates that the stone was not freshly quarried. An asterisk * after the test indicates that it was not very satisfactory.)

LIMESTONES.

	Formation	No.	Crushing strength, pounds per sq. in.				Remarks.
			1	2	3	Average	
Ashenhurst, Erin	Guelph	40*	13,836	12,530	....	13,183	Lower wedge, yields quietly.
Aylesworth, Newburgh	Black River	92*	29,654	....	....	29,654	Lower wedge.
Brennan, Sand Point	Black River	246*	21,493*	26,495	....	26,495	Vertical prisms.
Britnell, Burnt River	Black River	14	32,184	....	....	32,184	Exploded, vertical prisms.
Cook, Wiarton	Niagara	33	21,162	....	....	21,162	Exploded.
Central Prison, Guelph	Guelph	271	12,719	11,514	....	12,116	Slight pyramid.
Coughlin, Smiths Falls	Beekmantown	235	26,858	....	....	26,858	Fair lower pyramid.
Dyer, Brockville	Beekmantown	52	18,456	19,645	....	19,050	Exploded.
Gibson, Beamsville	Niagara	119*	9,670	....	....	9,670	Sharp upper and lower wedge.
Longford quarry, 15 in. bed	Black River	151	22,968	....	....	22,968	Prisms.
Longford quarry, top 9 in. bed	Black River	152	25,000	....	....	25,000	Prisms.
Macdonald, Point Anne, light blue	Black River	112	20,322	....	....	20,322	Exploded into small fragments.
McEwen, Carleton Place	Beekmantown	254*	15,588	....	....	15,588	Crumbled, small pyramids.
McPhie, Glen Robertson	Black River	107*	19,532	....	....	19,532	Prisms, no pyramids.
McCormick, Pelee island	Onondaga	115*	8,090	....	....	8,090	Irregular upper pyramid.
Marcotte, Mille Roches	Chazy	136	23,034	20,352	....	21,693	Pyramids and prisms.
Marshall, Hamilton, light brown beds	Niagara	126	19,548	....	....	19,548	Good lower pyramid.
Mills, Prescott	Beekmantown	264*	18,393	17,137	17,844	17,547	Good lower pyramid.
Manson, Mille Roches	Black River	135*	22,356	....	16,814	22,356	Exploded, vertical wedges.
Menard, Embrun	Black River	77*	17,975	....	....	17,975	Exploded, lower pyramid.
Perkins, Owen Sound, soft beds	Niagara	130	15,404	....	....	15,404	Upper and lower pyramid.
Queenston Quarry, blue beds	Niagara	276	18,691	....	....	18,691	Exploded.
Quinlan and Robertson, Crookston	Black River	239*	18,826	....	....	18,826	Vertical splinters, yielded quietly.
Robillard, Ottawa, 6 in. bed	Trenton	208	17,994	....	....	17,994	Crumbled.
Ross, Hawkesbury	Chazy	109*	12,591	13,189	....	12,890	Yielded quietly, lower wedge.
Solway Process Co., Amherstburg	Onondaga	11	15,883	....	....	15,883	
Thames Quarry Co., 28 in. bed	Onondaga	139	22,743	21,407	....	22,075	Yielded suddenly, no pyramids.
Thames Quarry Co., 8 in. bed	Onondaga	138	17,037	19,447	....	18,242	Yielded suddenly, fair lower pyramid.
Thebault, Ottawa	Trenton	218	17,604	....	....	17,604	Exploded, upper pyramid.
Wallace, Kingston, 9 in. bed	Black River	64	29,506	23,361*	....	29,506	Yielded suddenly, prisms.
Walker, Thorold	Niagara	88	10,363	10,299	....	10,331	Short lower pyramid.
Webster, Galt	Guelph	27*	10,101	11,880	....	10,990	Upper pyramid.
White, Pembroke	Chazy	170	22,706	....	....	22,706	Exploded violently, splinters and pyramids.
Pearce Co., Marmora	Trenton	278*	37,705	....	....	37,705	Exploded to small fragments.

SANDSTONES.

	Formation	No.	Crushing strength, pounds per sq. in.				Remarks
			1	2	3	Average	
Beckett's island, Pembroke	Chazy	169*	9,235	9,843	....	9,539	Fair and pyramids below.
Gordon, Kingston Mills	Potsdam-Beekmantown	69*	12,571	12,986	....	12,778	Exploded, lower wedge.
Government quarry, Westport	Potsdam-Beekmantown	43	11,221	....	....	11,221	Crumbled.
Hughes, McCue, purple-ribbed	Potsdam-Beekmantown	228*	15,459	....	....	15,459	Exploded, flat lower pyramid.
Logan, Georgetown	Medina	321	21,715	....	....	21,715	Wedges.
MacDonald, Cayuga	Oriskany	100	17,949	....	....	17,949	Exploded, good lower pyramids.
Nicholson, Orangeville	Medina	53	12,590	....	....	12,590	Good upper wedge.
Tillson, Bells Corners, hard	Potsdam-Beekmantown	217	21,627	....	....	21,627	Exploded.
Tillson, Bells Corners, white	Potsdam-Beekmantown	216	22,032	....	....	22,032	Good lower pyramid.
Wilson, Perth	Potsdam-Beekmantown	240*	31,793	....	....	31,793	Upper and lower wedges.

GRANITES AND GNEISSES.

	Formation	No.	Crushing strength, pounds per sq. in.				Remarks
			1	2	3	Average	
Brockville dark granite	Laurentian	324*	26,209	....	....	26,209	Exploded, good wedges.
Gananoque monumental syenite	Laurentian	200	23,152	....	....	23,152	Exploded.
Kingston granite	Laurentian	70*	30,421	....	....	30,421	Good lower pyramid.
Hall, Parry Sound, gneiss	Grenville	319	33,453	....	....	33,453	Good upper, poor lower pyramid, much powder.

CRYSTALLINE LIMESTONES AND MARBLES.

	Formation	No.	Crushing strength lbs. per sq. in.	Remarks
Arnprior marble	Grenville	242*	15,100	Yielded quietly, fair lower pyramid.
Ellis, Toronto, Madoc black marble	"	223*	12,079*	Good upper wedge, several lower wedges.
Jamieson, Renfrew, lime kiln quarry	"	250	14,562	Yielded quietly.
Lanark village, white marble	"	313*	15,343	Good upper pyramid, poor lower pyramid.
Legris, Calabogie, white marble	"	164*	24,456	Sharp upper pyramid, much powder.
McGinn, Haleys, white marble	"	258*	22,595	Yielded suddenly, small upper and lower pyramids.
North Lanark Marble Co., serpentine marble	"	154	16,068*	Vertical prisms.
Ontario Marble Co., variegated green	"	325	22,065	Good lower wedge, more prismatic than the other marbles.
Sanford Estate, Barrie white marble	"	191*	25,018	Good lower pyramid, much fine powder.

TABLE III.

The Comparative Crushing Strength of Fresh and Frozen Examples of Ontario Building Stone, and the loss in Weight on Freezing.

LIMESTONES.

	Formation	No.	Crushing strength, lbs. per sq. in.				Change in Weight on freezing, %	
			Fresh Sample	Frozen Sample	Loss	Gain	Loss	Gain
Ashenhurst, Erin	Guelph	40*	13,183	14,965	....	1,782	0·055	
Aylesworth, Newburgh	Black River	92*	29,654	25,756	4,898	....	....	0·099
Brennan, Sand Point	Black River	246*	26,495	23,525	2,970	....	0·0085	
Britnell, Burnt River	Black River	14	32,184	32,180	4	....	....	0·019
Cook, Wiarton	Niagara	33	21,162	18,555	2,607	....	0·0204	
Central Prison, Guelph	Guelph	271	12,116	13,600	....	1,484	0·160	
Coughlin, Smiths Falls	Beekmantown	235	26,858	20,505	6,353	....	....	0·250
Dyer, Brockville	Beekmantown	52	19,050	24,860	....	5,810	0·017	
Gibson, Beamsville	Niagara	119*	9,670	9,572	98	....	0·037	
Longford quarries, 15 in. bed	Black River	151	22,968	21,625	1,343	....	0·013	
Longford quarries, top 9 in. bed	Black River	152	25,000	19,723	5,277	....	0·0049	
Macdonald, Point Anne, light blue	Black River	112	20,322	17,400	2,922	....	0·028	
McEwen, Carleton Place	Beekmantown	254*	15,588	13,280	2,308	....	0·081	
MacPhie, Glen Robertson	Black River	107*	19,532	17,651	1,881	....	0·067	
McCormick, Pelee island	Onondaga	115*	8,090	6,354	1,736	....	0·0707	
Marcotte, Mille Roches	Chazy	136	21,693	29,445	....	7,752	....	0·008
Marshall, Hamilton	Niagara	126	19,548	18,844	704	....	0·024	
Mills, Prescott	Beekmantown	264*	17,547	20,183	....	2,636	0·305	
Manson, Mille Roches	Black River	135*	22,356	14,548	7,808	....	0·0204	
Perkins, Owen Sound	Niagara	130	15,404	12,916	2,488	....	0·0643	
Queenston quarry, blue beds	Niagara	276	18,691	12,689	6,002	....	0·092	
Quinlan and Robertson, Crookston	Black River	239*	18,826	13,935	4,891	....	0·026	
Robillard, Ottawa	Trenton	208	17,994	15,650	2,344	....	0·046	
Ross, Hawkesbury	Chazy	109*	12,890	14,479	....	1,589	0·058	
Solway Process Co., Amherstburg	Onondaga	11	15,883	16,990	....	1,107	0·0913	
Thames Quarry Co., 28 in. bed	Onondaga	139	22,075	23,014	....	939	0·028	
Thames Quarry Co., 8 in. bed	Onondaga	138	18,242	20,194	....	1,952	0·015	
Thebault, Ottawa	Trenton	218	17,604	17,600	4	....	0·049	
Walker, Thorold	Niagara	88	10,331	11,500	....	1,169	0·142	
Wallace, Kingston	Black River	64	29,506	33,420	....	3,914	0·0224	
Webster, Galt	Guelph	27*	10,990	9,801	1,189	....	0·232	
White, Pembroke	Chazy	170	22,706	24,500	....	1,794	0·028	
Menard, Embrun	Black River	77*	17,975	15,468	2,507	....	0·045	

* The sample was not freshly quarried.

SANDSTONES.

	Formation	No.	Crushing Strength, lbs. per sq. in.				Change in Weight on freezing, %	
			Fresh Sample	Frozen Sample	Loss	Gain	Loss	Gain
Beckett's island, Pembroke	Chazy	169*	9,539	10,673	....	1,134	0·253	
Gordon, Kingston Mills	Potsdam-Beekmantown	69*	12,778	17,052	....	4,274	0·081	
Government quarry, Westport	Potsdam-Beekmantown	43	11,221	7,569	3,652	....	0·094	
Hughes, MacCue, purple-ribbed	Potsdam-Beekmantown	228*	15,459	11,300	4,159		0·0009	
Logan, Georgetown	Medina	321	21,715	....	....	....	0·072	
MacDonald, Cayuga	Oriskany	100	17,949	....	....	....	0·034	
Nicholson, Orangeville	Medina	53	12,590	10,230	2,360	....	0·052	
Tillson, Bells Corners, hard	Potsdam-Beekmantown	217	21,627	19,731	1,896	....	0·041	
Tillson, Bells Corners, white	Potsdam-Beekmantown	216	22,032	....	....	....	0·023	
Wilson, Perth	Potsham-Beekmantown	240*	31,793	28,912	2,881	....	0·014	

* The sample was not freshly quarried.

GRANITES AND GNEISSES.

	Formation	No.	Crushing Strength, lbs. per sq. in.				Change in Weight on freezing, %	
			Fresh Sample	Frozen Sample	Loss	Gain	Loss	Gain
Brockville dark granite	Laurentian	324*	26,209	24,634	1,575	....	0·0048	
Gananoque monumental syenite	Laurentian	200	23,152	20,536	2,616	....	0·006	
Hall, Owen Sound, gneiss	Grenville	319	33,453	32,271	1,182	....	0·0066	

* The sample was not freshly quarried.

CRYSTALLINE LIMESTONES AND MARBLES.

	Formation	No.	Crushing Strength, lbs. per sq. in.				Change in Weight on freezing, %	
			Fresh Sample	Frozen Sample	Loss	Gain	Loss	Gain
Arnprior marble	Grenville	242*	15,100	14,347	753	....	0·0305	
Jamieson, Renfrew, lime kiln quar'y	"	250	14,562	14,560	2	....	0·0425	
Lanark village, white marble	"	313*	15,343	14,565	777	....	0·025	....
McGinn, Haleys, white marble	"	258*	22,595	20,219	2,276	....	0·012	
Sanford Estate, Barrie white marble	"	191*	25,018	21,737	3,281	....	0·018	
Ontario Marble Co., green variegated	"	325	22,065	....	....	....	0·008	

* The stone was not freshly quarried.

TABLE IV.

The Transverse Strength of Ontario Building Stones.

LIMESTONES.

	Formation	No.	Transverse Strength, Modulus of Rupture, lbs. per sq.in.	Remarks
Asheahurst, Erin	Guelph	40*	2,022	Straight break, ¼ in. from centre, parallel to central line.
Aylesworth, Newburgh	Black River	92*	2,382	Straight break, crossing central lines diagonally.
Brennan, Sand Point	Black River	246*	3,923	Straight break on central line.
Britnell, Burnt River	Black River	14	4,291	Straight break on central line.
Cook, Wiarton	Niagara	33	2,280	Straight break, crossing central line diagonally at very low angle.
Central Prison, Guelph	Guelph	271	1,250	Straight break on central line. Faces of break convex and concave.
Coughlin, Smiths Falls	Beekmantown	235	2,968	Straight break, ⅛ in. from central line and parallel.
Dyer, Brockville	Beekmantown	52	2,086	Straight break one inch from central line on one side and two-thirds of an inch on the other.
Gibson, Beamsville	Niagara	119*	931	Crooked break, one inch from central line.
Longford quarries, 14 in. bed	Black River	151	2,281	Straight break, ½ in. from centre on one side, on line at the other.
Longford quarries, top 9 in. bed	Black River	152	2,324	Straight break, crossing central line diagonally.
Macdonald, Point Anne, light blue bed	Black River	112	2,561	Straight break, crossing central line diagonally.

* The stone was not freshly quarried.

LIMESTONES—*Continued*

	Formation	No.	Transverse Strength, Modulus of Rupture, lbs. per sq. in.	Remarks
McEwen, Carleton Place	Beekmantown	254*	1,130	Straight break, crossing central line diagonally at low angle. Faces of break irregular.
McPhie, Glen Robertson	Black River	107	2,290	Straight break, 1/4 in. from central line at one side and 3/4 in. at the other.
McCormick, Pelee island	Onondaga	115*	1,404	Irregular break, on central line at one side and 1/4 in. distant at the other.
Marcotte, Mille Roches	Chazy	136	3,423	Straight break, slightly inclined on central line. Faces of break irregular.
Marshall, Hamilton, light brown	Niagara	126	3,172	Straight break, crossing central line diagonally at low angle.
Mills, Prescott	Beekmantown	264*	2,107	Curved break, on central line at one side and 1/4 in. distant at the other. Faces of break irregular.
Manson, Mille Roches	Black River	136*	3,069	Straight break, inclined at angle of 35° on central line.
Perkins, Owen Sound	Niagara	130	1,111	Doubly curved break 1/2 in. from central line.
Queenston quarry, blue beds	Niagara	276	2,361	Slightly curved break, on central line at one side, 1/4 in. from line at other.
Queenston quarry, grey beds	Niagara	275	1,619	Straight break, crossing central line at angle of 15°.
Quinlan and Robertson, Crookston	Black River	239*	2,545	Straight break, crossing central line diagonally. Faces of break irregular.
Robillard, Ottawa, 6 in. bed	Trenton	208	2,863	Straight break close to central line.
Ross, Hawkesbury	Chazy	109*	2,038	Crooked break. Irregular faces.
Solway Process Co., Amherstburg	Onondaga	11	2,064	Straight break close to central line.
Thames quarries, 28 in. bed	Onondaga	139	3,015	Straight break, crossing central line diagonally at low angle.
Thames quarries, 8 in. bed	Onondaga	138	3,474	Straight break, 1/4 in. from central line at one side and 5/8 in. at the other.
Thebault, Ottawa	Trenton	218	2,447	Straight break, slightly inclined on central line at 1/4 in. distance.
Wallace, Kingston	Black River	64	2,100	Straight break, on central line at one side and 1/4 in. distant at the other.
Walker, Thorold	Niagara	88	1,529	Slightly irregular break, 1/4 in. from central line.
Webster, Galt	Guelph	27	817	Very irregular break, crossing central line diagonally.
White, Pembroke	Chazy	170	2,441	Very irregular break, 1/2 in. from central line. The fracture shows a strong tendency to run out along the bedding planes.

* The stone was not freshly quarried.

SANDSTONES.

	Formation	No.	Transverse strength, Modulus of Rupture, lbs. per sq. in.	Remarks
Beckett's island, Pembroke	Chazy	169*	1,124	Straight break on central line. Faces of break irregular
Gordon, Kingston Mills	Potsdam-Beekmantown	69*	1,162	Slightly irregular break close to central line.
Government quarry, Westport	Potsdam-Beekmantown	43	619	Straight break close to central line.
Hughes, MacCue	Potsdam-Beekmantown	228*	417	Straight break parallel to central line and $\frac{1}{4}$ in. distant.
Logan, Georgetown	Medina	321	1,614	Slightly curved break near central line. Faces of break irregular.
MacDonald, Cayuga	Oriskany	100	2,186	Straight break, crossing central line diagonally at angle of 10°.
Nicholson, Orangevillle	Medina	53	568	
Tillson, Bells Corners, hard	Potsdam-Beekmantown	217	1,885	Straight break on central line.
Tillson, Bells Corners, white	Potsdam-Beekmantown	216	1,620	Straight break, crossing central line diagonally at angle of 10°.
Wilson, Perth	Potsdam-Beekmantown	240*	1,635	Straight break parallel to central line and $\frac{1}{4}$ in. distant.

* The stone was not freshly quarried.

GRANITES AND GNEISSES.

	Formation	No.	Transverse Strength, Modulus of Rupture lbs. per sq. in.	Remarks
Kingston granite	Laurentian	70	3,382	Straight break on central line at one side and $\frac{1}{4}$ in. distant at the other. Fracture faces irregular.
Gananoque monumental syenite	Laurentian	200	2,791	Straight break, crossing central line diagonally at angle of 10°.
Brockville dark granite	Laurentian	324	2,480	Fairly straight break, $\frac{1}{4}$ in. from central line at one side and $\frac{1}{2}$ in. at the other.
Hall, Parry Sound, gneiss	Grenville	319	1,546	Straight break on central line. Fracture faces slightly uneven.

* The stone was not freshly quarried.

CRYSTALLINE LIMESTONES AND MARBLES.

	Formation	No.	Transverse Strength Modulus of Rupture, lbs. per sq. in.	Remarks
Arnprior marble	Grenville	242*	1,677	Straight break, crossing central line diagonally at 10°. Faces of break irregular.
Ellis, Toronto, Madoc black marble	"	223*	1,666	Curved break ½ in. from central line.
Jamieson, Renfrew, lime kiln quarry	"	250	2,090	Straight break crossing central line at 30°. Fracture faces irregular.
Lanark village, white marble	"	313*	1,394	Straight break, on central line at one side and ½ in. distant at the other. Fracture faces very irregular.
McGinn, Haleys, white marble	"	258*	1,745	Straight break, ¼ in. from central line at one side and ¾ in. at the other. Fracture faces very irregular.
North Lanark Co., serpentine marble	"	154	1,091	Straight break ¼ in. from central line. Fracture faces somewhat irregular.
Ontario Marble Co., variegated green	"	325	3,734	Straight break, on central line at one side and ½ in. distant at the other.
Sanford Estate, Barrie white marble	"	191*	1,858	Straight break, crossing the central line at a very low angle.

* The stone was not freshly quarried

TABLE V.

Table showing the loss of weight, in grams per square inch, and the change in colour effected by soaking the specimens in carbonic acid water for four weeks according to the method described on page 69.

LIMESTONES.

	No.	Loss in Weight, grams per sq. in.	Change in Colour.
Ashenhurst	40	0·00586	Scarcely perceptible.
Aylesworth	92	0·182	Turns very white with fine dark lines.
Brennan	246	0·08003	The blue colour becomes a dirty yellow-brown.
Britnell	14	0·038	The red becomes slightly yellowish and more mottled.
Cook	33	0·00527	Scarcely any change.
Central Prison	271	0·01154	Scarcely any change.
Coughlin	235	0·019	Becomes slightly yellow-green,
Dyer	52	0·017	Slightly lighter yellow and more mottled.
Gibson	119	0·00777	Scarcely any change.
Longford	151	0·309	Becomes very light with fine dark spots.
Longford	152	0·189	Becomes very white with fine dark lines.
Macdonald	112	0·017	Loses blue colour, becomes much lighter and grey and white dotted.
McEwen	254	0·01228	Very little change.
McPhie	107	0·102	Loses blue, becomes dirty yellow and grey mottled.
McCormick	115	0·01525	Dirty brown and yellow spotted.
Marcotte	136	0·1547	Loses blue, becomes light and dark grey mottled and streaked.
Marshall	126	0·00296	No change.
Mills	264	0·00537	Slightly lighter brown.
Manson	135	0·163	Loses blue, turns much lighter with a dull grey and brown mottled effect.
Perkins	130	0·00805	No change.
Queenston	275	0·00791	Scarcely any change.
Queenston	276	0·0581	Loses blue, becomes slightly lighter, yellowish grey and fine spotted.
Quinlan and Robertson	239	0·1507	Loses blue, becomes very much lighter, greyish and finely mottled.
Robillard	208	0·207	Loses blue, becomes light grey finely mottled with dark
Ross	109	0·07226	Loses blue, becomes light grey with fine yellow, grey and dark spots.
Solway Process Co	11	0·118	Becomes a dirty yellow-brown with white lines.
Thames Quarry Co.	139	0·298	Becomes much lighter, slightly yellow, uniform.
Thames Quarry Co.	138	0·3321	Becomes much lighter, slightly yellow and less uniform.
Thebault	218	0·106	Loses blue, becomes grey and fine dotted.
Wallace	64	0·291	Loses blue, becomes very light with blackish dots.
Walker	88	0·0963	Becomes slightly lighter
Webster	27	0·0148	Very little change.
White	170	0·112	Becomes very dirty yellow and yellowish white in marked clouds.

SANDSTONES

	No.	Loss in Weight, grams per sq. in.	Change in Colour.
Beckett's island......	169	0·0193	Very little change.
Gordon	69	0·0048	Very little change.
Government, Westport	43	0·018	The greenish part becomes yellow.
Hughes	228	0·00386	Very little change.
Logan	321	0·0131	Slightly lighter.
MacDonald..........	100	0·071	No change.
Nicholson	53	0·1135	Slightly lighter.
Tillson	217	0·00147	No change.
Tillson...............	216	0·064	No change.
Wilson	240	0·00181	No change.

GRANITES AND GNEISSES.

Brockville	324	0·000164	No change
Gordon	200	0·0088	No change.
Kingston.............	70	0·0045	No change.
Hall (gneiss).........	319	0·0015	Slightly yellow and dirty.

CRYSTALLINE LIMESTONES AND MARBLES.

Arnprior	242	0·936	Less blue, the contrast between the light and dark parts is sharpened.
Ellis	223	0·0875	Loses blue cast, becomes dark grey.
Jamieson............	250	0·0877	Less blue, stronger contrast.
Lanark village........	313	0·2015	Less blue, stronger contrast
McGinn	258	0·00196	No change.
North Lanark Co.	154	0·158	Calcite etches out, serpentine becomes light yellow and opaque.
Ont Marble Co.......	325	0·00101	No marked change.
Sanford	191	0·0223	No marked change.

TABLE VI.

Table for comparing the porosity and permeability of the samples which contain more than one per cent of pore space. The permeability is expressed as the number of cubic centimetres of water that pass through a plate of the stone three millimetres thick in one hour under a pressure of 15 pounds to the square inch.

Owner	Stone	No.	Porosity per cent.	Permeability cc. per sq.in. per hour
Ashenhurst	Guelph dolomite	40	15·88	90·5
Cook	Niagara dolomite	33	10·44	12·75
Central Prison	Guelph dolomite	271	15·58	90·20
Gibson	Niagara dolomite	119	13·427	32·7
Dyer	Beekmantown limestone	52	1·31	0·72
McEwen	Beekmantown dolomite	254	12·607	13·12
McCormick	Onondaga dolomite	115	10·98	45·00
Marshall	Niagara dolomite	126	8·939	2·37
Mills	Beekmantown dolomite	264	2·72	5·25
Perkins	Niagara dolomite	130	10·4	37·6
Queenston Quarry Co.	Niagara dolomite	275	....	600·
Queenston Quarry Co.	Niagara limestone	276	6·92	5·
Walker	Niagara limestone	88	4·395	4·
Webster	Guelph dolomite	27	14·62	155·1
Beckett's island	Chazy sandstone	169	17·517	2·25
Gordon	Potsdam-Beekmantown sandstone	69	12·408	30·7
Westport	Potsdam-Beekmantown sandstone	43	8·24	10·25
Hughes	Potsdam-Beekmantown sandstone	228	8·969	1845·
Logan	Medina sandstone	321	12·04	143·40
MacDonald	Oriskany sandstone	100	6·55	6·7
Nicholson	Medina sandstone	53	10·44	2130·
Tillson	Potsdam-Beekmantown sandstone	217	5·958	17·5
Tillson	Potsdam-Beekmantown sandstone	216	7·22	4·87
Wilson	Potsdam-Beekmantown sandstone	240	4·947	1·75

TABLE VII.

The coefficient of saturation of Ontario building stones. The ratio of the fine pore space to the total pore space, as determined by the method described on page 64.

LIMESTONES.

	Formation	No.	Coefficient of saturation
Ashenhurst, Erin	Guelph	40	0·48
Aylesworth, Newburgh	Black River	92	0·26
Brennan, Sand Point	"	246	0·507
Britnell, Burnt River	"	14	0·61
Cook, Wiarton	Niagara	33	0·45
Central Prison, Guelph	Guelph	271	0·43
Coughlin, Smiths Falls	Beekmantown	235	0·39
Dyer, Brockville	"	52	low
Gibson, Beamsville	Niagara	119	0·28
Longford quarries, 14 in. bed	Black River	151	0·27
Longford quarries, 9 in. bed	"	152	0·95
Macdonald, Point Anne	"	112	0·582
McEwen, Carleton Place	Beekmantown	254	0·3
McPhie, Glen Robertson	Black River	107	0·85
Marcotte, Mille Roches	Chazy	136	0·26
Marshall, Hamilton	Niagara	126	0·34
Mills, Prescott	Beekmantown	264	0·8
Manson, Mille Roches	Black River	135	0·53
Perkins, Owen Sound	Niagara	130	0·37
Quinlan and Robertson, Crookston	Black River	239	0·11
Queenston Quarry Co., blue beds	Niagara	276	0·32
Robillard, Ottawa	Trenton	208	0·91
Ross, Hawkesbury	Chazy	109	0·8
Solway Process Co., Amherstburg	Onondaga	11	0·43
Thames Quarry Co., St. Marys, 28 in. bed	"	139	0·9
Thames Quarry Co., St. Marys, 8 in. bed	"	138	0·72
Thebault, Ottawa	Trenton	218	0·61
Wallace, Kingston	Black River	64	0·4
Walker, Thorold	Niagara	88	0·56
Webster, Galt	Guelph	27	0·48

SANDSTONES

Beckett's island	Chazy	169	0·57
Gordon, Kingston Mills	Potsdam-Beekmantown	69	0·33
Government quarry, Westport	Potsdam-Beekmanstown	43	0·49
Hughes, MacCue	Potsdam-Beekmantown	228	
Logan, Georgetown	Medina	321	0·53
MacDonald, Cayuga	Oriskany	100	0·28
Nicholson, Orangeville	Medina	53	0·57
Tillson, Bells Corners, hard Nepean	Potsdam-Beekmantown	217	0·44
Tillson, Bells Corners, white Nepean	Potsdam-Beekmantown	216	0·21
Wilson, Perth	Potsdam-Beekmantown	240	0·32

GRANITES AND GNEISSES.

	Formation	No.	Co-efficient of saturation
Brockville dark granite	Laurentian	324	0·67
Gordon, Gananoque, monumental syenite	"	200	0·73
Kingston granite	"	70	0·7
Hall. Parry Sound	Grenville	319	0·8

CRYSTALLINE LIMESTONES AND MARBLES.

Arnprior marble	Grenville	242	0·76
Ellis, Madoc black marble	"	223	0·58
Jamieson, Renfrew	"	250	0·58
Lanark village, white marble	"	313	0·44
McGinn, Haleys	"	258	0·9
North Lanark Marble Co.	"	154	0·51
Ontario Marble Co., Bancroft	"	325	0·68
Sanford Estate, Barrie white marble	"	191	0·94

TABLE VIII.

Table indicating the "chiselling factor" of the stones tested for this report. This factor was determined by the method described on page 77, and it must be interpreted from the point of view there explained.

LIMESTONES.

	Formation	No.	Chiselling factor
Ashenhurst, Erin	Guelph	40	5·3
Aylesworth, Newburgh	Black River	92	4·95
Brennan, Sand Point	"	246	6·03
Britnell, Burnt River	"	14	0·15
Cook, Wiarton	Niagara	33	4·2
Central Prison, Guelph	Guelph	271	8·5
Coughlin, Smiths Falls	Beekmantown	235	0·05
Dyer, Brockville	"	52	3·0
Gibson, Beamsville	Niagara	119	3·75
Longford quarries, 14 in. bed	Black River	151	6·9 (stone broke)
Longford quarries, 9 in. bed	"	152	4·86 (stone broke)
Macdonald, Point Anne	"	112	6·22
McEwen, Carleton Place	Beekmantown	254	5·4
McPhie, Glen Robertson	Black River	107	1·3
McCormick, Pelee island	Onondaga	115	6·9
Marcotte, Mille Roches	Chazy	136	0·8
Marshall, Hamilton	Niagara	126	6·00

LIMESTONES—*Continued.*

	Formation	No.	Chiselling Factor
Mills, Prescott	Beekmantown	264	3·85
Manson, Mille Roches	Black River	135	3·15
Perkins, Owen Sound	Niagara	130	4·4
Quinlan and Robertson, Crookston	Black River	239	5·6
Queenston Quarry Co., blue beds	Niagara	276	4·6
Queenston Quarry Co., grey beds	"	275	6·4
Robillard, Ottawa	Trenton	208	5·7
Ross, Hawkesbury	Chazy	109	4·6
Thames quarry, St. Marys, 28 in. bed	Onondaga	139	
Thames quarry, St. Marys, 8 in. bed	"	138	5·5
Thebault, Ottawa	Trenton	218	5·1
Wallace, Kingston	Black River	64	5·5
Walker, Thorold	Niagara	88	7·2
Webster, Galt	Guelph	27	6·8
White, Pembroke	Chazy	170	5·2

SANDSTONES.

Beckett's island	Chazy	169	5·6
Gordon, Kingston Mills	Potsdam-Beekmantown	69	4·49
Logan, Georgetown	Medina	321	4·02
MacDonald, Cayuga	Oriskany	100	0·22
Nicholson, Orangeville	Medina	53	3·9
Tillson, Bells Corners, hard Nepean	Potsdam Beekmantown	217	Inappreciable.
Tillson, Bells Corners, white Nepean	" "	216	0·25
Wilson, Perth	" "	240	Inappreciable.
Hughes, MacCue	" "	228	2·37
Westport	" "	43	3·6

CRYSTALLINE LIMESTONES AND MARBLES.

Arnprior marble	Grenville	242	3·2
Ellis, Toronto, Madoc black marble	"	323	2·95
Jamieson, Renfrew	"	250	2·2
Lanark village, white	"	313	4·5
McGinn, Haleys	"	258	2·3
North Lanark Marble Co , serpentine marble	"	154	5·00
Ontario Marble Co., Bancroft, green clouded	"	325	0·2

GRANITES AND GNEISSES.

This test is too delicate to give appreciable results with the granites and gneisses; the only stone sufficiently affected to give a measurable loss was the gneiss from Parry Sound, as below:

Hall, Parry Sound, Grenville gneiss	Grenville	319	0·5

APPENDIX II.

Annual Production of Stone in Ontario, Compiled from Ontario *Bureau of Mines Report.*

1891	$1,000,000	1901	$ 850,000
1892	880,000	1902	1,020,000
1893	721,000	1903	845,000
1894	554,370	1904	700,000
1895	438,000	1905	700,000
1896	394,000	1906	660,000
1897	no statistics	1907	675,000
1898	750,000	1908	530,041
1899	667,532	1909	660,000
1900	650,342	1910	*761,112

* Subject to revision.

APPENDIX III.

Production of Stone in Ontario, 1909.

	Building	Ornamental	Curb & Paving	Rubble	Crushed	Flux		Total Value
	Value	Value	Value	Value	Value	Tons	Value	
	$	$	$	$	$		$	$
Granite	....	2,700	36,500	....	3,500	....	....	42,700
Limestone	69,616	9,207	169	66,885	297,589	427,422	196,208	639,670
Marble	....	....	780	2,661	....	....	....	3,441
Sandstone	29,584	....	17,774	12,903	2,563	....	....	62,824
	99,200	12,687	54,443	82,449	303,652	427,422	196,208	748,639

APPENDIX IV.

Production of Stone in Ontario, 1910.

(Subject to correction)

	Building	Ornamental	Curb & Paving	Rubble	Crushed	Flux		Total Value
	Value	Value	Value	Value	Value	Tons	Value	
	$	$	$	$	$		$	$
Granite	1,100	200	30,320	3,513	9,545	....	....	44,678
Limestone	53,301	9,529	738	100,991	368,911	406,394	189,293	722,763
Marble	4,100	....	....	....	....	....	....	4,100
Sandstone	24,311	....	34,530	1,046	1,370	....	....	61,257
	82,812	9,729	65,588	105,550	379,826	406,394	189,293	832,798

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CANADA

DEPARTMENT OF MINES

MINES BRANCH

HON. ROBERT ROGERS, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

REPORTS AND MAPS OF ECONOMIC INTEREST

PUBLISHED BY THE

MINES BRANCH

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2. Great Landslide at Frank, Alta. Report on—by R. G. McConnell and R. W. Brock, M.A. 1903.
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    Vol. III—
      Appendix I
        Coal Washing Tests and Diagrams, by J. B. Porter.
    Vol. IV—
      Appendix II
        Boiler Tests and Diagrams, by R. J. Durley.
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        Producer Tests and Diagrams, by R J. Durley.
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168. Map showing Pyrites mines and prospects in Eastern Canada—by Dr. A. W. G. Wilson.

171. Geological Map of Sudbury Nickel Region, Ont.—by Prof. A. P. Coleman, Ph.D.

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