Tyndall limestone. Parliament buildings, Regina, Saskatchewan

CANADA
DEPARTMENT OF MINES
MINES BRANCH

HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR

REPORT

ON THE

Building and Ornamental Stones

OF

CANADA

VOL. IV.

PROVINCES OF MANITOBA, SASKATCHEWAN, AND ALBERTA

BY

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

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LETTER OF TRANSMITTAL.

EUGENE HAANEL, PH.D.,

DIRECTOR MINES BRANCH,

DEPARTMENT OF MINES.

CANADA.

SIR,—I have the honour to submit, herewith, the fourth volume of a Report on the Building and Ornamental Stones of Canada. The first three volumes, already published, contain an introductory section dealing with the general technology of stone and quarries, and systematic descriptions of the stones of the eastern provinces. The present volume deals with the Building and Ornamental Stones of Manitoba, Saskatchewan, and Alberta.

In the earlier volumes of this report, the work was extended but slightly beyond actual quarries; in the present instance, the investigations include possible sources of supply which have not been exploited. In consequence of this change of plan the report has reached a length, compared with the earlier volumes, which is somewhat out of proportion to the relative importance of the building stone industry in the three Provinces under consideration.

I have the honour to be, Sir,

Your obedient servant,

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

UNIVERSITY OF TORONTO,

DECEMBER 23, 1915.

AUTHOR'S PREFACE.

The field work in connexion with the present report was carried on during the summers of 1914 and 1915; the work in the former year being confined to the Province of Manitoba, and in the latter year to the Provinces of Saskatchewan and Alberta. About five months, in all, were required for the investigations in the field.

In the eastern provinces, an examination of actual quarries, supplied, in large part, the information necessary for the preparation of the report, as quarries are numerous, and most outcrops of rock, in positions at all accessible, have been prospected for building and ornamental stone. In the west, however, actual quarries are few in number, and prospecting has not been carried on to the same extent as in the east. The demand for stone on the part of a rapidly increasing population and the lack of a local supply at many places render it advisable to extend the present volume beyond a consideration of actual quarries, and to make it include statements as to the value of possible sources of supply. It is apparent that completeness in this respect is not to be expected, for all sources of supply would include the whole of the eastern ranges of the Rocky mountains, the numberless exposures on the northern lakes of Manitoba, and a great number of outcrops in the river valleys and coulées of Alberta. While it is not possible, therefore, to describe all known outcrops of rocks, an attempt has been made to examine type localities of each geological formation, and to present an account of the rocks from the point of view of the building stone industry. In consequence of this plan of investigation, detailed tests have been made of stones which present little possibility from the present point of view. The results of these investigations are included in the report, partly for comparative purposes, and partly in the hope that the information may prove useful to users of stone for other purposes than building. It is thought that all stone quarries, for whatever purpose worked, are included; therefore, the report may be regarded as fairly indicative of the stone industry in general. It is to be remembered, of course, that the point of view has remained the same and consequently all tests have been made with the object of ascertaining the suitability of the stones for building purposes only.

The preliminary chapter contains a brief account of the different kinds of stone which occur in the three provinces and an outline of the procedure in making the various tests; it also contains general averages of results, comparative statements, and references to striking or unique features which have been ascertained in carrying on the work. The only departure from the practice of previous years is the introduction of an improved type of machine for determining the chiselling factor. Many unsatisfactory and anomalous results were obtained with certain of the physical tests, particularly in the case of the Manitoba limestones. Most of these apparent errors are due to the irregularly cavernous nature of the stones which makes many of the physical tests variable and doubtful.

The second chapter is devoted to a short account of the geology of the three provinces, the subject being regarded from the point of view demanded by the nature of this report.

The systematic portion of the report is arranged on the basis indicated below:—

(1) According to the kind of stone: limestone, sandstone, granite, etc.; (2) According to the geological formations; (3) According to certain arbitrary, but more or less distinct, geographical districts which are termed "areas"; and (4) According to owner, or where no owner is known, according to locality.

As far as possible the description of individual properties is given under the name of the owner, which is conspicuously printed in italics. In many cases, however, the outcrops are on Crown lands, or the name of the owner has not been ascertained: in such cases the locality is indicated in the same style of type. As in previous reports, the detailed description of the stone is kept distinct from general observations on quarry conditions, etc. The stone is referred to by number in the general account, and is described in detail later. It is to be understood that the detailed descriptions of the various stones refer to the samples only; they must be considered with due regard to the preceding remarks on formational features.

The arrangement of the descriptive matter under an individual owner or locality is as follows:—

Owner.
Location.
Quarry description.
The stone:—
  General description.
  Physical tests.
  Chemical analysis.
Quarrying methods.
Prices, statistics, and economic remarks.
Buildings constructed of the stone.

At convenient intervals, short summaries have been introduced for the benefit of readers not interested in the detailed descriptions. These summaries are printed with a conspicuous heading, and, together with the introductions to the various sections, give a general account of the subject devoid of detail.

The sawing, grinding, and general preparation of test material was done in the laboratory of the Royal Ontario Museum of Geology, Toronto; the transverse and shearing strength tests were made in the engineering laboratory of the University of Toronto; the crushing strength tests were conducted in the engineering laboratory of McGill University, Montreal;

and the analyses were made in the laboratory of the Mines Branch at Ottawa.

All the work in connexion with the determination of specific gravity, porosity, etc., was carried on by Mr. Alex. MacLean, in the laboratory of the department of geology, University of Toronto.

While engaged in the field I met with uniform kindness and assistance from quarry owners and operators; in this connexion I particularly wish to express my thanks to the officers of the Lake Winnipeg Shipping Company and the Wallace Sandstone Company. I am also indebted to Captain Charles Sparks of Jasper Park, and to Mr. S. Clark, supervisor of the Brazeau Forest Reserve, for material assistance afforded me in reaching certain points difficult of access. In selecting the localities to be visited and in laying out my itinerary I received great assistance from Messrs. Dowling, Keele, and McInnes of the Geological Survey of Canada; from Messrs. Joseph Tyrrell, James McEvoy, and Alex. MacLean of Toronto; from Professor R. C. Wallace of the University of Manitoba, and from Professor J. A. Allan of the University of Alberta. I am also indebted to Professors Wallace and Allan, and to Mr. Dowling and Dr. E. M. Kindle of the Geological Survey, Canada, for information as to the geological horizons of certain strata. To Dr. Frank D. Adams and Professor H. M. Mackay of McGill University I am again indebted for permission to use the large Wicksteed machine for crushing strength tests.

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CHAPTER I.

INTRODUCTORY.

VARIETIES OF BUILDING AND ORNAMENTAL STONES OCCURRING IN THE PROVINCES OF MANITOBA, SASKATCHEWAN, AND ALBERTA. METHODS OF TESTING AND SUMMARIES OF RESULTS.

The actual production of building stone in the three provinces is practically confined to the mottled limestones of Tyndall, Manitoba, and the Paskapoo sandstones of Alberta, although the provinces embrace the great ranges of the eastern Rocky mountains and the stony regions of eastern and northern Manitoba.

The Tyndall limestone is of a characteristic mottled aspect; it is soft and easily worked, and is to be regarded as one of the most desirable building stones produced in Canada.

The Paskapoo sandstones of Alberta are quarried at many points, and yield stone varying in colour from blue to yellow, and in hardness from actual incoherence to a degree of cohesion beyond the limit of practical working. Most of the finer buildings of Calgary, Edmonton, and other Alberta cities, are constructed of this stone.

Limestone strata are exposed at many points on the shores of Lakes Winnipeg, Winnipegosis, and Manitoba; also in the intermediate regions and throughout the more northerly parts of the Province of Manitoba. For the most part, these stones are hard, cavernous, thin bedded, or of poor weathering properties; in consequence, they are not well suited to purposes of construction. Nevertheless, certain possibilities exist and some stone is actually used for building, but it is obtained as an incidental product from quarries operated for other purposes.

The great bulk of the eastern ranges of the Rocky mountains consists of limestone which is usually so hard and so badly shattered that practically no quarrying has been attempted. A little stone has been used along the lines of the Canadian Pacific railway, and it is possible, with a greater local demand, that more favourable sites may be located.

In addition to the Paskapoo sandstones, already referred to, stone of this class occurs on Lake Winnipeg, at the base of Turtle mountain in southern Manitoba, in southern Saskatchewan and Alberta, and in many river valleys of central Alberta. Of these various occurrences, that at Turtle mountain is the only one that has yielded any structural stone. Softness and friability seem to be the main deterrent factors in the other instances. The foothills of the Rockies present certain bands of indurated sandstones which are undoubtedly capable of yielding a hard type of stone suitable for rough purposes. Unfortunately these stones are not possessed of good weathering properties in respect to colour.

Granites occur in considerable masses along the eastern shore of Lake Winnipeg; they might well be exploited for structural purposes. Variability and the lack of any particular beauty would probably prevent the use of these stones for monumental purposes. Gneisses also occur in this district; they have been employed for making crushed stone and incidentally for rubble.

Hard and somewhat schistose conglomerates and many varieties of quartzite occur in the Rocky mountains; some of these have been employed locally to a very limited extent. In this connexion the pink, banded St. Piran quartzites of Lake Louise are worthy of especial mention.

Decorative stone is practically confined to varieties of limestone, of which the fine-grained, dolomitic type from Broadvalley, Manitoba, quarried under the name "manitobite," is the only example that has been worked. Possibilities exist in the case of other Manitoba stones, particularly the Silurian limestone from Fisher Branch and the Hudson Bay railway, and the Upper Devonian limestone of Point Wilkins, Lake Winnipegosis. The hard black limestone of the Lower Banff formation of the mountains is capable of a brilliant polish and presents possibilities as a marble. True crystalline marbles occur in the Vermilion pass and near the line of the Grand Trunk Pacific railway, but their commercial possibilities have not been proved.

A large deposit of bluish anhydrite in northern Manitoba has attracted some attention as a decorative stone, but the application of this substance to decorative purposes on a commercial scale has not been established.

Of the rarer decorative materials, opal and petrified wood occur in the Cretaceous strata of Alberta. These substances have been referred to as of possible value, but I have learned of no attempt to utilize them. In all probability their occurrence is much too scattered for commercial exploitation.

The methods employed in the preparation of material and in the conduct of experiments have been explained in some detail in the introductory chapters of the earlier volumes of this report. No serious modifications were introduced for the present volume, the only change being the adoption of an improved type of chiselling machine.

The following physical constants were determined for each of the stones tested. These factors are recorded in the same order in the descriptions of the stones and are tabulated in the appendix:—

(a) Specific gravity.
(b) Weight per cubic foot, lbs.
(c) Pore space, per cent.
(d) Ratio of absorption, per cent, one hour.
(e) " " " two hours.
(f) " " " slow immersion.
(g) " " " in vacuo.
(h) " " " under pressure.
(i) Coefficient of saturation, one hour.
(j) " " two hours.
(k) " " slow immersion.
(l) " " in vacuo.
(m) Crushing strength, lbs. per sq. in., dry.
(n) " " " wet.
(o) " " " wet after freezing.
(p) Transverse strength, lbs. per sq. in.
(q) Shearing strength, lbs. per sq. in.
(r) Corrosion, loss or gain, grams per sq. in.
(s) Drilling factor, mm.
(t) Chiselling factor, grams.

(a) *The specific gravity* was determined by weighing, suspended by fine silk threads, in water, the cubes of stone which had been thoroughly saturated with water as per experiment "h". The dry weight divided by the loss of weight in water gives the specific gravity, *i.e.*, the weight of the stone compared with the weight of an equal bulk of distilled water.

The average specific gravity of 22 Manitoba limestones is 2·702. The highest result, 2·867, was obtained for the dolomite from the Grand rapids of the Saskatchewan river, and the lowest, 2·696, for the Devonian limestone from Point Wilkins, Lake Winnipegosis. Four samples of limestones from the mountains of Alberta gave an average specific gravity of 2·714.

The almost pure quartz sandstone from Punk island, Lake Winnipeg, has the lowest specific gravity (2·635) of the samples tested. The highest result was obtained for the yellow ferruginous sandstone from Entwistle, Alberta (2·72). The variation in 21 other samples is very slight as the mineral constituents vary but little. The fluctuations in gravity seem to be chiefly in accord with the amount of carbonates present in the cementing matter.

(b) *The weight per cubic foot* was determined as follows:—(1) Multiply the weight of a cubic foot of pure water (62·426 lbs.) by the specific gravity of the stone: this gives the weight of a cubic foot of solid stone.

(2) Knowing the pore space per cent, calculate this percentage of the weight of the solid cubic foot as determined above: this gives the weight of the stone that would fill the pore space.

(3) Subtract the weight of the stone that would fill the pore space from the weight of the solid cubic foot: this gives the weight of the actual cubic foot.

It is apparent that the weight per cubic foot depends on the specific gravity and the pore space. The figures herein given were obtained from perfectly dry stone and are somewhat lower in every instance than would be obtained from stone under normal conditions of weather.

Of the Manitoba limestones, the lowest weight per cubic foot is that of the buff stone from Tyndall (151·54 lbs.). The greatest weight is shown by the close grained Silurian dolomite from the Hudson Bay railway north of The Pas (177·143 lbs.). As this is a complex factor depending on gravity and pore space, a general average can have no particular significance.

The sandstones vary remarkably showing all gradations between the two extremes—115·47 lbs. for the grey stone from Entwistle, Alta., and 163·24 lbs. for the Dakota sandstone from Coleman on the Crowsnest line of the Canadian Pacific railway.

(c) *The pore space* is expressed as volume per cent of the stone: it was determined in the following way:—

(1) A cube of stone, about one inch square in the case of limestones, and 1½ inch square in the case of sandstones, was thoroughly saturated with water by slow soaking, removing the air by suction, and filling the pores under a water-pressure of 2,000 lbs. to the square inch continued for 24 hours.

(2) The cube was weighed while saturated.

(3) The cube was dried for 24 hours at 110°C. and weighed.

(4) The latter weight subtracted from the former gave the weight of the water occupying the pore spaces.

(5) This weight multiplied by the specific gravity of the stone gave the weight of the stone that would be required to fill the pore space.

(6) This weight added to the weight of the dry cube gave the weight of the cube if it were solid.

(7) "(5)" expressed as a percentage of "(6)" gave the volume per cent of pore space.

The most porous of the Manitoba limestones is the upper bed at Inwood (12·72%) but it is closely approached by the buff Tyndall stone and the upper beds at Stonewall. The most compact stones are the Silurian limestone from the Hudson Bay railway (6·503%) and the Devonian limestone from Steep Rock (6·595%).

The Rocky Mountain limestones are all of very low porosity, with a minimum of 0·292% for the Permo-Triassic stone at Banff and a maximum of 1·88% for the stone of similar age from near Nordegg.

The sandstones vary greatly in pore space, ranging from 3·22% in the Dakota sandstone from McLeod river to 31·81% in the yellow stone from Entwistle, Alta.

The gneiss from Lake Winnipeg has a porosity of 0·193% and the granite from Rabbit point is rather porous for a stone of its class (0·606%). The schistose and highly altered conglomerate or sandstone from the Cambrian formations of the mountains shows a porosity of 0·483%.

(c) *The ratio of absorption* is the weight of the water absorbed expressed as a per cent of the weight of the dry stone. For reasons explained in the earlier volumes of this report, it is advisable to obtain the ratio of absorption under different conditions of soaking.

In order to make the tests, two sets of cubes were prepared; in the case of limestones and hard compact sandstones, granites, etc., the cubes were approximately one inch square; in the case of the softer sandstones the cubes were made about 1·5 in. in diameter. After drying for 24 hours at 110°C. the cubes of one set were weighed, plunged under water for one hour and again weighed. From the figures obtained the *ratio of absorption for one hour* was calculated. The cubes were again dried and weighed, plunged under water for two hours, weighed, and the *ratio of absorption for two hours* calculated from the results. The other set of cubes, after being dried and weighed as above, was placed in a flat vessel into which water was admitted at such a rate that the cubes were covered after four hours. They were then allows to stand under water for 24 hours and weighed. The results gave the *ratio of absorption for slow immersion.* These cubes were then dried, weighed, and placed in a container from which the air was gradually exhausted by a water pump. A small amount of water was then admitted to the container which was surrounded by warm water in an outer vessel. Under the reduced pressure the water in the container boiled vigorously. By keeping up this ebullition and maintaining the pump in operation for 24 hours, it was thought that the air had practically been exhausted from the container. Water was then slowly admitted until the cubes were covered. The weight of the cubes, thus soaked, gave the figures from which the *ratio of absorption in vacuo* was calculated.

The cubes, without drying and weighing, were placed in a steel cylinder and submitted for 24 hours to a water pressure of 1,500 to 2,000 lbs. to the square inch. They were then weighed and the *ratio of absorption under pressure* calculated from the results. This ratio is the *true ratio of absorption* as it is derived from the total filling of the pores of the stone; from it the pore space is calculated. Finally the cubes were again dried and weighed and the total ratio of absorption calculated from the loss of water; this served as a check on the previous determination. Usually slight differences were observed, and in such cases it was thought preferable to use the results obtained from the final weighing.

The above procedure is in accord with that adopted for previous reports. The friable nature of the Paskapoo sandstones of Alberta necessitated a modification to prevent loss by abrasion. In the case of the one-hour, the two-hour and the slow immersion experiments, the cubes were placed in watch glasses and the weight of any fragments was added to the weight of the cube. In the case of the vacuum and pressure experiments the cubes were placed in squares of a light but closely woven fabric (mull). The corners of the squares were picked up and tied together above the cubes. In the case of the vacuum experiment, the little bags were suspended by threads in the container to prevent any attrition due to the ebullition of the water. In each instance, the particles resulting from abrasion were weighed and the result added to the weight of the wet cube.

In making the large number of weighings necessary for these reports, it was found that the greatest care must be exercised in standardizing conditions, not only in the case of wet cubes but also with the dry samples. Weighing a wet object is necessarily a matter of difficulty owing to evaporation, and with stones of low porosity an appreciable error is to be expected. This error may be reduced, at least for comparative purposes, by uniformity of operation in each instance.

The following suggestions are offered as the result of our experience in weighing a great number of wet stones:—

(1) The weighings must be made thoroughout by the same individual. Weighings made by Mr. MacLean are uniformly higher than mine.

(2) The same balance must be used throughout. The results of a "fast" balance are not comparable with those obtained with a slower instrument.

(3) The cubes, when taken from the water, should be rapidly touched on each face with blotting paper but not allowed to rest on the paper.

(4) The approximate weight should be known before, and this weight should be on one scale pan before the wet cube is placed on the other. Considerable time and consequent evaporation is thus saved.

(5) The weight should be recorded the first time the indicator swings equally across the central mark.

(6) The weighings should be made under the same atmospheric conditions. This is practically impossible, but by making the weighings all at one time the error is reduced. We have found that weighings made in the afternoon differ considerably from results obtained in the evening.

(7) It has been advised to wait until the surface of the cube is dry: we have obtained the most unfortunate results in attempting to apply this method.

The weighing of dry cubes requires scarcely less care than in the case of wet ones. The work must be done quickly and uniformly to obtain reliable results. In some stones the absorption of water from the atmosphere is so marked that the weight rapidly increases. The cubes must be dried and weighed between each soaking, as, in some cases, there is a real change in weight due to solution and possible chemical alterations. Limestones dissolve perceptibly under the pressure soaking.

Other factors being equal, the less water a stone absorbs relative to its total capacity, the greater its power of resistance to disintegrating forces. The present determinations are therefore of great importance, as from them is calculated the *coefficient of saturation* described later. Much variation is to be observed in different stones as to the rate of increase under the different conditions. The Manitoba limestones and dolomites vary much within themselves. The averages of 22 stones are as follows:—

Ratio of absorption		Increase
One hour	0·809	
Two hours	1·184	0·375
Slow immersion	1·619	0·435
In vacuo	2·127	0·508
Under pressure	2·214	0·097

We may conclude, therefore, that in the case of the Manitoba limestones there is a perceptible increase between the one and two hour soakings, and between the two hour soaking and the slow immersion. More significant is the fact that the greatest increase occurs between the slow immersion and the vacuum experiments. As slow immersion simulates the worst possible natural conditions, it is important to note that a considerable proportion of the total pore space is not filled with water. The fact that a very small increment is due to the pressure experiment indicates that sealed pores are infrequent in stones of this class.

The sandstones vary greatly in their power of absorption. The true ratio of absorption is proportional to the pore space with a slight modification for the differences in gravity. Extreme examples have already been mentioned under "Pore space."

The averages of 23 sandstones are tabulated below:—

Ratio of absorption		Increase
One hour	4·46	
Two hours	4·64	0·18
Slow immersion	5·83	1·19
In vacuo	7·12	1·29
Under pressure	7·83	0·71

It will be observed that the increment for the second hour's soaking is slight and that a much greater increase occurs under the slow soaking. The greatest increase occurs between the slow immersion and vacuum soakings and there is only a slight addition under the pressure soaking. The significance of these figures is referred to under "Coefficient of Saturation" below.

(i) *The coefficient of saturation* is calculated from the ratios of absorption: it expresses in the form of a decimal fraction the extent to which the total pore space is filled with water under the different conditions. In other words, it is the ratio of absorption for the condition considered divided by the ratio of absorption under pressure. The importance and significance of these figures have been fully explained in previous volumes and will not be reconsidered here (See Vol. I, page 64, Vol. II, pages 4 and 21, Vol. III, page 9 *et seq.*). The coefficient of saturation for slow immersion is considered as the coefficient of saturation proper. When the expression is used without modification it will be understood that this factor is meant.

The 22 Manitoba limestones tested show that the danger line of 0·8 is never exceeded by the one and two hour experiments and that the slow immersion experiment seldom gives results beyond this limit.

In the case of the one and two hour experiments, the only sandstone which exceeds the danger line is the Boissevain sandstone from Turtle mountain. All the really commercial Paskapoo sandstones are below 0·8, but the hard buff variety from Calgary and the fine-grained stone from Mrs. Arnold's property at Monarch exceed this limit; the same is true of the blue and buff stones from the Pembina quarries. The four Dakota sandstones all exceed 0·9 and must therefore be regarded as in great danger of injury by frost. The granites seem to be particularly immune, but the conglomerate schist from the mountains shows a coefficient of saturation of 0·9.

(m) *The dry crushing strength* determinations were made on cubes at the temperature of the laboratory. The cubes were prepared with the greatest care to insure plane and parallel bearing faces. Flat bearing faces being more important than exact parallelism, this desideratum received first attention in preparing the cubes. The swivel head on the Wicksteed machine at McGill University which was used in making the tests permitted an adjustment for any slight lack of parallelism. The cubes were crushed between case hardened, polished steel plates from which they were protected by sheets of blotting paper. In the case of the harder stones, cubes approximately two inches square were used, but in the case of the softer sandstones, it was thought advisable to use cubes of 2·25 to 2·5 inches in diameter in order to minimize any error that might arise through the abrasion of edges and points.

Duplicate tests of sandstones did not vary more than 500 lbs. per sq. in., but in the case of many of the limestones the variation was very much greater. While this lack of definiteness is much to be regretted, it is the natural outcome of the character of the stones tested. The reason lies in the lack of homogeneity in most of the limestones which makes it impossible to prepare cubes which are strictly comparable. This variation in structure may be expressed in the following manner:—

(1) Practically all the limestones of Manitoba, from the Ordovician formations to the top of the Devonian, have a mottled structure which appears to be due to different degrees of dolomitization in different parts of the stone; it is obviously impossible to prepare strictly similar cubes of such

material. In order to test this factor of variation, three cubes of the buff limestone from Tyndall were prepared with the greatest care: the results were 10,100, 10,806 and 9,195 lbs. per sq. in. respectively. Two cubes of the blue limestone from the same locality gave 9,289 and 10,724 lbs. respectively.

(2) Many of the Manitoba limestones are of a cavernous nature with such large vacuities that cubes at all comparable are impossible of preparation.

(3) Many of the limestones are of extraordinary strength. It has already been demonstrated, even in the case of homogeneous stones, that closely comparable results are not to be obtained at pressures above 30,000 lbs. per sq. in.

(4) The Rocky Mountain limestones have been subjected to great pressures in the course of mountain making processes: this has resulted in many incipient flaws, and although the stone is largely recemented, a lack of uniformity of structure remains.

The figures recorded in this report are the direct results of experiment, in most cases on a single cube only. Readers, therefore, will understand that some latitude must be allowed and that the figures given must be considered with due regard to the nature of the stone, *e.g.*, if a stone is described as mottled or cavernous or if its strength exceeds 30,000 lbs. per sq. in., considerable variation from the figures given might be obtained from further tests.

Twenty-five limestones gave an average crushing strength of 29,419 lbs. per sq. in. as compared with 22,000 lbs. for Quebec limestones. The lowest crushing strength (10,006 lbs.) was found in the excellent building stone from Tyndall, Manitoba, while the Silurian limestone from the Grand rapids of the Saskatchewan exceeded the limit of the machine (52,708 lbs.) without any sign of crack or flaw. Extraordinary strength was shown by many other stones, *e.g.*, the argillaceous limestone from near Nordegg, Alberta, which also exceeded the capacity of the machine (52,400 lbs.), the limestone from the Spray river near Banff, Alberta, (50,000 lbs.), and the Winnipegosan limestone from Whiteaves point, Lake Winnipegosis (47,883 lbs.).

The average crushing strength of 17 Paskapoo sandstones (including one Edmonton) was found to be 7,320 lbs. per sq. in. with a maximum of 14,089 lbs. and a minimum of 1,793 lbs. The average of four Dakota sandstones was 19,982 lbs. per sq. in. The Trenton sandstone from Punk island, Lake Winnipeg, gave 6,439 lbs., and the sandstone from Turtle mountain, Manitoba, 19,703 lbs. per sq. in.

Granite from Rabbit point, Lake Winnipeg, showed a strength of 29,526 lbs., and the gneiss from the quarries of the Lake Winnipeg Shipping Company on Lake Winnipeg registered 46,516 lbs. per sq. in.

The Cambrian conglomerate schist from the Rocky mountains along the line of the Grand Trunk Pacific railway crushed at 19,615 lbs. per sq. in.

(n) *The crushing strength of wet samples* was determined on cubes prepared in the same way as for the dry tests. In the case of the Manitoba stones the cubes were soaked under pressure, but as the Alberta stones consisted largely of friable sandstones they were soaked by very slow immersion in order to avoid the considerable amount of handling involved in the preparation under pressure. As it is very unlikely that close comparisons will be required between Manitoba limestone and Alberta sandstones, this slight difference in procedure is unessential.

The softening effect of soaking in water is now regarded as one of the best measures of the general durability of a stone, but in the case of the non-homogeneous, cavernous, or extremely strong limestones the results are of little real value as the inevitable instrumental error together with the error due to variable structure probably exceed the effect of soaking. On the other hand, the more homogeneous sandstones, crushing at a lower pressure, give results worthy of greater confidence. In tabulating the results in Table IV, page 294, I have recorded the exact figure obtained in the second column, but in the fourth column I have recorded the difference due to soaking only when it is reasonably in accord with expectation and when there is no reason to suspect an excessive error due to the variable nature of the stone.

Of the 25 limestones tested only 14 give results worth recording: these show an average loss in strength of 3,644 lbs. per sq. in. Of the remaining 14 examples, 5 show a higher figure for the wet than for the dry test, but in each instance the difference is slight and quite within a reasonable latitude of error considering the nature of the stone. We may reasonably conclude in these cases that the stone is not appreciably affected by soaking. Adding these 5 to the 14 recorded cases, we have 19 out of 25 examples giving results of at least approximate value. In the remaining six cases the results are so much lower than one would expect from the character of the stone that they are not recorded: in five of these cases the crushing strength is the result of imperfect failure due to the cavernous or non-homogeneous nature of the stone: the fifth case is evidently due to instrumental error consequent upon unusually high pressure.

The 17 Paskapoo or Edmonton sandstones give uniformly consistent results showing an average loss in strength of 2,457 lbs. per sq. in. or almost exactly one-third of their average dry crushing strength. The 4 Dakota sandstones show an average loss of 4,068 lbs. which is nearly one-half of their dry crushing strength. The Trenton sandstone from Lake Winnipeg shows a slightly higher result for the wet cube: ascribing this slight increase to instrumental error we may conclude that the stone is not softened by soaking (See page 154).

The granite from Rabbit point, Lake Winnipeg, appears to be seriously affected by soaking while the gneiss from the quarries of the Lake Winnipeg Shipping Company is much less reduced in strength. The conglomerate schist from the Yellowhead pass seems to act much like a sandstone, losing about one-third of its strength.

(o) *The crushing strength of frozen samples* was determined on cubes prepared as above: these cubes were alternately frozen and thawed 40 times and crushed wet. The Manitoba stones were frozen by natural frost during the winter of 1914–1915; the Alberta stones were frozen by artificial means.

The value and object of the freezing test have been rather fully considered in the earlier volumes of this report, particularly in the third volume dealing with the stones of the Province of Quebec (page 12 *et seq.*). The reader interested in this aspect of the subject is particularly requested to familiarize himself with the principles there considered before attempting to draw conclusions from the figures given in this volume. The effect of freezing is calculated by subtracting the figure obtained for the wet frozen cube from that obtained for the wet cube. It has been found that the comparison can not be made dry, for certain stones undergo a process of recementation on wetting and drying which makes the comparison of very doubtful value. The figures given in Column 3 of Table IV are the exact results of experiment. The differences (Column 5) are recorded only when they are somewhat in accord with what might be expected.

In the case of the limestones the statements as to variability made under "dry crushing strength" and "wet crushing strength" apply with greater force to the present tests. In fact it may be freely admitted that the non-homogeneous character of most of these stones makes the results of no value, as the injury brought about by 40 freezings is not a measurable quantity considering the sources of error already enumerated. Having made these experiments at the expense of considerable trouble, the figures are given for what they are worth. It is not to be understood that the results are *wrong* in themselves; for I believe them to be substantially correct in view of the care taken in preparing the cubes and in conducting the tests, but we are forced to the conclusion that the test is inapplicable to non-homogeneous stones and to stones of low porosity and high crushing strength. I am convinced that only by taking the average of a large number of experiments could satisfactory figures be obtained for this type of stone.

Of 24 limestones tested, 12 show a decrease of strength on freezing while 12 show an increment. Not admitting that an increase of strength is possible, it is apparent that the experiment is a failure. The figures, however, are not quite as bad as appears at first sight, for, in the case of the increases, the amount is relatively small while in the case of the decreases it is greater. The only practical conclusion, and a rather hazardous one, is that an increase or decrease of 1,000 lbs. in the case of stone crushing under 10,000 lbs. per sq. in. indicates that the material is not appreciably affected by the experiment. In the case of stones crushing at a pressure of over 10,000 lbs. per sq. in. a latitude of 2,000 lbs. should be allowed.

The sandstones give much more satisfactory figures as the result of the freezing test. All the Paskapoo sandstones of Alberta show decreases, but one of the Dakota sandstones and the stone from Turtle mountain, Manitoba, show increases. This latter case is remarkable in view of the fact that the coefficient of saturation is ·93. The average loss in strength of the 17 Paskapoo stones is 1,580 lbs. per sq. in. which is only a little more than half the loss due to soaking.

The granite from Rabbit point, Lake Winnipeg, loses only 320 lbs. while the gneiss from the same vicinity loses 6,723 lbs. These results are the converse of those obtained from the wet cubes.

(p) *The transverse strength* was determined on strips approximately one inch thick and 2 inches wide. The bearing edges of the testing machine were placed 5 inches apart.

Manitoba limestones vary greatly in transverse strength, with more pronounced extremes than in the case of crushing strength. The low result of about 800 lbs. per sq. in. was obtained for the yellow rubble from Gunton and the Winnipegosan limestone from Whiteaves point, Lake Winnipegosis. The other Manitoba limestones show a varying strength up to the remarkable maximum of 5,304 lbs. for the close grained Silurian dolomite from the Grand rapids of the Saskatchewan river. Even this figure is exceeded by the argillaceous Permo-Triassic limestones from Banff and Nordegg which show 6,657 and 6,302 lbs. respectively. The variation in the transverse strength of the limestones is so great that no particular significance is attached to an average.

The four hard Dakota sandstones tested give an average transverse strength of 2,149 lbs. per sq. in. The range is from 1,510 to 3,081 lbs. and there is no accord with the crushing strength.

The Winnipeg sandstone from Punk island shows 575 lbs. and the highly calcareous sandstone from Turtle mountain, Manitoba, has a transverse strength of 1,151 lbs.

The Paskapoo sandstones, omitting the hard types and the soft stones from Entwistle which can not be regarded as commercial stones, range from 308 to 663 lbs. per sq. in., with an average of 496 lbs. per sq. in. The transverse strength is not always in accord with the crushing strength but the agreement is much closer than in the case of the limestones.

The Rabbit point granite is not high (1,700 lbs.) but the gneiss shows a strength of 5,419 lbs. per sq. in.

(q) *The shearing strength* was determined from the broken ends of the same strips which served for the transverse strength. Theoretically there should be a close agreement between the transverse and shearing strengths: while such an agreement is apparent in our results there are many departures from the rule.

While the average transverse strength of 21 Manitoba limestones is 2,276 lbs. per sq. in., the average of the shearing strength is 1,523 lbs. These figures express very well the usual relationship of the two factors in these stones, for in a few cases only was the shearing strength found to be in excess of the transverse strength. The anomaly in these instances is probably due to a lack of homogeneous structure, for the conditions of the transverse strength determination present a greater opportunity for breaking on flaws and on the lines of union of different component parts in mottled stones.

The Punk Island sandstone is about equal in the two factors, but the transverse strength of the Boissevain stone is much higher than the shearing strength—1,151 and 866 lbs. respectively.

The Dakota sandstones average a little lower in shearing than in transverse strength.

The Paskapoo sandstones, omitting certain stones which can not be regarded as of commercial importance, average 472 lbs. per sq. in. as compared with an average of 496 lbs. in transverse strength. It is apparent, in the case of these stones, that the theoretical relation between the two factors is better maintained than in the limestones.

(r) *The corrosion test* was made by suspending cubes of stone in a vessel containing water into which carbonic acid gas and oxygen were allowed to pass. The operation was continued for four weeks and the water was changed twice weekly. The cubes were dried, weighed and their superficial extent determined before being placed in the container. On the completion of the operation they were removed, brushed lightly, dried and weighed. The loss or gain in weight was then calculated to square inch of surface exposed. These results are recorded in Table VIII of the Appendix together with the colour changes observed. Mr. MacLean who has conducted these operations observed that the rate of solution of limestone is materially affected by the pressure maintained in the containing bottle. In order to standardize this pressure he has devised the apparatus represented in Plate II. The container consists of a large glass bottle in which the cubes are suspended by threads. The free ends of these threads are brought to the outside of the bottle and are fastened to strips of celluloid on which the numbers of the cubes are marked. This precaution is necessary because the solution is sufficient, in some cases, to remove a number inscribed on the cube of stone itself. The container is sealed with a cork in which are three holes. Through one of these holes carbonic acid is conducted by a tube to the bottom of the bottle, the gas being generated in the Kipp apparatus to the right of the figure and cleaned by passing through a wash bottle. Oxygen is obtained from the tank on the left of the figure; after being washed, it is conducted to the bottom of the bottle through the second hole in the cork. The gases escape through a tube in the third hole and are conducted into a wash bottle in which a head of three inches of water is maintained. The whole circuit is thus kept under a constant pressure and uniformity of solution is secured.

This test is of value for two purposes—to determine the actual loss per square inch of surface exposed, and to give an indication of the colour changes that would be caused by exposure to the weather.

The actual loss of the limestones is roughly in inverse ratio to their content of magnesium carbonate. The actual figures are, of course, small but if regarded in a comparative way they are very significant. The Upper Devonian limestones from Point Wilkins, Lake Winnipegosis, are the most seriously corroded and the fine-grained dolomites of the Silurian are the least affected. The Upper and Lower Banff limestones of the mountains are moderately attacked but the hard argillaceous stones are much less corroded.

The corrosion of a sandstone is indicated, not only by the solution of the cementing matter, but by the loss of grains thus set free. The soft stones from Entwistle suffer considerably but the better grades of commercial Paskapoo sandstones are not seriously affected. The yellow stone of the Calgary area shows the greatest average loss but it is not greatly in excess of the greyish type from Cochrane. The Macleod-Brocket stones are more resistant and the Monarch stones show the least loss.

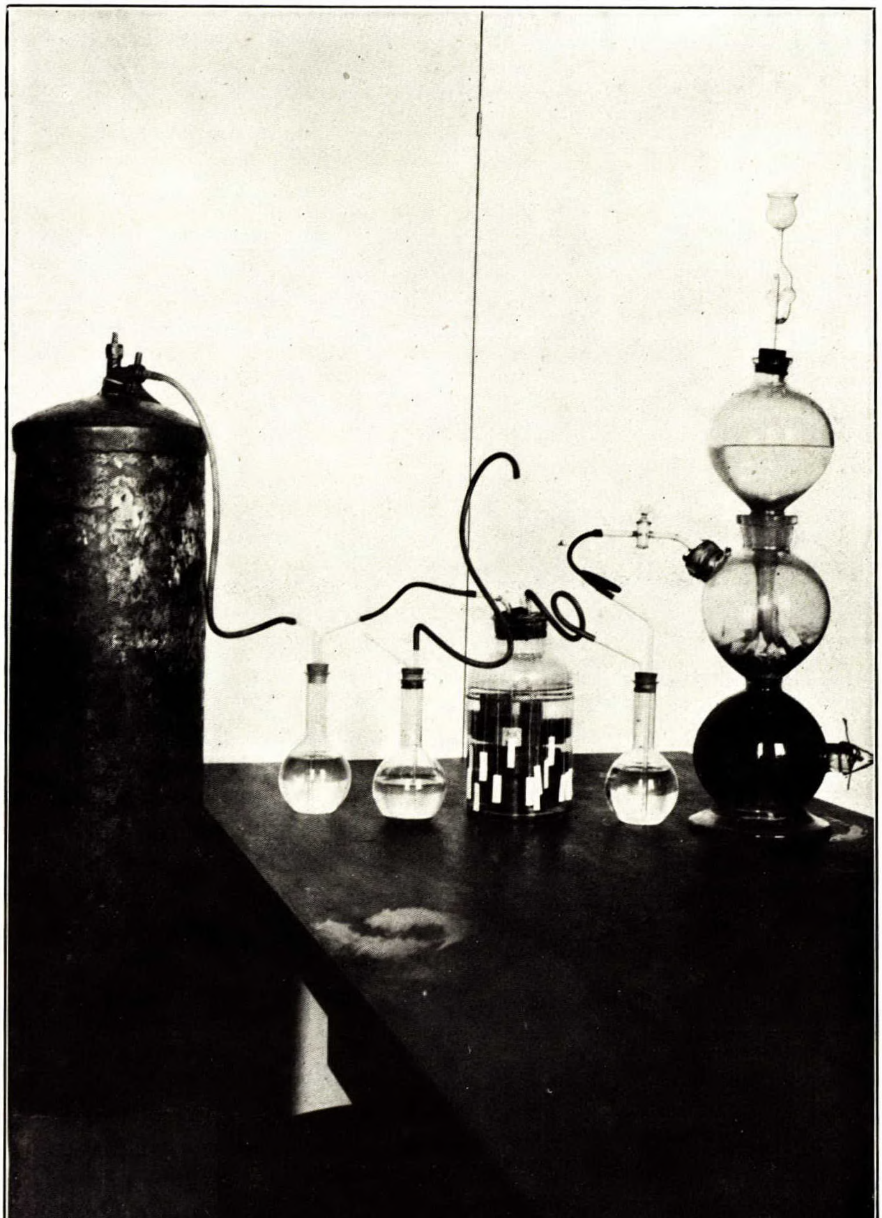
The colour changes are very expressive of the probable behaviour of the stone when exposed in the walls of a building. While the experiment simulates in an intensified form the chemical action of the atmosphere, it fails to exactly reproduce external conditions in that the "dirt" of the atmosphere is not represented. The imbibition of particles of foreign matter, dust, smoke, etc., is a factor of considerable importance in determining the changes in colour that a stone may suffer on exposure to the air.

The Manitoba limestones show different types of pitting and etching, but in many cases the colour changes are not marked. The limestones from the mountains are more affected, and change greatly in colour and in the character of the surface.

The average commercial Paskapoo sandstone is only slightly changed in colour, if we except the blue varieties; these are rapidly altered with a loss of the blue tint and an approach to the typical yellow or buff colour. The Dakota sandstones are changed slightly but the Boissevain sandstone from Turtle mountain shows a marked alteration. It was observed that a less pronounced change, but quite similar to that produced by the test, resulted from the treatment of wetting and drying to which the stone was submitted in making the porosity tests.

(s) *The drilling factor* was determined by ascertaining the depth to which a half-inch + bitted drill sank into the stone in 30 seconds when pressed down by a weight of 8 lbs. and actuated by a size "A" Barre pneumatic tool under an air pressure of 60 lbs. to the square inch. The drills were sharpened and tempered as nearly alike as possible and while in operation the hole was kept clear of debris by a stream of air.

The depth of the hole in mm. is recorded directly as the drilling factor. The ease with which a stone can be worked depends on more than one



Apparatus for corrosion tests.

physical characteristic. Readers are warned that the drilling factor can not be taken as a direct measure of the relative ease with which the stones can be worked: it in only an expression indicative of the behaviour of the different stones under the conditions outlined above. It is to be borne in mind also that a different type of drill, differently weighted, would give a different series of comparative results.

The drilling factors given in this volume are not comparable with those of the earlier volumes, as it was found necessary to use a less pressure on the drill on account of the softness of the Paskapoo sandstones.

(t) *The chiselling factor* is a second expression which will aid in determining the ease with which the different stones can be worked. Like the drilling factor, it can not be considered a direct measure of this property, as the maximum amount of material that may be chiselled from the surface of a block of stone with a given expenditure of energy is a function, not only of the character of the stone, but of the type of instrument employed. If this were not the case there would be no necessity for different types of tools for workers in granite, limestone, and sandstone. The chiselling factor, therefore, is to be regarded only as the result of experiment under fixed conditions. Taken alone or considered together with the drilling factor it will convey a distinct meaning to the stonecutter. A satisfactory expression that may be taken as a direct measure of the ease of working and which may be applied by persons not familiar with stonecutting has yet to be devised.

The instrument originally designed for the determination of the chiselling factor was described and figured in the first volume of this report. It consisted essentially of a device whereby a pneumatic tool actuated a chisel against a test slab of stone. The stone was moved against the chisel at the rate of 3 inches per 10 seconds. The loss of weight in grams was recorded directly as the chiselling factor. Two serious difficulties were met in the use of this apparatus—the first due to the construction of the machine, and the second due to the fact that the same procedure is not applicable to all kinds of stone.

The mechanical difficulty lay in the impossibility of moving the test slab with a smooth and uniform motion by hand power by means of rack and pinion. To assure a smooth and positive motion a new machine has been constructed in which the carriage is shifted by a motor. The new instrument was made in the shops of the Mines Branch and is briefly described below.

The base consists of two uprights about 2 ft. 6 in. long, 7 inches high and 5 inches apart, with a flat extension at one end to serve as a bed for the motor and with cross connexions where necessary; all this is in one casting. The upper edges of the uprights are machined and serve for the support of a travelling carriage which glides smoothly the length of the base. This carriage is provided above with a recess into which the test slab of stone may be bolted. Below, it is fitted with a nut through which a long, finethreaded screw passes. The screw is actuated by a $\frac{1}{8}$ h.p. motor through a reducing gear which is provided with a reversing apparatus. The gearing is so arranged that the carriage may be shifted backwards or forwards at the rate of 3 inches in 10 seconds.

Two A-shaped castings are bolted to the sides of the uprights and extend to a height of 18 inches. The inner sides of the forward limb of these pieces are machined and serve as guides for a carriage which moves freely up and down between them. This carriage is in three pieces with the central part capable of eccentric motion on the outer parts. To the face of this central part the pneumatic tool is clamped and from its lower edge extends a support for the chisel. This support or guide consists of a steel ring provided with set screws to hold a split sleeve through which the chisel passes. The hole in the sleeve is square and the shanks of the chisels are tooled to fit it. This guide was found to be absolutely necessary, for without it there is a tendency for the chisel to twist and also to bind in the nose of the pneumatic tool.

In operating the instrument, the test slab of stone, after having been weighed, is bolted into the recess in the travelling carriage and carefully levelled so that the cutting edge of the chisel bears evenly. The motor is started and the air turned into the tool. The reversing clutch is then thrown in and the chisel is brought in contact with the stone at the same instant. After 10 seconds the chisel is lifted and the clutch thrown out. The slab of stone is then removed and weighed. The loss of weight in grams is recorded directly as the "chiselling factor."

The first attempts to operate the instrument gave results so unsatisfactory that they had to be discarded. The cause of the trouble lay in the friction of the travelling block in its guides which made the pressure on the chisel very uncertain. As no amount of lubrication served to remove the difficulty, the expedient was adopted of loosening the pneumatic tool in the sleeves which attach it to the travelling block and thus permitting it to have a free and independent motion. The tool was then weighted to the desired pressure by means of pulleys. The results under these conditions were entirely satisfactory.

The second difficulty with the original instrument was due to the fact that the same angle of inclination, the same air pressure, and the same type of chisel under uniform pressure are not desirable in testing stones of greatly different hardness. Nevertheless, if we are to have results which may be compared with one another it is necessary to maintain fixed conditions throughout. In the three first volumes of this report the conditions were kept constant, but not always with the most satisfactory results. The best means of avoiding this inherent difficulty seems to be a division of stones into classes, each of which may be tested under conditions most suitable for its physical characteristics. The results in any one class would then be comparable among themselves, but the results in different classes could not be compared. Practically, this plan has many advantages, for it is unlikely that any worker in stone would desire to know the relative ease of chiselling of a soft sandstone and a granite. On the other hand, he would be far more concerned with a reliable statement as to the relative hardness of competitive sandstones. I have been forced to adopt two sets of conditions for this report as it was found quite impossible to test the soft Paskapoo sandstones under the same fixed conditions that gave satisfactory results with the limestones.

The use of a different type of machine would make a comparison of results with those recorded in the earlier volumes very hazardous in any event; in consequence, I have adopted two sets of conditions, and propose to add a third for the granites and other rocks of a very hard nature.

The fixed conditions for limestones, etc., are given in column I and for sandstones of a soft nature in column II:—

	I	II
Type of chisel	Thin smooth edged chisel, 0·75 inch wide.	The same.
Angle of inclination	54° 30′	51°
Pressure	8 lbs.	$3\frac{1}{2}$ lbs.
Air pressure on pneumatic tool	60 lbs. per sq. in.	40 lbs. per sq. in.
Rate of motion	3 inches per 10 seconds	The same.

I am convinced that the figures obtained by using these different sets of conditions are more satisfactory than could be obtained by any attempt at uniformity. The results obtained by the first method are given throughout the volume without comment: the results under the second set of conditions are followed by II. Care must be taken not to attempt comparisons between the two sets or to compare any of the results herein given with the figures recorded in the earlier volumes of these reports.

The chemical analyses included in this report have been derived from different sources: some are quoted from published works and some have been communicated by private individuals; the greater number, however, were made in the laboratory of the Mines Branch at Ottawa.

In the case of limestones, the analyses are particularly valuable as indicating:—

(1) The ratio between the carbonates of lime and magnesia, *i.e.*, the degree of dolomitization of the stone.

(2) The character and amount of impurities.

(3) The amount of ferrous oxide. Other factors being equal, the amount of ferrous oxide is a fair indication of the colour permanence of the stone.

(4) The insoluble residue or sandy material.

In the case of sandstones, the character of the constituent grains is not well shown by analysis and may be better determined by a microscopic examination. The first point of importance in a sandstone analysis is to determine the total amount of cement. It is difficult or even impossible to make this determination with great accuracy as any reagent of sufficient strength to dissolve the cementing matter will attack the more easily soluble mineral grains. In reporting the analyses of the sandstones the chief chemist states:—

"In making the examinations detailed below, the following procedure was adopted:—

"The finely ground material was treated with dilute hydrochloric acid, and afterwards evaporated to dryness. 'Insoluble residue' therefore includes sand, and the silica of any silicates decomposable by hydrochloric acid. 'Soluble portion' is the difference between 100 per cent and the per cent of insoluble residue as above defined. It does not strictly represent the whole of the soluble matter of the stone in that the silica so dissolved has been rendered insoluble by evaporation and has been included in the 'insoluble residue' as above stated.

"You will notice that the partial analysis of the 'soluble portion' does not sum up to the total of such portion. The difference is made up of the undetermined constituents common to most rocks—the principal of which are, water (hygroscopic and combined), alumina, alkalies, titanic acid, etc."

From observation of the physical behaviour of the Paskapoo sandstone I am convinced that hydrated or colloidal silica plays a considerable role in the cementing matter. By the method of analysis adopted this silica is added to the insoluble residue. The error may be offset in part by the amount of soluble material derived from the mineral grains. Time has not sufficed for the complete working out of the problem presented but it is hoped that a special contribution on the subject will shortly appear.

Assuming that the soluble portion represents the cementing material, the object of an analysis is to determine the natureof this cement; the chief determinations to this end are:—

(1) The amount of carbonates of lime and magnesia.

(2) The amount of clayey matter which may roughly be regarded as the difference between the total of the carbonic acid, lime, magnesia, and iron oxides and the total soluble matter. This can not be expressed in percentages as it is much too uncertain—it includes water and the alkalies but lacks the silica.

Carbonates of lime and magnesia and ferric oxide are good cements; ferrous oxide and clay are bad. It must be remembered that no general deductions as to durability can be drawn from the total amount of cement. Conclusions of this kind can be arrived at only by a due regard to the nature of the cement and the factors of porosity. As the Paskapoo sandstones of Alberta are the only sandstones of economic importance in the three provinces, a critical review of the analyses is given on page 192 in the introduction to the section dealing with those stones.

CHAPTER II.

AN OUTLINE OF THE GEOLOGY OF THE PROVINCES OF MANITOBA, SASKATCHEWAN, AND ALBERTA FROM THE POINT OF VIEW OF THE BUILDING STONE INDUSTRY.

The great plains constitute the most conspicuous physical feature of the three provinces: they are typically developed over most of Manitoba, all of Saskatchewan, and the whole of Alberta with the exception of a comparatively narrow western belt occupied by the eastern ranges of the Rocky mountains. As the plains are heavily covered by soil, outcrops of rock are only to be seen where deep river valleys have been cut through the overburden or where the lateral erosion of slight eminences permits the rock formations to be seen. The heart of this great region, the typical prairie of Saskatchewan and eastern Alberta, shows this lack of visible rock formations in the most pronounced manner, as only along the southern boundary are any outcrops of rock to be seen, and these present little possibilities as producers of building stone. Towards the margins of the great plains, in eastern Manitoba and western Alberta, the typical prairie characteristics are less pronounced and rock formations are more frequently exposed. It may therefore be stated that the region of the great plains, in a general way, can be expected to yield stone only on its eastern and western margins.

On its eastern side the prairie region fades imperceptibly into the more wooded and more rocky district of the Manitoba lakes and finally into the truly rocky country east of Lake Winnipeg. On the western side, the prairies terminate more abruptly, their extinction by the great ranges of the Rockies being heralded by only a few miles of foothills. This difference is due to the fact that the eastern boundary is the original rocky rim of the basin in which the strata were formed, while the western boundary was determined by a subsequent event—the great upheaval of the Rocky mountains.

The oldest rocks of the earth's crust have been so greatly altered by the forces of nature throughout such vast periods of time that they have been converted into hard crystalline rocks, chiefly gneisses and the crystalline schists, which have been invaded by enormous masses of igneous rocks, so that the whole series constitutes a great crystalline complex. This complex assemblage is commonly referred to as the Pre-Cambrian or Archæan system. Rocks of this system form the floor of sea basins in which the later formations have been deposited. The material for these newer formations is derived from the decay of old land surfaces and is deposited in level layers on the bottom of the seas.

At the close of Pre-Cambrian time the North American continent was probably smaller than at present, and there is little doubt that it decreased very much during later time until great shallow seas stretched from the vicinity of Lake Winnipeg to beyond the present location of the Rocky mountains proper. The various seas that from time to time occupied parts of this great area became gradually filled with sediments, not uniformly or without fluctuations, but irregularly and with many warpings. The net result, however, was the production of a great series of flat-lying rocks which eventually were lifted out of the water and became the floor of the great prairies.

The old Pre-Cambrian rocks are to be seen on the eastern side, beyond the maximum advance of these great continental seas, in that part of Manitoba lying to the eastward of Lake Winnipeg. Here only are the gneisses, granites, and crystalline schists to be obtained, and here are situated the only quarries in rocks of that class in the three provinces. Alberta does not extend to the western limit of the great interior seas and consequently the Pre-Cambrian rim of the western side of the trough is not seen except where the enormous elevation of the Rocky mountains has brought the rocks into sight near the summit of the Kicking Horse pass. Here the Pre-Cambrian rocks are represented, not by granites and gneisses, but by hard, indurated, sandstones and shales.

The rocks deposited in the great interior basin are usually classified as follows, in descending order, *i.e.*, the youngest at the top of the column and the oldest at the bottom:—

Group	System	Alberta	Saskatchewan	Manitoba
Tertiary	Eocene	Paskapoo	Fort Union ?	Fort Union ?
Mesozoic	Upper Cretaceous	Edmonton	Lance ?	Lance ?
		Pierre Bearpaw	Pierre	Odanah
		Brazeau Belly River	Belly River	
		Lower Dark Shales Claggett Wapiabi Bighorn Cardium Niobrara		Millwood Niobrara
		Benton		Benton
		Dakota Blairmore		Dakota
	Lower Cretaceous	Kootenay		
	Jurassic	Fernie		
	Triassic	Upper Banff Shale		

Group	System	Alberta	Saskatchewan	Manitoba
	Permian	Upper Banff Shale		
	Carboniferous	Rocky Mountain Quartzite Upper Banff Limestone Lower Banff Shale		
Palæozoic	Devonian	Lower Banff Limestone Intermediate Limestone Sawback Limestone		Manitoban Winnipegosan Elm Point
	Silurian	Halysites Beds		Silurian
	Ordovician	Graptolite Shale Goodsir Shale		Cincinnatian Trenton
	Cambrian	Numerous Formations		

A brief study of the above table will serve to emphasize the following outstanding facts:—

(1) The oldest rocks, the Cambrian, were deposited only in the western portion of the great basin.

(2) The oldest rocks on the eastern side are the Trenton: these rest directly on the Pre-Cambrian floor.

(3) None of the older rocks are known in Saskatchewan because they are entirely covered by deposits of later age.

By the end of Mesozoic time the process of filling this great continental basin with strata was nearly completed, then occurred the great event which may be called the birth of the Rocky mountains, a stupendous elevation of the western margin of the great basin whereby the level rocks were upturned and thrown into the great ranges of the eastern Rocky mountains. This elevation was brought about by a thrust from the direction of the Pacific ocean accompanied by cracks in the earth's crust running in a general northwest and southeast direction. The masses of rock between these cracks (fault blocks) were twisted, broken, and forced upwards as the result of the tremendous terrestrial pressure which was so great that not only were the blocks elevated but in many cases they were actually pushed over one another and over the level region east of the great system of cracks. The various ranges of the Rocky mountains of Alberta may therefore be regarded as great fault blocks with the steep broken faces towards the east, and with more gentle slopes on the western sides which correspond to the position of the upturned strata.

It is apparent that the effect of these great mountain building forces could not cease abruptly at the line of the most easterly great fault. Deforming effects are seen still farther east in the crumpling of the rocks contiguous to the mountains resulting in the ranges of minor hills known as the "foothills."

Subsequent to the period of elevation, the newly formed, more or less broken and shattered ranges, were an easy prey for the forces of destruction such as heat, rain, frost, etc., with the result that the higher layers of rock

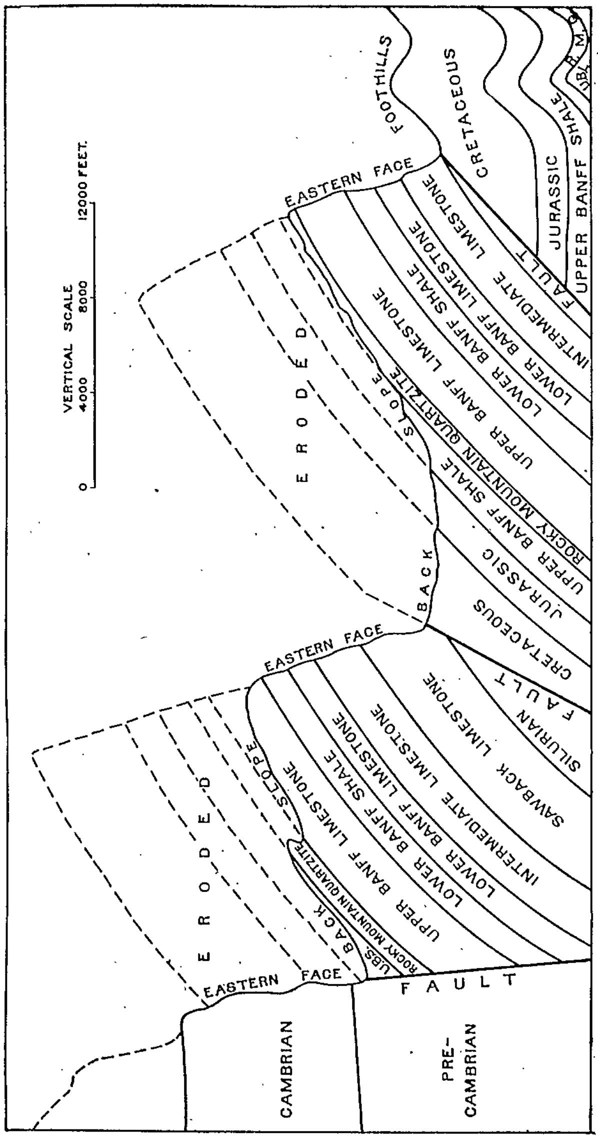


Fig. 1. Ideal section showing the structure of the Rocky mountains in southern Alberta.

were washed away, until, at the present time, the Rocky Mountain quartzite forms the summit of many of the great ranges. In the case of the more westerly fault blocks, which were uplifted to a greater extent, the whole series of formations above the Cambrian have totally disappeared.

It is apparent that the erosion would be less pronounced in the valleys between the great ranges; as a consequence, we find younger rocks still preserved on the back slopes of the outer ranges. It is from these rocks that a large part of the coal of Alberta is mined.

The accompanying sketches, Figs. 1 and 2, are intended to express in a purely diagrammatic way the relationships and positions of the strata

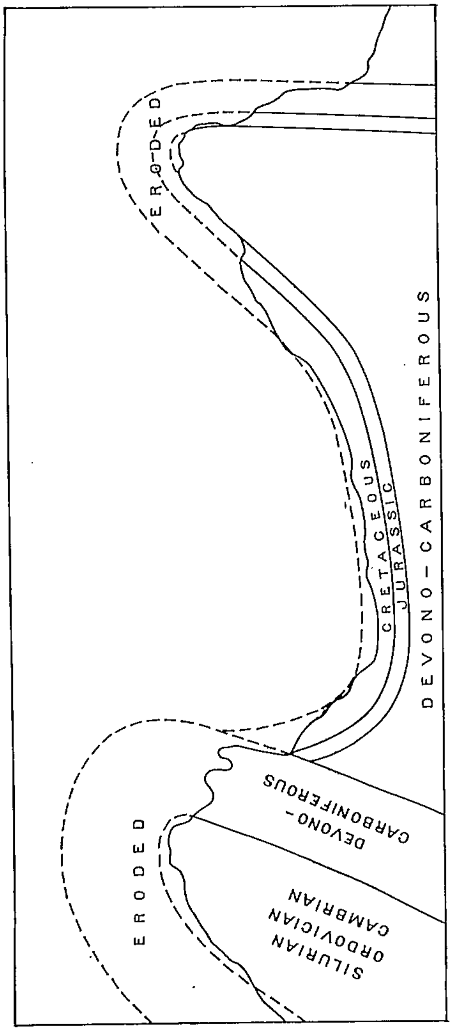


Fig. 2. Ideal section showing the structure of the Rocky mountains in northern Alberta.

of the eastern Rocky mountains. Figure 1 indicates the conditions in southern Alberta where the fault blocks have been overthrust. The vertical scale is roughly 8,000 feet to the inch, but the horizontal scale is greatly shortened; in consequence, the planes of overthrust, marked "fault," are much too inclined. The actual disposition of the strata in any given line of section is much more complicated than indicated by the figure. The second diagram is not drawn to scale, either vertical or horizontal: it is intended to express the general conditions in the northern part of the province where the fault blocks are not overthrust but are folded into sharp anticlines.

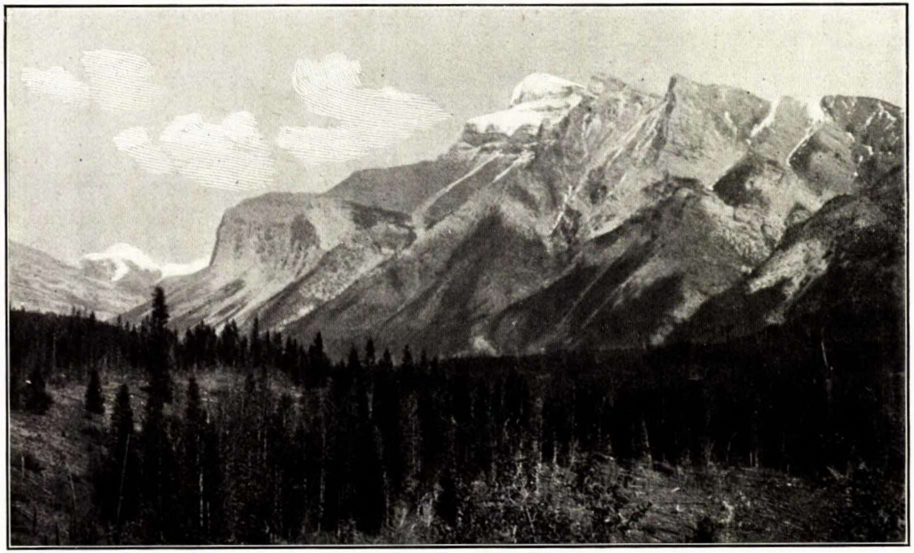
The differential weathering of the shales, limestones, and quartzites gives a characteristic appearance to the mountains when viewed in the direction of the general strike: this is well shown in Plate III.

The enormous stresses to which the rocks of the mountains have been subjected have effected great changes in their original physical condition. The limestones have become hard and brittle, and, in some cases they have been converted into marble; the sandstones have been hardened, until, in extreme cases, they are now quartzites; the shales, particularly in the older formations, have been converted into slates. The hardening of the stone is not to be regarded as an evil in every instance, for the soft Edmonton sandstones present greater possibilities where they have been affected by the mountain building forces, and the Dakota sandstone, which is usually soft and pulverulent at points distant from the mountains, occurs in the foothills as a hard resistant rock.

The folding and crumpling of the rocks in the process of mountain building has naturally resulted in a degree of shattering not at all favourable to the prosecution of the building stone industry. Most of the rocks are so filled with irregular cracks and flaws that the winning of quarry blocks is practically impossible; it is only in very favourable locations that this unfortunate feature is not present.

The sequence of rock formations from the Cambrian to the Tertiary is indicated in the table on page 22. A brief account of each of the great systems with special reference to those formations capable of yielding building stone is given below.

Cambrian system.—Strata of this system were deposited to the enormous thickness of 18,000 feet in a great trough which extended in a general north and south direction to the eastward of the Selkirk and Purcell ranges. The sea in which these rocks were deposited probably did not extend far to the eastward, and at that time the greater part of the mid-continental region was a Pre-Cambrian land surface. The Cambrian rocks have been divided into lower, middle, and upper divisions and each of these divisions into a number of formations. The Lower Cambrian is characterized by great masses of quartzites and shales while the higher formations contain more limestones. Rocks of this age are not commonly exposed in the outer or eastern ranges, but the more elevated fault blocks to the west have brought them into view. On the Crowsnest branch of the Canadian Pacific railway there are no Cambrian rocks east of the summit but on the main line of the Canadian Pacific railway and on the Grand Trunk Pacific railway the rocks near the summit and for some distance east belong to this age. A formation of the Lower Cambrian known as the St. Piran quartz-



Mountain near Banff, Alberta, showing Lower Banff limestone, Lower Banff shale, Upper Banff limestone, and Rocky Mountain quartzite.

ite has been quarried on Lake Louise; Cambrian limestones present possibilities near Castle station; and marbles of this age occur in the Vermilion pass. On the Grand Trunk Pacific line the Cambrian limestones appear to be of little value but marbles occur on the Athabaska river near Mount Geikie. The prevailing Cambrian rock of this region is a hard sandstone or conglomerate interstratified with slates. This rock has a possible value for rough building but it can never be applied to purposes of fine construction.

Ordovician system.—The rocks of this system as exposed in the Rocky mountains consist chiefly of shales; they are not well developed on the Alberta side of the inter-provincial boundary and are of no importance from the present point of view. In Manitoba, however, we find in this system the most important building stones of the province. The lower rocks of the system are comparable in age with the Trenton series of eastern Canada; three members are recognized—the Winnipeg sandstone, the Lower Mottled limestone and the Upper Mottled limestone. The higher Ordovician strata are of Cincinnatian age.

The Winnipeg sandstone is exposed at points on the west shore and on islands in Lake Winnipeg; it is a soft and friable stone of little promise as a structural material.

The Lower Mottled limestone is seen on islands and along the west shore of Lake Winnipeg. It is mostly thin-bedded and hard, but some of the stone quarried on Big island, Lake Winnipeg, is used for rubble.

The Upper Mottled limestone is the most important Ordovician formation: it yields an excellent quality of building stone from the quarries near Lyall and Tyndall, Man.

The Upper Ordovician member belongs to the Cincinnatian series and is comparable in age with the Richmond formation of the Ohio valley. The stone is mostly thin-bedded and hard, but it is used for rubble and occasionally for ashlar. The only important outcrops are at Stony mountain and a few other points to the northward of Winnipeg.

Silurian system.—In the Rocky mountain region, the Silurian is represented by the "Halysites beds" which consist of dolomites and quartzites with interbedded shales. I have learned of no attempt to use the stone for structural purposes. Outcrops are not of easy access.

In the Manitoba region, this formation has a great extent and presents many locations at which quarrying might be carried on. The rocks occupy a broad belt between Lake Winnipeg and Lakes Manitoba and Winnipegosis. Outcrops occur on Portage bay of Lake Winnipeg, on the northeastern shore of Lake Winnipegosis, on the shores and islands of Cedar lake and other lakes north of Lake Winnipegosis, and on the Saskatchewan river, particularly at the Grand rapids. Most of the stone is rather hard and of a cavernous nature, but it has been used for building purposes from the quarries at Stonewall and Gunton. Near Broadvalley, Manitoba, a fine-grained Silurian dolomite is being quarried under the name "manitobite."

It is from this formation that the gypsum of northern Manitoba is obtained, and the anhydrite deposits north and east of Gypsumville may have a value as decorative stone.

Devonian system.—This system is represented in the Rocky mountains by three formations—the Sawback limestone, the Intermediate limestone, and the Lower Banff limestone.

The Sawback limestone is to be seen at the point where the line of the Canadian Pacific railway crosses the Sawback range to the west of Banff. The stone, on exposed faces, is much fractured, but polished surfaces show a unique colouration in pink and grey indicating a possible value as decorative material.

The Intermediate limestone occurs at the base of the scarped faces of the outer or eastern ranges and is accessible at many points. The stone is usually very hard and rough and breaks with a sulphurous odour.

The Lower Banff limestone, with a thickness of about 2,000 feet, is a conspicuous element in the eastern ranges: it is frequently responsible for the lower vertical cliff (Plate III). The stone is hard and dark, frequently cherty, and usually much shattered. While giving little promise as a building stone, its dark colour and its capacity for receiving a good polish suggest its use as a black marble (Plate XXV).

In Manitoba, the Devonian system occupies a belt about 40 miles wide in which lie Lakes Manitoba, Winnipegosis, Dauphin, Swan, and Red Deer. Numerous outcrops are to be seen on all these lakes and a number of quarries have been worked for concrete, lime, macadam, and cement. The thin bedding of the stone has prevented its use for building but some of the unworked outcrops on Lake Winnipegosis may be exploited for structural purposes in the future. Three subdivisions of the Devonian are recognized —the Elm Point, the Winnipegosan, and the Manitoban.

Carboniferous system.—The Carboniferous formations in the Rocky mountains, in descending order, are as follows:—Rocky Mountain quartzite (800 ft.), Upper Banff limestone (2,300 ft.), Lower Banff shale (1,200 ft.).

The Rocky Mountain quartzite is an extremely hard and resistant rock; in consequence, it has well withstood erosion and now forms the summit of many of the eastern ranges.

The Upper Banff limestone is a lighter coloured and somewhat softer and more crystalline stone than the Lower Banff limestone of the Devonian. In places it is highly cherty but phases are known which present some possibilities as building stone. This formation is responsible for the upper vertical cliffs of many of the ranges. The upper cliff shown in Plate III is composed of Upper Banff limestone overlaid by Rocky Mountain quartzite.

The Lower Banff shale is a soft rock of no importance from our point of view: it forms the darker coloured, more sloping, median portion of the mountain face shown in Plate III.

Permian system.—This system and possibly the Triassic also is represented by the Upper Banff shales which are of no interest from our point of view. Certain hard, black, argillaceous limestones which occur on the Spray river near Banff have been quarried for the construction of buildings at Banff: they represent calcareous layers of this series.

Jurassic system.—The Fernie shales are not well exposed on the Alberta side of the inter-provincial boundary: they are of no present interest.

Cretaceous system.—The lower part of the Cretaceous system, the Kootenay formation, occurs only in the western part of Alberta and is entirely absent in the Manitoba region where the Upper Cretaceous rests directly on the Devonian. The Kootenay formation consists chiefly of shales and coal seams with some interbedded sandstones. These sandstones are mostly thin, very hard, and possessed of poor weathering properties. Some authors recognize a "Lower ribboned sandstone" below the coal measure, and an "Upper ribboned sandstone" above them. The formation occurs all along the foothills and on the back slopes of the outer or more easterly ranges of the mountains. A number of important coal mines are worked in this formation.

The lowest member of the Upper Cretaceous series is the Dakota formation which consists chiefly of sandstone with some shale. In Manitoba, the Dakota sandstone rests directly on the Devonian: its outcrops are few and the stone is not of a desirable nature. In the Rocky mountains the Dakota sandstones are seen overlying the Kootenay coal-bearing series in the foothills and on the back slopes of the outer ranges. The sandstone is hard and usually of a greenish colour with poor weathering properties, but it presents possibilities as a rough structural stone.

Overlying the Dakota are the dark grey to black shales of the Benton formation. These shales occur both in Manitoba and in the mountains but they are of no interest from the present point of view.

The succeeding Niobrara formation is well developed in Manitoba where it consists of light grey calcareous shales with thin bands of limestone. The Bighorn, Cardium and Niobrara formations of the mountains are similar, and, like the Manitoba Niobrara, are of little or no promise as producers of stone.

The Lower dark shales, the Claggett, and Wapiabi formations of the mountains and the Millwood formation of Manitoba are essentially shales with some thin bands of limestone of little or no use.

The Belly River formation is of wide extent in Alberta and Saskatchewan. The rocks are sandy clays with shales and sandstones; the latter are usually too soft to be of value but it is possible that some of the harder layers near the foothills may be of local use.

The Pierre and Odanah formations are essentially shales but some sandstones occur. The Boissevain sandstone of Turtle mountain in southern Manitoba probably belongs to this horizon.

The Edmonton formation is now considered as the top of the Cretaceous system: it was formerly classified as the lower member of the "Laramie." The formation in southern Alberta known as the St. Mary River beds is now considered to be in part equivalent to the Edmonton. This formation is of considerable extent in Alberta and represents a transition from marine to fresh water conditions. The rocks are sandy clays, white clays, and sands of little coherence except in occasional layers which are very hard. Where exposed in river valleys on the plains, the stone is not of structural value but in the foothills some of the indurated layers of sandstone may have a local application.

Eocene system.—The Paskapoo formation, formerly considered to be the upper part of the Laramie, consists essentially of sandstone and was formed when marine conditions ceased and great fresh water lakes occupied wide areas of the western plains. The most important belt overlies the Edmonton in western Alberta and extends with an average width of 40 to 60 miles from near the international boundary to beyond the line of the Grand Trunk Pacific railway and doubtless into the little explored regions farther north. The sandstone of this formation has been extensively quarried in the vicinity of Calgary, on the Crowsnest and main lines of the Canadian Pacific railway, and along the railway from Macleod northward nearly to Wetaskiwin.

The sandstones of the Souris River valley in southern Saskatchewan, questionably ascribed to the Fort Union formation, are of an age comparable with the Paskapoo. These sandstones are soft and of little promise.

The great lakes in which the Paskapoo rocks were deposited having finally disappeared other smaller lakes followed in which still later Tertiary strata were laid down, but none of these later rocks are sufficiently coherent or uniform to be of value for building stone.

The Tertiary era was brought to a close by a great refrigeration of the northern part of the continent whereby the glaciers of the Rocky mountains were permitted to descend to lower levels. A deposit known as the Saskatchewan gravel or quartzite shingle was formed by these glaciers and reaches far out on the plains. A continuance of glacial conditions led to the establishment of a great centre of dispersion in Keewatin from which the ice spread out in all directions, overriding the Saskatchewan gravels and reaching to the base of the mountains. This glacial advance covered the whole of the mid-continental region of Canada with the stony clay typical of glacial deposits. Boulders of Pre-Cambrian rock from the region north and east of Lake Winnipeg were transported hundreds of miles and scattered over the whole face of the country. These boulders are employed for building purposes at many points on the great plains, and in the absence of accessible ledges of desirable rock, form an important asset from our point of view. Not only were Pre-Cambrian boulders thus transported but large masses of the Silurian limestones from the region of northern Manitoba were in like manner carried for long distances and deposited on the retreat of the glaciers. Notable examples of large boulders of limestone are to be seen near Prince Albert and Saskatoon. At a still later date in the Ice age, glaciers gathered in Labrador and spread outwards in all directions. Evidence of the advance of these glaciers at right angles to the path of the Keewatin ice sheets may be seen along the shores of Lake Winnipeg.

Following the final retreat of the glaciers came a period when large lakes covered parts of the area under review. The sediments deposited in these lakes form the present surface soil over most of Manitoba and considerable portions of Alberta and Saskatchewan.

CHAPTER III.

LIMESTONES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Limestones make up the great bulk of the eastern ranges of the Rocky mountains in Alberta and likewise constitute the prevailing rock in eastern and northern Manitoba. Notwithstanding the wide distribution, the accessibility, and the enormous supplies of this type of stone, the quarrying of limestone for structural purposes is practically confined to one locality—the vicinity of Tyndall and Lyall, Manitoba. At Broadvalley on the Inwood branch of the Canadian Northern railway some development has been done with the direct object of producing building stone, and a small amount for local use has been quarried near Banff, Alberta. The university buildings at Saskatoon, Saskatchewan, are built of limestone obtained from boulders in the vicinity, and a limited amount of similar origin has been used for various buildings in Killarney, Manitoba. With the above exceptions and possibly a few others, any limestone used for building has been obtained as an incidental product from quarries operated for other purposes.

The formations yielding limestone are indicated in the table below:—

System	Series	Formation	
		Alberta	Manitoba
Cretaceous	Colorado		Niobrara
Permo-Triassic		Upper Banff Shale	
Carboniferous		Upper Banff Limestone	
Devonian		Lower Banff Limestone Intermediate Limestone Sawback Limestone	Manitoban Winnipegosan Elm Point
Silurian		Halysites beds	Silurian
Ordovician	Cincinnatian		Richmond
	Mohawkian (Trenton)		Upper Mottled Limestone Lower Mottled Limestone
Cambrian	Upper Cambrian	Various Formations	
	Lower Cambrian	Various Formations	

According to the practice hitherto followed in these reports, the limestones will be considered in the order of their geological age, beginning with the oldest—the Cambrian.

Limestones of the Cambrian System.

The great Cambrian system is developed in the Rocky mountains to the enormous thickness of about 18,000 feet. Rocks of this system are not seen in Alberta on the Crowsnest line of the Canadian Pacific railway, but on the main line they constitute the bulk of the mountain ranges from a short distance west of Banff to the summit. On the Grand Trunk Pacific railway, Cambrian rocks begin a little east of Fitzhugh and continue to the divide. The Cambrian system is divided into a lower, a middle, and an upper division, each of which is again subdivided into a number of formations. Limestones occur in the upper parts of the system but the lower horizons are characterized chiefly by quartzites and quartzitic sandstones.

The limestones and dolomites of the upper and middle divisions are usually so cherty, arenaceous or argillaceous, and are so excessively shattered that the probability for the production of building stone is slight. So numerous and diversified are the limestone strata that even a generalized account is quite beyond the scope and purpose of this work. As far as I can ascertain only one exposure of Cambrian limestone has attracted any attention: this outcrop is at the base of Castle mountain and is briefly described below. A few notes are also given on the limestone formation east of Fitzhugh on the line of the Grand Trunk Pacific railway. In order to preserve a uniformity of arrangement, these occurrences are ascribed to two "areas," but, in this instance, these areas are of very indefinite significance.

Canadian Pacific Railway Area.

Castle Mountain, Alberta.

Immediately north of Castle Mountain station is an exposure of limestone which has been opened in a small quarry for lime burning. The strata are disposed at high angles and the stone is excessively checked, hard, and splintery: in places it shows blebs and lines of whitish calcite which weathers brown. The whole mass weathers to a light brown colour with characteristic etched lines. The stone is easy of access and could readily be quarried, but it gives little promise from the present point of view (1322).

East of Castle Mountain station (one mile east of Johnson creek), and about a half mile north of the railway is an exposure of limestone forming a cliff of 50 to 75 feet in height at the base of Castle mountain. The formation extends for a considerable distance and rises towards the west. The face of the escarpment seems to be a joint plane and the formation is crossed by other joints at right angles. These latter partings are widely spaced as a rule but in places they are close together forming shattered zones. As the bedding is unusually heavy and the amount of fracturing much less than usual it is possible to quarry blocks of any reasonable dimensions. The stone itself is more desirable than most of the Cambrian limestones and is described below as No. 1333. The formation overlies a hard black brittle limestone. The accessibility of the location, the formational features of the strata, and the quality of the stone are more favourable here than in any other outcrop of Cambrian limestones with which I am familiar.

The stone: No. 1322.—A very hard, fine-grained, semi-crystalline limestone of dark grey colour. The stone is not pitted or cavernous but it is rather badly checked; it weathers to a dirty grey surface with a minutely pitted appearance.

No. 1333.—A coarsely crystalline, light greyish limestone: it closely resembles No. 1315 from the Upper Banff limestone described on page 143. The present stone is softer, darker, less "clean" on freshly fractured surfaces, and without the slightly bluish cast of No. 1315; it would probably be of less strength and greater porosity. The stone is decidedly softer than No. 1315 and has a distinct grain indicating a certain degree of schistosity; it has a tendency to crumble under repeated blows of the hammer.

Grand Trunk Pacific Railway Area.

Mile 1022 Grand Trunk Pacific Railway.

A rock cut at this point exposes thin-bedded, nodular limestones which weather red and brown and present a very different appearance from that of the limestones of the more easterly Devono-Carboniferous mountains. Rocks of this type apparently form a part of Pyramid mountain and probably represent the Castle Mountain series of the Cambrian. The stone, while sufficiently coherent to come out in great blocks, possesses intimate, thin-bedded, wavy and nodular characteristics, which, together with its habit of rusty weathering, unfits it for any purposes of construction (1244).

The stone: 1244.—A dark argillaceous limestone with strongly developed wavy planes of parting; it has a distinct tendency to weather red. The stone is quite worthless for our purpose.

Limestones of the Ordovician System.

In the Rocky mountains, the Ordovician system is represented almost entirely by shales and consequently may be disregarded; in Manitoba, the system presents three formations—the Lower and the Upper Mottled limestones of the Trenton formation and the Stony Mountain series which is probably to be ascribed to the Richmond formation.[1]

The Lower Mottled limestone and the Richmond limestones are mostly hard and thin-bedded: they are used chiefly for crushed stone and rubble. The Upper Mottled limestone is one of the best building stones in Canada and is largely quarried for structural purposes.

[1]A formation known as the Cat Head limestone lies between the Upper and Lower Mottled limestones but it is apparently of little importance from our point of view.

LOWER MOTTLED LIMESTONE.

Lake Winnipeg Area.

The Lower Mottled limestones are exposed at a number of points along the west side of Lake Winnipeg and on many of the islands. The rock is usually very thin-bedded, hard, and of poor weathering qualities. Many of the exposures present favourable locations for quarrying, but from our present point of view, the stone is of little value except for rubble. A full list of occurrences may be found in the Report on the Shores and Islands of Lake Winnipeg (Geol. Sur. Can., Parts F and G, Vol. XI). Outcrops on Big island, Bull head, and Grindstone point are described below as typical of the formation.

Lake Winnipeg Shipping Co., 201 Tribune building, Winnipeg; Hugh Sutherland, president; F. W. Smith, manager; C. Sifton, superintendent.

This company operates a quarry in the Lower Mottled limestone on the east shore of Big island in Lake Winnipeg. The company holds the northwest quarter of section 28, township 25, range 6 east of the first principal meridian. Here a cliff of limestone faces the lake with a general direction of N.30°W.; it extends for nearly half a mile and shows an elevation of 9 feet at the southeast end which gradually increases to a height of 27 feet at the northwest end. The average height is about 18 feet. The beds dip S.40°W. at about $2\frac{1}{2}°$ which accounts for the increasing height of the cliff towards the northwest. On the west side of the island, the top bed appears at the water level. This disposition of the strata results in a decreasing height of face and an increasing overburden as the quarry is extended inland. The stripping at the brow of the cliff is about 2 feet, but 175 feet from the shore it has increased to 5 feet. The general section is as follows:—

2 ft.—Thin-bedded, white weathering stone (1016).

5 ft. 6 in.—Average stone in beds 4 to 8 inches thick (1017).

5 ft. 6 in.—Best quality, blue mottled stone, in beds of suitable thickness for rubble (1018).

3 ft. +—Mottled limestone in less even beds and with shaly partings in places (1019).

The beds are separated in places by layers of sand which seem to be of later origin and to have been introduced into solution cavities between the strata by the waves of the lake (Plate IV).

The subdivisions of the strata as given above is economic rather than stratigraphic, for little difference is to be observed in the stone throughout the whole exposure other than a variation in the thickness of the layers and in the degree to which alteration has advanced.

The upper layers (1016) are distinguished by their thin bedding and they are rather sharply demarkated by their white weathering. The

PLATE IV.

Lower Mottled limestone. Big Island quarry, Lake Winnipeg, Man.

average stone shows a light grey base with yellowish mottlings; it resembles the thin stone from Punk and Deer islands, Dog head, Bull head and many other points along the coast.[1]

In working the quarry, these upper beds are rejected.

The second series of beds (1017) presents a mottled appearance in blue and brown rather than in grey and yellow as with the upper layers. Sand partings occur between certain of the beds, and near these, the stone cannot be distinguished from the overlying material. Towards the bottom of this series, the beds have a blue unaltered centre with a deep oxidized border showing mottling in brown and bluish-grey.

The third series (1018) is thicker bedded and less altered. The layers show a centre of mottled aspect in light and dark blue with disseminated fine-grained pyrite, particularly on flaws. The oxidized zone is narrow and is frequently wanting.

The jointing is irregular with a main set striking north and south with a dip of 70° to the east. The spacing of these joints varies from 2 to 10 feet. A second and less well defined set of joints strikes northwest, resulting in the division of the formation into diamond-shaped blocks. All joint planes are deeply stained with oxide of iron.

The stone: No. 1018.—This stone is hard with a crystalline structure and a prevailing light blue colour: it resembles No. 1048 from Tyndall in its mottling, but it is a much harder stone, more compact and of a finer grain. Under the corrosion test a serious alteration results: the light bluish cast of the ground mass is entirely lost and gives place to a dirty, whitish-yellow colour with small dark specks. The darker mottlings are less affected and assume a rusty brown colour. No apparent change is produced by the freezing operation.

The physical properties are indicated below:—

Specific gravity	2·745
Weight per cubic foot, lbs	164·194
Pore space, per cent	4·07
Ratio of absorption, per cent, one hour	0·992
" " " " " two hours	1·22
" " " " " slow immersion	1·31
" " " " " in vacuo	1·51
Coefficient of saturation, one hour	0·64
" " " two hours	0·79
" " " slow immersion	0·84
" " " in vacuo	0·97
Crushing strength, lbs. per sq. in., dry	24,208·
" " " " " wet	17,400·
" " " " " wet after freezing	18,700·
Transverse strength, lbs. per sq. in	2,375·

[1] Geol. Sur. Can., Ann. Rep., Part F., Vol. XI.

Shearing strength, lbs. per sq. in.	2,835·
Loss on corrosion, grams per sq. in.	0·198
Drilling factor, mm.	11·3
Chiselling factor, grams	4·90

The characteristic mottled structure of this stone, as in the case of the numerous other mottled stones of the Winnipeg basin, makes it very difficult to prepare cubes which are strictly comparable: an evidence of this is seen in the apparent increase of strength after freezing. In view of the non-homogeneous nature of the stone we can only assume that it is not appreciably affected by the freezing experiment.

An analysis by Leverin shows this stone to be a magnesian limestone with a content of magnesia comparable with that of the Upper Mottled limestone from the Tyndall and East Selkirk areas. The harder character of the stone is shown by the much higher content of insoluble matter. The great excess of iron, particularly the ferrous oxide, over the alumina indicates a tendency to change colour on weathering.

	Per cent.
Calcium carbonate	73·21
Magnesium carbonate	6·26
Ferric oxide	0·57
Ferrous oxide	0·51
Alumina	0·04
Soluble silica	0·22
Insoluble matter	16·98

No. 1016.—This stone is of the same general character as No. 1018 described above, but it is softer and yellowish instead of blue in colour: it doubtless bears the same relation to the blue stone that the buff Tyndall stone bears to the blue variety at that locality. This stone is softer than No. 1018 and shows fossils, particularly joints of crinoids, with greater clearness; it is also more inclined to break along the planes of stratification.

No. 1017.—This specimen is about 8 inches thick vertical to the bedding: it shows a central third of blue stone essentially the same as No. 1018 with an outer third on either side of stone like No. 1016 but not quite so yellow. There is no doubt that the yellow part has arisen from the alteration of the original blue stone.

No. 1019.—This stone is blue like No. 1018 but it is less distinctly coarse mottled and is of a rougher nature, breaking with very uneven fracture. Little pyrite was observed.

In quarrying, holes are sunk at intervals of 8 feet along a line 7 feet back from the face. These holes are drilled with 1½-inch steel almost to the bottom of the blue beds: they are fired with 12 sticks of 60% dynamite each, which serves to break up the beds, but not to dislodge the stone, which is removed by pick and bar and loaded by hand on skips of about one cord capacity. For about a quarter mile, the length of the present face, a standard gauge track is laid along the quarry floor; outside and parallel is a narrow gauge track. A locomotive crane of 8 tons capacity, by the Ohio Locomotive Works, travels on the inner track and lifts the skips to the cars on the narrow gauge track. The train of cars is hauled to the dock by a small locomotive manufactured by the Davenport Locomotive Co. of Davenport, Iowa. At the dock, the skips are loaded into barges of 120 cords capacity by a crane which commands the slip in which the barges are moored. On arriving at Winnipeg, the loaded skips are lifted from the barges, thus obviating any necessity of a second transfer by hand.

Stripping is done by a novel device, consisting of two ordinary scrapers attached to a wire cable operated by a small hoisting engine and portable boiler.

In addition to this equipment, the following appliances are installed:—

10 narrow gauge cars.

6 standard gauge cars.

Stationary boiler for crusher, pumping, and sawing wood for fuel.

1 Little Giant No. 43 drill.

1 portable boiler supplying steam to drill.

1 Symms crusher of 80-yard capacity per 10-hour day.

Twelve buildings have been erected, including a blacksmith shop, etc.

A tug and three barges are employed to transport the stone to Winnipeg.

At the present time rubble only is produced: in 1913, 4,000 cords were shipped. The average price of this stone delivered at the work in Winnipeg is $10 per cord.

Bull Head, Lake Winnipeg.

The section presented at this point is as follows:—

19 ft.—Thin-bedded, mottled limestone, seldom more than 3 inches thick (1042).

30 ft.—Shale and sandy shale mostly covered by talus.

16 in. to 2 ft.—Bed of soft yellow sandstone (1043, see page 155).

2 ft.—Similar bed to water level.

The limestone is well jointed, N.30°W. and at right angles to that direction. Large slabs, 10 or 12 feet square, could easily be procured. The stone on moderate weathering presents a light grey colour with brown mottling; the severely weathered stone is quite yellow and softer (1045). Similar stone is to be obtained in quantity at many points along these cliffs.

The stone: No. 1042.—A hard, brittle, blue mottled limestone closely resembling No. 1018 from the Big island quarries, but it is rather more oxidized and is passing into the yellow variety in places.

No. 1045.—Decomposed limestone, soft and almost friable: it shows mottling in two shades of dirty yellow.

Punk Island, Lake Winnipeg.

The Lower Mottled limestone is well exposed on the north side of this island (see page 153). The undermining of the cliffs by the waves of the lake causes great slabs of the stone to fall on the beach. The large size of these slabs, together with the even bedding, suggests a use as paving stone (Plate V).

The stone: No. 1021.—Rather distinctly mottled in bluish and yellowish components: the specimen is derived from the surface and is somewhat decomposed; it does not differ essentially from the altered margin of No. 1017 from Big island.

Grindstone Point, Lake Winnipeg.

The Lower Mottled limestone is exposed on this point overlying the Winnipeg sandstone (see page 152).

The stone: No. 1026.—This example is strongly mottled and is evidently considerably weathered. The greyish-blue and deep yellow of the two components are in strong contrast.

UPPER MOTTLED LIMESTONE.

The Upper Mottled limestone forms the summit of the Trenton strata in the Lake Winnipeg basin. The formation is exposed at Lower Fort Garry on the Red river, at East Selkirk, and near Tyndall; it has been worked for building and ornamental stone at all three localities, but of recent years at Tyndall only. This stone is undoubtedly the finest building material produced in the Province of Manitoba and as an architectural stone it ranks above any other limestone quarried in Canada. While the three localities mentioned above are the only ones which have received the attention of operators, the northward extension of the series is shown by outcrops at many points along the shores of Lake Winnipeg. In view of the importance of this stone it seems advisable before proceeding to a detailed description of the deposits that have been worked to give a list of occurrences as determined by Tyrrell and Dowling[1]:—

Red river at St. Andrews. Low shelving limestone very little exposed.

Lower Fort Garry. Eight to ten feet in horizontal beds. (See page 41).

East Selkirk. (See page 42).

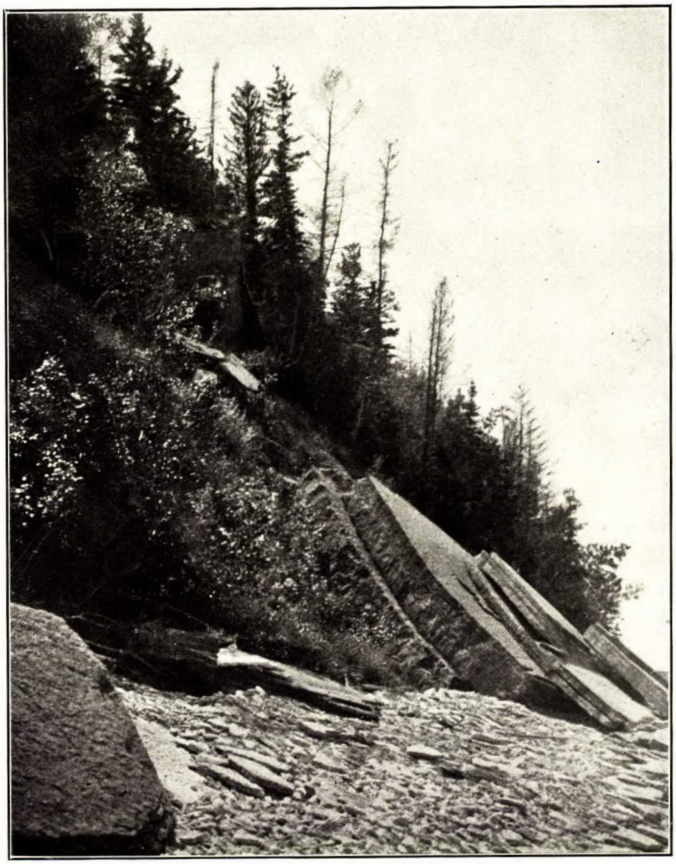
Section 6, Tp. 13, R. 6 East. The Garson district. (See page 45).

Mission on Fisher river. Two feet of soft rock resembling the Selkirk stone.

One mile south of above mission. Slabs of a dark yellow granular limestone in a ridge four or five feet high.

Dancing point, Lake Winnipeg. Four and a half feet of a dark semi-crystalline dolomitic limestone rather harder than that at Selkirk.

[1] Geol. Sur. Can., Rep. 1898, pp. 77-88 F.



Lower Mottled limestone. Fallen blocks, Punk island, Lake Winnipeg, Man.

Carscallen point, Lake Winnipeg. Several exposures of soft impure limestone in beds from two to three feet thick.

Limestone or Clark point, Lake Winnipeg. Fourteen feet of the formation but apparently not comparable with the Selkirk stone.

Mouth of Little Saskatchewan river. Similar to above.

Selkirk island, Lake Winnipeg. Several exposures. On north side are ten feet of hard dolomitic limestone, mottled with dark olive brown spots, the matrix generally a yellow colour.

Robinson point to Howell point, Lake Winnipeg. Several exposures. Upper beds thick—up to 5ft. 6 in.

For a detailed description of the above localities the reader is referred to the report already cited. A re-examination of these localities was not attempted for the present work but from what the writer has observed, as well as from a close study of Dowling's report, it would appear that the stone exposed on the shores of Lake Winnipeg is not comparable either in quality or in formational features with that at Lyall and Tyndall.

The exposures of Upper Mottled limestone may conveniently be considered under the following areas:—

Lower Fort Garry area.
East Selkirk area.
Tyndall area.
Lake Winnipeg area.

Lower Fort Garry Area.

This area is of historical rather than of present economic interest: the exposure was first noted by Major Long in 1823. The walls of the fort and warehouses were built of the stone in 1832 and some was quarried during the winter of 1883–84 for the construction of the asylum at Selkirk. Many small kilns along the river between Lower Fort Garry and Lockport show that the material has long been used for the production of lime.

Dowling describes the exposure as consisting of 8 or 10 feet of limestone in horizontal beds on the western side of the river. At the present time little is to be seen of actual exposures on account of the heavy covering of drift above and the talus of this material on the lower slopes of the river bank. Near the fort the bank is 33 feet high and shows interrupted outcrops of limestone in heavy beds to a height of 12 or 15 feet above the water. The stone is the soft mottled variety described below as No. 1046. Pieces dug out from the mud show remarkably little surface alteration or disintegration although it is probable that colour changes have occurred throughout. The more protected portions of the walls of the fort and buildings show that the lighter parts have become almost white and that the darker parts have assumed a light brownish-yellow colour deep into the blocks In copings and other exposed portions of the buildings, the darker blotches have become a very dark brownish-black colour as in the case of the stone from East Selkirk described on page 43. The cut stone in the main building of the old fort has been prepared with tooled margins which have retained perfectly every mark of the chisel. Little or no evidence of the action of frost was observed in any of the structures about the fort.

The heavy covering of 15 or more feet of drift renders impossible the profitable extraction of stone at this locality under present economic conditions. Should the more accessible stone at Tyndall be exhausted, the large supply available here might be utilized, but it could be obtained only by removing the heavy overburden or by tunnelling beneath it.

The stone: No. 1046.—A soft porous limestone most distinctly mottled. It so closely resembles the buff stone from Tyndall (No. 1047, page 48) that it is best described by pointing out the differences. The stone is somewhat softer than No. 1047 and is lighter in both components, the light-coloured matrix being almost white, and the darker portions distinctly yellow rather than buff. It differs from the highly altered Tyndall stone (No. 1051, page 56) in that the yellow component is of a much lighter shade.

Dowling reproduces two analyses of this stone which were originally published by D. D. Owen and show a great variation. No. 1 is described as a compact limestone and No. II as a spotted and banded limestone.[1]

The analyses follow:—

	No. I Per cent	No. II Per cent
Carbonate of lime	53·7	78·1
Carbonate of magnesia	40·5	17·8
Insoluble matter	·8	1·0
Alumina, oxide of iron and manganese	4·0	1·4
Water and loss	1·0	1·7
	100·0	100·0

East Selkirk Area.

The quarries at East Selkirk were described by Professor J. Hoyes Panton as presenting 4 feet of overburden towards the south but fully 10 feet towards the north of the opening[2]. The strata on the east side are described as horizontal but towards the west they are said to lie at an angle of 45° with vacant spaces like caves beneath them. Dowling's report of 1900 contains the following extract from J. B. Tyrrell's notes. "It (the quarry) is a pit on the west side of a small knoll cut down to a depth of about 12 feet. The exposed face runs S.35°E., and the north end of the exposure consists of horizontal thick-bedded limestone for 7 feet, overlain by 5 feet of till or boulder clay, consisting of white clay holding fragments of limestone lying in every direction. The surface of the limestone under this

[1] Geol. Sur. Can., Ann. Rep., Vol. XI, Pt. F., p. 78.
[2] Transaction No. 15, Man. His. and Sc. Soc., Winnipeg, 1884.

very irregular till, is rough, but not scored or polished. The southern portion of the exposure consists of large irregular masses of limestone, lying in all directions, between which the spaces are packed with smaller masses and white clay, often with a few pebbles and small boulders of the Archæan rocks. This has evidently been a pre-glacial hill of limestone, and the glacier from the northeast has broken off the upper portion and shoved it down as a tail-deposit behind. Near the station, only a few hundred yards away, it is necessary to dig about 30 feet to the limestone rock."

Operations must have ceased shortly after Mr. Tyrrell's visit, for I am informed that it is at least 12 years since the last work was done. The present condition of the quarries is indicated in the descriptions given below under the names of the three proprietors.

Mrs. H. Nelson, East Selkirk, Man. Three and one-third acres of lot 70, village of East Selkirk.

The quarry is about 100 feet square and is opened in the southwest face of a slight rise which maintains its elevation for some distance to the north and east. The quarry presents the best face towards the northeast side where it is about 20 feet high. The stripping of soil is light and beneath are great dislodged blocks of limestone, mingled, more particularly towards the top, with boulder clay. I could see no evidence of the presence of horizontal beds, and I have been informed that no solid beds were ever encountered in quarrying: this is not to be credited, however, in the face of the assertions of Tyrrell and Panton. Whether the horizontal beds mentioned by those authors have been worked out or whether the present condition is the result of the breaking down of the face I am unable to say. The blocks of stone lying in the quarry show that the original beds must have been two or three feet thick, at least in places. All the stone is the light mottled variety described below as No. 1197; it is soft and breaks with facility under the hammer in any desired direction. Weathering has produced very little effect on the large blocks but excessive exposure produces the results described below for specimen No. 1198.

The stone: No. 1197.—This stone is very similar to the buff Tyndall stone described in detail as No. 1047 on pages 48-51. The only difference is a lack of distinct yellowness in the darker portions. In general appearance this stone is close to No. 1050 (page 56) but it is more solid and coherent.

No. 1198.—This severely altered stone shows little difference in the lighter parts; the darker component, however, has become of variable colour in yellows and browns and with a "dirty" effect. Freshly broken pieces show no distinct external oxidized zone. The surface of the lighter part is still white except for adhering dirt, but the darker portion is distinctly grey rather than buff or yellow in colour.

Notre Dame Investment Co., Winnipeg, Part of Lot 70, village of East Selkirk.

This quarry is about 100 feet square and rather less than 20 feet deep; it adjoins Mrs. Nelson's quarry to the northwest (W. 15°N. mag.). The best face is on the north side rather than on the northeast as in the quarry previously described. The stone is similar to that of the other quarry and shows no present evidence of being disposed in horizontal beds as only angular dislodged blocks are to be seen.

Many fossil corals, receptaculites, and cephalopods occur throughout the formation in both quarries: while these fossils are of little detriment for rock face work they would occasion considerable loss in selecting stone for fine cut surfaces.

Wells gives analyses of East Selkirk stone in his Report on the Limestones and Lime Industry of Manitoba (Dept. Mines, Mines Branch, 1905). As one of the specimens probably came from this quarry the results are reproduced below.

	(I) Per cent	(II) Per cent
Moisture	......	0·07
Insoluble matter	0·91	1·15
Alumina and iron oxides	0·30	0·45
Lime carbonate	82·61	88·32
Magnesium carbonate	16·92	10·41
Sulphur trioxide	......	0·07
	100·74	100·47

(I) East Selkirk, locality not specified.
(II) East Selkirk, Hick's quarry.

Estate of Sir William Van Horne, Montreal (Old Mitchell quarry).

The estate of Sir William Van Horne comprises a large acreage both to the east and the south of the quarries described above. Across this estate the elevated tract is less pronounced than at the site of the other quarries, but a narrow quarry about 12 to 15 feet deep extends along the face of the slight elevation in a direction E.30°S. for a distance of 400 feet. The westerly end of the excavation is a short distance due south of Mrs. Nelson's quarry. The overburden is heavier here and little could be seen except occasional blocks buried in masses of drift. No limestone strata were seen *in situ.*

Summary—East Selkirk Area.

A soft, uniformly mottled, whitish-yellow limestone was formerly quarried near the village of East Selkirk. The stone was obtained along the face of a slightly elevated tract facing towards the southwest. In their present condition the quarries expose only large, irregular, dislodged masses of stone, but it would appear that horizontal beds were encountered during the time the quarries were worked. Tyrrell ascribed the broken character of the formation to the action of the glaciers advancing from the northeast and shoving the broken stone over the declivity to the southwest. As the country to the north and east maintains its altitude, it is a reasonable assumption that more solid stone would be obtained by advancing the workings in this direction.

East Selkirk stone was formerly employed to a large extent in Winnipeg for buildings of the best class, but it has been replaced by the product of the quarries at Tyndall. The Selkirk stone is softer and of a lighter colour than the Tyndall stone. Where it is protected from excessive weathering, the stone maintains its colour well, but in exposed positions the darker portions of the mottled mass become much darker—almost black—as may be seen in the old post-office, now the custom house in Winnipeg, and in the volunteer's monument in front of the city hall.

A detailed account of the stone is given on page 43; it is very similar to the stone from Lower Fort Garry described on page 42.

Literature:—Geol. Sur. Can., Ann. Rep., Part F, Vol. XI, 1898.

Man. Hist. and Sci. Soc., Transaction No. 15, 1884.

Dept. Mines Canada, Mines Branch, Limestones and Lime Industry of Manitoba, 1905.

Geol. Sur. Can., Ann. Rep., Part E, Vol. IV, 1888-89.

Royal Soc. Can., Vol. VII, Section IV, 1889.

Tyndall Area.

This area is undoubtedly the most important source of building stone in the western provinces; it is situated about 30 miles northeast of Winnipeg and may be approached either from Garson or Tyndall station on the Canadian Pacific railway. The quarries are connected with the Canadian Pacific railway by spurs, but a stranger visiting the locality would find it more convenient to drive from Tyndall.[1]

The area may be said to extend in a north and south direction for a distance of about three miles, reaching from the north halves of sections 33 and 34, township 12, range 6 east, through sections 6 and 9, township 13, range 6 east to the northwest quarter of section 15, township 13, range 6 east. The stone is by no means accessible over the whole of this area for it is thickly covered by drift, except where the folding of the strata has brought the formation near to the surface. The crown of the main fold, on which are situated the quarries now being actively exploited, runs for about a mile in a northwest direction near the line between sections 3 and 10, township 13, range 6 east. The main productive ridge is quite narrow, probably not more than a half mile wide, with a very gentle falling off both to the northeast and southwest. While rock folding is doubtless responsible

[1] "Garson Quarry" post-office has recently been changed to "Lyall."

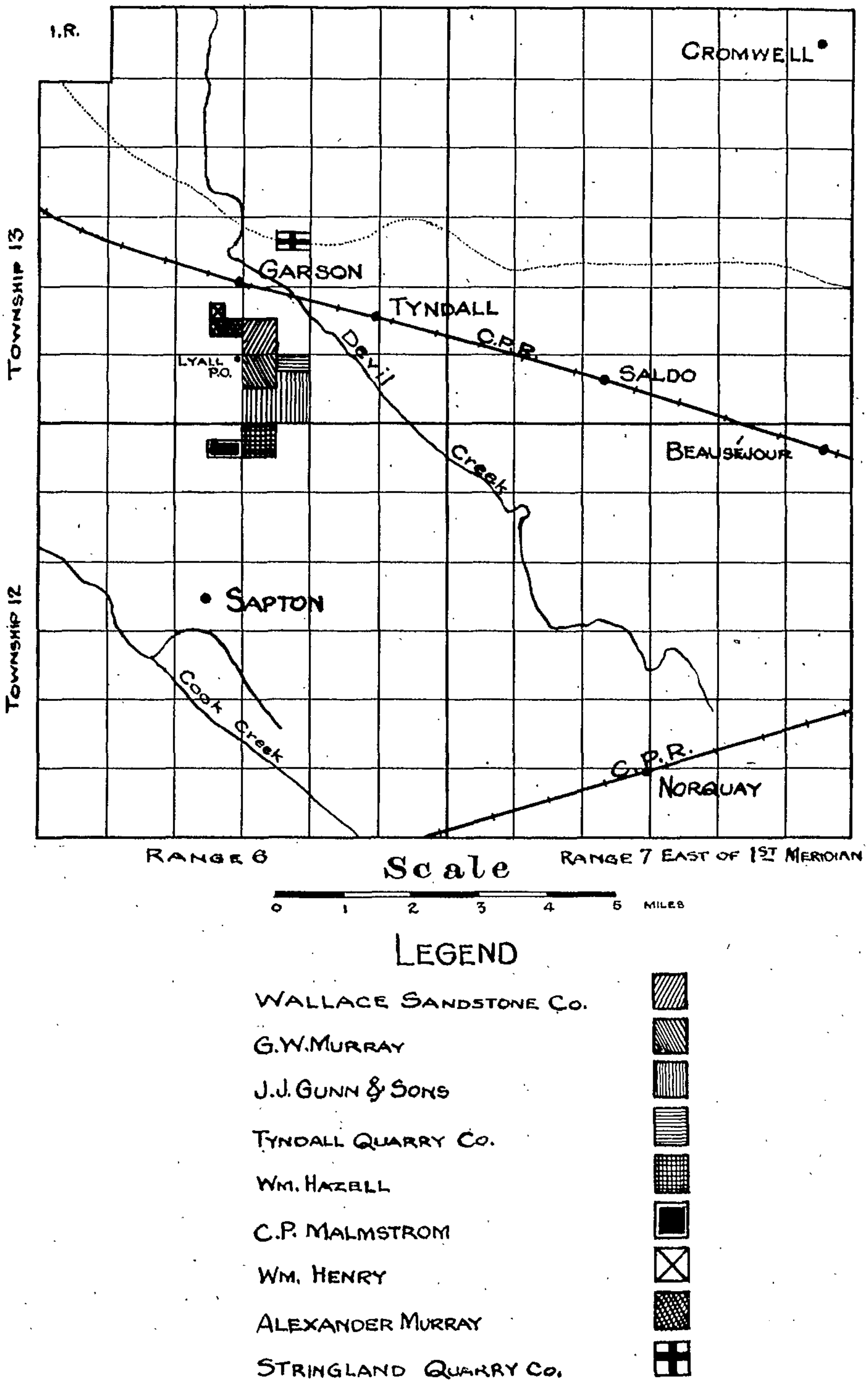


Fig. 3. Sketch map showing the quarry properties in the Tyndall area, Manitoba.

for the elevation of the tract it is evident that glacial or pre-glacial erosion has greatly modified the original anticline, at least on the northeast side, for successively lower and more broken beds are encountered on proceeding north and east from the axis of the ridge. This latter feature is so pronounced, that, admitting the position of the accessible stone to be defined by a slight anticline, its present elevation and consequent accessibility is much more due to differential erosion in pre-glacial time. This being the case, it is well for operators to note that the thickness of the overburden at any given point cannot be determined from observations made on the slant or dip of the layers of stone.

The outlying quarries of the area both southwest and northeast of the main axis above described, are apparently situated on quite distinct lines of elevation of which one occurs about a mile southwest of the main ridge and two to the northeast. Of these latter ridges, the first is about a half mile northeast of the main ridge and the second rather more than a mile farther north and somewhat more to the west.

Wallace Sandstone Quarries, Limited; Wm. Lyall, president, 505 Transportation Building, Montreal; Albert V. Coté, general manager, 1001 Electric Ry. Chambers, Winnipeg; James Marr, quarry manager, Lyall, Manitoba.

The quarry of this company is situated on the southwest quarter of section 10, township 13, range 6 east: it is known locally as the Garson quarry having been first opened by Wm. Garson about 1898.[1]

The opening is located near the southwest corner of the quarter-section and extends about 1,500 feet east and west by about 500 feet north and south. Between the quarry and the road allowance to the south are 115 feet of available stone and about 100 feet still remain between the present opening and the road to the west. At the time of my visit the excavation was advancing in this direction.

The quarry is opened on the northeastern side of the elevated tract which runs in a general northwest direction. It is apparent, therefore, that the western end of the opening has advanced farther into the ridge and consequently presents a greater face. The upper layers of stone at the west end disappear towards the east proving that the present form of the elevation is due to erosion. On the north side, more particularly towards the east, there is a further reduction of the upper layers and much evidence of superficial decay with a greater thickness of overburden.

The section at the west end is as follows:—

6 ft.—Stripping. A little deeper towards south and thinner towards north.

3 ft. 3 in.—Mottled buff stone, shattered and used only for lime-burning. It is of the same quality as the bed below.

[1] I have been variously informed as to the date of the first opening of quarries in this area; some of my informants claim as early a date as 1894.

21 in.—Solid bed of buff mottled stone. } United in parts of the
21 in.—Solid bed of buff mottled stone. } quarry (1047).
2 ft.—Solid bed of buff mottled stone.
3 ft.— " " " " " "
2 ft. 6 in.— " " " " "
1 ft. 8 in.— " " " " "
2 ft. 8 in.—Solid bed of blue mottled stone (1048).
2 ft. 8 in.— " " " " " "

At the east end of the quarry, the top bed of the above section fails entirely and the surface decomposition and fracturing has extended into the lower beds for a distance of about 6 feet. Below these fractured strata, the lower buff beds of the western section appear in practically the same thicknesses down to the blue stone. Here, in descending order, the workable beds are 2 ft. 4 in., 2 ft. 3 in., and 1 ft. 8 in. thick.

In places the quarry has been sunk into the underlying blue beds exposing a bed of five feet in thickness below the blue beds mentioned in the section at the east end. A well of 170 feet shows 90 feet in all of blue stone with a recurrence of the buff variety beneath.[1]

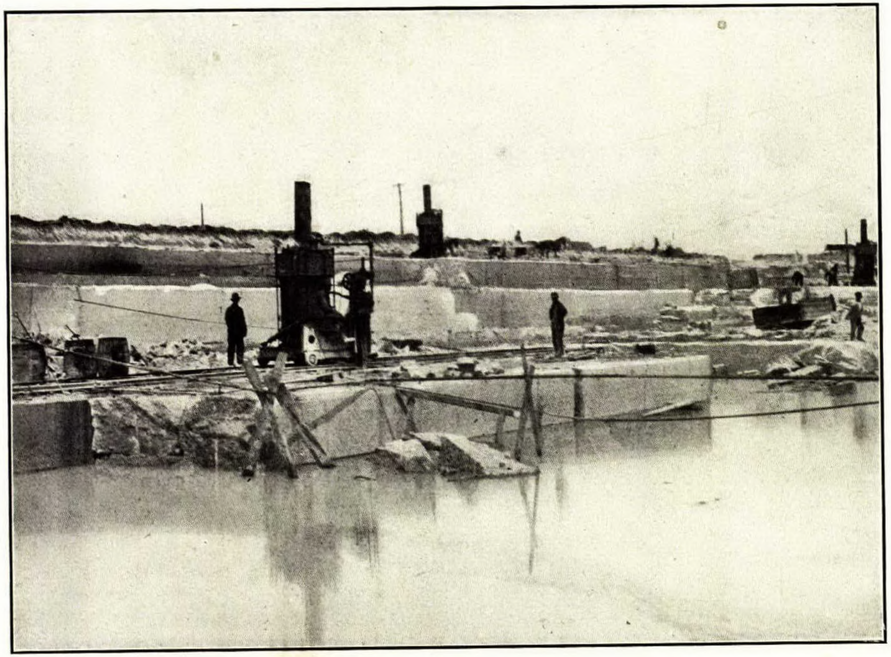
Joints are infrequent and do not seriously interfere with quarrying operations. The main series strikes east and west and is disposed in a vertical manner. The joints of this series are not continuous but appear and disappear. One of them forms the south wall at the eastern end of the quarry but it fails towards the west. It is said that only two or three such joints appear across the whole width of 500 feet. Cross joints in a north and south direction appear at intervals of about 400 feet. On the whole it may be said that the formation is practically free of joints which would seriously interfere with quarrying and in consequence stone of any desired dimensions can be obtained with facility (Plate VI).

While the formational jointing is not excessive, the solidity and colour of the stone are affected in places by the occurrence of the so-called yellow headings. One such heading occurs towards the southwest corner of the present quarry: it appears to represent a continuation of the main joint which forms the south wall, which has here spread out into a fractured zone about 25 feet wide. This altered zone shows 7 or 8 distinct fractures between which the stone is soft and has assumed a pronounced yellow colour in the darker component (No. 1051, page 56).

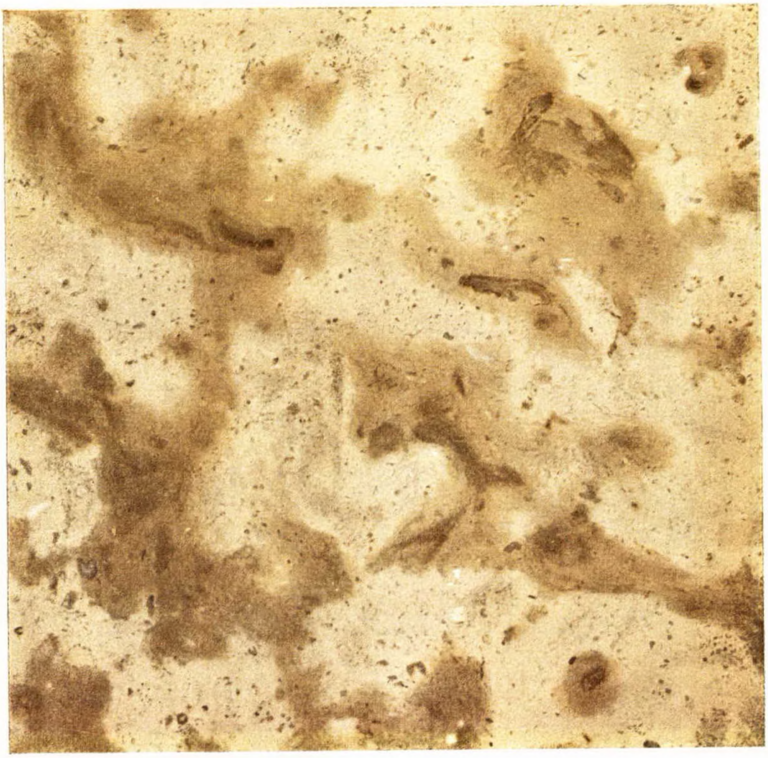
The stone: No. 1047.—This example is typical, not only of the present quarries, but of all the quarries in the Tyndall area. The stone is known to the trade as buff Tyndall or Garson limestone and it is commonly regarded as the best building stone of the western provinces.

The mass of the rock consists of a light buff coloured, even grained, fragmental limestone. With remarkable uniformity through this base are

[1] This statement was obtained from one of the local operators; it is not in accord with Dr. Wallace's section which is as follows: buff mottled, 14 ft.; blue mottled, 13 ft.; thin buff mottled, 62 ft. The total thickness of the formation is given as 130 feet.



Tyndall limestone. Quarry of the Wallace Sandstone Company, Lyall, Man.



Buff Tyndall limestone, parallel to bedding.

PLATE VIII.

Buff Tyndall limestone, vertical to bedding.

scattered large vermicular patches of a dark brownish material which probably amounts to about a third of the whole mass. Parallel to the bedding (Plate VII) these darker patches are larger, more continuous and with more evidence of inosculation; vertical to the bedding (Plate VIII) they are narrower and more lineal in arrangement. The remarkable uniformity with which these patches are distributed throughout the whole thickness of the formation (including the blue stone, probably 130 feet) is a feature very difficult of explanation. Professor R. C. Wallace who has made a careful study of the phenomenon is inclined to ascribe the mottling to local dolomitization induced by the presence of vegetable matter. The following extracts from Dr. Wallace's paper well describe the structural and chemical peculiarities of the stone.

"The darker coloured patches are evenly crystallized, showing sections of rhombohedra of dolomite, set close together, and occasional crystals of hematite passing over into limonite. The colour is due to the hematite and more particularly, the limonite, to which the action of percolating water has imparted a banded structure. Excepting a few large shells, which have not been affected, there are no traces of organic remains in the dolomitized areas. The light coloured areas, on the other hand, contain numerous fragments of brachiopod shells, with occasional patches of polyzoa and corals. These are set in a fine-grained calcitic material, strikingly different, even at the margin between the two areas, from the fairly perfectly crystallized dolomite.

"The following may be taken as representative of several sets of analyses:—

	Light coloured	Dark coloured
	Per cent	Per cent
Silica	1·56	1·56
Total iron as ferric oxide	0·16	1·94
Ferrous oxide	0·12	0·45
Alumina	0·06	2·27
Calcium carbonate	94·02	71·03
Magnesium carbonate	4·33	23·35
Total	100·13	100·15[1]

This remarkable mottling is not confined to the Upper Mottled limestone but it appears to a greater or less extent throughout the whole series of Palæozoic sediments of the Manitoba region from the Lower Mottled limestone to the Devonian. The analyses show that the dark parts contain much more iron than the lighter portions: in some rocks the mottling is expressed chiefly by the presence of iron. I should be inclined, therefore, to look to the iron rather than to algæ for an explanation of the phenomenon. It is to be hoped that Dr. Wallace will continue his studies of this remarkable structural feature.

[1] Journal of Geology, Vol. XII, No. 5, 1913.

The corrosion test shows that the stone is seriously affected, as the lighter portions are much etched out and present a rough appearance with little dark specks standing in relief. The darker portions are much less affected, doubtless due to their dolomitic nature, and seem to suffer only by the assumption of a rather more muddy brown colour. The most remarkable effect of natural weathering is the acquisition of a very dark—almost black—colour by the darker parts of the stone.

The most objectionable feature of the Tyndall stone is the occasional occurrence of large fossils, particularly *Receptaculites*, *Maclurina*, and *Halysites*. These disfigurations frequently spoil a block for fine cut work but generally they may be avoided in selecting blocks for more conspicuous positions. The mottling of the stone does much to detract from the conspicuousness of the included fossils.

It is apparent that a coarsely mottled stone, possessing two elements of quite different characteristics, will give varying results under the physical tests. In the case of crushing strength three examples gave 10,806, 10,100 and 9,195 lbs. per sq. in., respectively. There is no doubt that a similar variation would be found in the other tests and in consequence the results given below must be regarded as approximate only.

Specific gravity	2·767
Weight per cubic foot, lbs	151·54
Pore space, per cent	12·17
Ratio of absorption, per cent, one hour	1·076
" " " two hours	2·702
" " " slow immersion	3·816
" " " in vacuo	4·57
" " " under pressure	5·01
Coefficient of saturation, one hour	0·21
" " two hours	0·54
" " slow immersion	0·76
" " in vacuo	0·91
Crushing strength, lbs. per sq. in., dry	10,806· 10,100· 9,195·
Crushing strength, lbs. per sq. in., wet	8,000·
" " " " wet after freezing	8,818·
Transverse strength, lbs. per sq. in	1,382·
Shearing strength, lbs. per sq. in	1,063·
Loss on corrosion, grams per sq. in	0·158
Drilling factor, mm	30·0
Chiselling factor, grams	11·30

It will be observed that the crushing strength is greater after freezing; this result is doubtless due to an unavoidable difference in the cubes and must be interpreted as meaning that the stone is not appreciably affected by the freezing test. It is also worthy of remark, that this—the most desirable building stone of the three provinces—is low in both crushing and transverse strength and high in porosity. In other words, softness and the consequent susceptibility to carving, together with general appearance and formational advantages far outweigh superior strength and low porosity. The real coefficient of saturation—that for slow immersion—is well below the danger line.

Wells gives two analyses of stone from this quarry but he does not state whether they are the buff or the blue variety. I assume, however, that the buff stone is referred to. The figures are as follows:—

	Average sample	Selected sample
	Per cent	Per cent
Moisture	0·03	0·03
Insoluble matter	1·20	0·90
Alumina and iron oxides	0·70	0·70
Lime carbonate	89·67	90·52
Magnesium carbonate	8·40	6·54
Sulphur trioxide	traces	0·14
	100·00	98·83[1]

No. 1048.—This stone, known as the "blue Tyndall or Garson limestone," is very similar in all its properties to the buff stone with the exception of colour. The ground mass has a slightly bluish cast and the darker parts are greyish or bluish-brown (Plate IX). Architects favour the buff variety but the blue stone is also extensively used.

A comparison of the following table with that given for the buff stone on page 50 shows that very little physical difference exists between the two varieties.

Specific gravity	2·741
Weight per cubic foot, lbs	152·88
Pore space, per cent	10·55
Ratio of absorption, per cent, one hour	1·595
" " " two hours	2·296
" " " slow immersion	3·841
" " " in vacuo	4·296
Ration of absorption, per cent, under pressure	4·296
Coefficient of saturation, one hour	0·37
" " two hours	0·53
" " slow immersion	0·89
" " in vacuo	1·00

[1] Dept. Mines Can., Mines Branch, Report on the Limestones and Lime Industries of Manitoba, 1905.

Crushing strength lbs. per sq. in., dry	10,724· 9,289·
" " " wet	8,357
" " " wet after freezing	9,012·
Transverse strength, lbs. per sq. in	1,297·
Shearing strength, lbs. per sq. in	1,048·
Loss on corrosion, grams per sq. in	0·182
Drilling factor, mm	20·0
Chiselling factor, grams	9·90

In this case, as with the buff stone, the crushing strength after freezing is higher. We must attribute this anomalous result to differences in the cubes. Judging from the coefficient of saturation the blue stone is more susceptible to injury by frost than the buff variety. The corrosion test lessens but does not entirely remove the blue cast of both the lighter and the darker parts. As in the case of the buff stone, a serious etching of the lighter portion occurs. Little if any effect is to be observed as a consequence of the freezing test.

The overburden and the upper shattered beds having been removed, the good beds of buff stone are attacked in the following way:

(1) A channel cut is run across the quarry, *i.e.*, north and south to a depth of 5 ft. 6 in. or through the three upper workable beds. This channel is made five feet back from the face.

(2) Two cross channels are made at each end of the strip and the key blocks removed.

(3) The strip is raised by plug and feathers. For this purpose holes 6 inches apart and 6 inches deep suffice.

(4) The strip is cut into lengths of 8 to 15 feet by plug and feathers.

The quarry equipment is as follows:—

3 Sullivan rigid head channellers with boilers on carriages. Efficiency, 800 sq. ft. per day of 10 hours.

3 Ingersoll Rand tripod drills (air or steam).

12 Ingersoll Rand Butterfly jackhammers.

1 Ingersoll Rand compressor, 650 cubic feet of free air per minute, at a pressure of 90 lbs.

5 derricks of about 18 tons capacity. Each has separate hoist (4 electric, one steam).

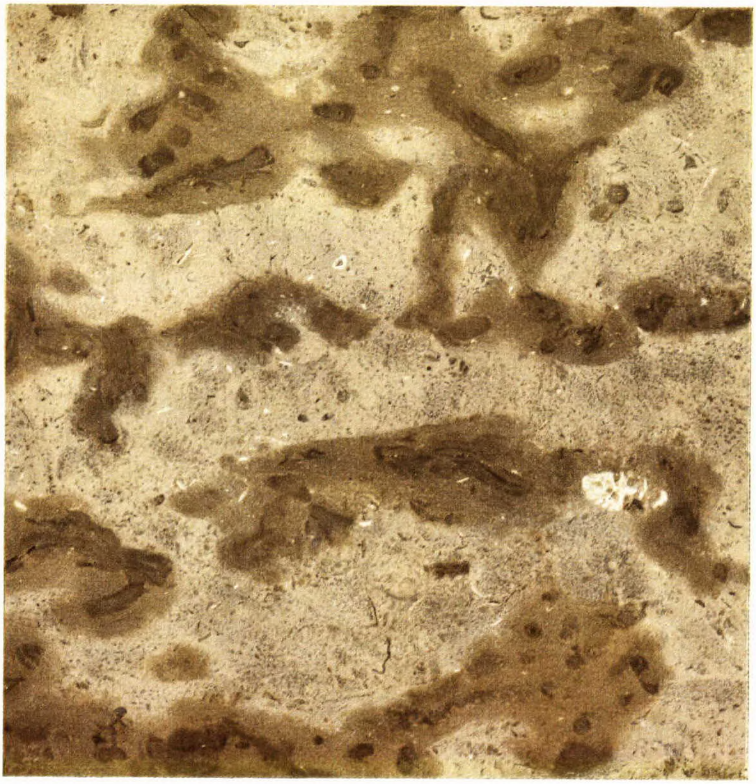
1 Marion, model 28, steam shovel.

The company maintains a well equipped mill on the quarry property in which a large part of the output is worked up into dressed stone. The mill building is 600 by 100 feet and is equipped with the following appliances:—

Crane gantry running the length of the mill with 65 feet span.

1 25-ton crane, two motor, Lane Manufacturing Co.

1 electric crane, Whiting Foundry Co., Harvey, Ill.



Blue Tyndall limestone, vertical to bedding.

1 5-ton electric crane, Dominion Bridge Co., Montreal.
1 small hand crane in stacking yard.
1 gang saw, Bedford Foundry and Machine Co., Bedford, Ind.
1 gang saw (short hanger), Geo. Anderson, Montreal.
1 gang saw, New Albany Manufacturing Co., Rutland, Vt.
3 diamond saws, Geo. Anderson, Newark, N.J.
1 12-ft. rubbing bed, F. R. Patch Manufacturing Co., Rutland, Vt.
1 planer, Young and Farrell, Diamond Stone Sawing Co., Chicago and New York.
4 planers, Lincoln Iron Works, Rutland, Vt. (One with Thompson's patent circular attachment.)
2 lathes.
1 pneumatic bush hammer machine, Trow and Holden, Barre, Vt.
1 Gardiner Rix compressor, 150 cu. ft. free air per minute.
36 pneumatic tools.

The above equipment was in operation at the time of my visit in July, 1914; since that time the company has installed a double diamond saw, a drag diamond saw, and 4 planers. The mill building has been extended 70 feet.

The gang saws all work with chilled shot (W.H. 393) and have an efficiency of 5 inches per hour on general work. The diamond saws cut 5 inches per minute regardless of thickness; two of the saws are double bladed and can accommodate work 3 ft. 6 in. thick; one is single bladed with a capacity for work 3 ft. thick. Each of the planers averages 50 cubic feet of dressed stone per day of ten hours.

Power is obtained from the city of Winnipeg's power plant at Point du Bonnet. The current is received at 1,300 volts from the sub-station at Saldo junction and is reduced to 550 volts by 3 transformers, by the Canadian Westinghouse company. As each machine in the mill is operated by a separate motor, 35 are in use; they are all of 60 cycle, 3 phase type. A lighting system is installed with pole transformers whereby the voltage is reduced to 110. At the time of my visit the company was using 630 h.p. in all.

Besides the mill the company has erected buildings as below:—

Manager's residence.
Two boarding houses.
Transformer house.
Machine shop.
Blacksmith shop.
Boiler house, now used as supply storage house.
Stables and several small buildings.

The blacksmith shop contains 3 forges and the machine shop is thoroughly equipped for all sorts of repairs; it is supplied with crucibles for brazing high speed steel to the shanks of the planer tools whereby a considerable saving of the expensive steel is effected.

The company also owns 2 miles of siding to the Canadian Pacific railway at Garson. In all, $3\frac{1}{2}$ miles of track are maintained. The rolling stock consists of one locomotive by the Davenport Locomotive Works, Davenport, Iowa, one flat car and one dump car.

Waste stone is converted into lime in 6 draw kilns. A well of about 200 feet in depth supplies water for the works. This well is equipped with a powerful pump working at about one stroke per second and delivering 75 gallons per stroke. A large centrifugal pump is installed for unwatering the quarry.

At the time of my visit 250 men were employed in all. The average scale of wages is as follows:—

Stonecutters	65	cents	per	hour.
Machinists	50	"	"	"
Planer men	50	"	"	"
Blacksmiths	45	"	"	"
Crane men	40	"	"	"
Diamond saw men	40	"	"	"
Channeller and hoist men	40	"	"	"
Quarrymen	$27\frac{1}{2}$–30		"	"
Gang saw men	25	"	"	"
Labourers	25	"	"	"

The average price of cut stone is $1.25 per cubic foot, f.o.b., and quarry blocks are quoted at 20 to 25 cents per cubic foot.

The production in 1913 and 1914 was as follows:—

	1913	1914
Cut stone	105,000 cu. ft.	78,000 cu. ft.
Quarry blocks	99,100 cu. ft.	126,000 cu. ft.
Rubble	2,776 cords	1,996 cords
Lime	128,000 bushels	112,000 bushels

A few of the more important buildings of this stone are given below:—

Royal Alexandra hotel, Winnipeg.
Law courts, Winnipeg (part).
Parliament buildings, Regina (Plate I).
Presbyterian church, Moosejaw, Sask.
Court house and Land Titles building, Humboldt, Sask.
Armouries, Prince Albert, Sask.
Court house and Land Titles building, Swift Current, Sask.
Registry office, Fort William, Ont.
Post-office, Sault Ste. Marie, Ont.
Gaol and gaoler's house, Sault Ste. Marie, Ont.

It is interesting to note that a carload of stone was shipped as far east as Montreal and that the company is at present engaged in cutting stone for the new Canadian Pacific Railway station in North Toronto.

G. W. Murray, 333 Rosedale Ave., Winnipeg.

Mr. Murray is operating on part of the northwest quarter of section 3, township 13, range 6 east. This property is leased on royalty from John Gunn of Winnipeg who owns the greater part of the section. The quarry (Plate X) lies directly south of the quarry of the Wallace company: its western face has not advanced quite as far in that direction as the west wall of the Wallace quarry; it extends about 600 feet south. In the east and west direction the quarry has a length of about 550 feet and has been worked up to the road allowance on the north throughout this distance. Mr. Murray proposes to extend the opening west and south but the available stone is limited in the former direction as building lots have been sold along the road between sections 3 and 4. The sequence of strata exposed on the south face is as follows:—

11 ft.—Stripping, including the upper broken stone. The upper broken bed is exposed at the east and is absent at the western end of this face.
2 ft. 6 in.—3 ft.—Buff mottled stone somewhat pitted; this is not used for fine work.
2 ft.—Solid bed of buff mottled stone.
22 in.—Solid bed of buff mottled stone.
2 ft. 4 in.—Solid bed of buff mottled stone.
2 ft. 6 in.—Solid bed of buff mottled stone.
1 ft. 8 in.—Solid bed of buff mottled stone.
————Blue mottled stone.

A comparison of this section with that given for the Wallace quarry on page 47 shows that the two beds immediately overlying the blue stone are identical and that a general similarity continues upwards. In the present quarry, however, the total thickness of good beds is 10 ft. 4 in., while in the Wallace quarry it is 12 ft. 8 in., omitting the upper broken stone in both instances. Assuming, with reason, that the upper surface of the blue stone marks a common horizon in both quarries it is apparent that the axis of the ridge has been passed before the southwest angle of the present quarry is reached. This conclusion is further supported by the fact that higher beds occur towards the east end of the south face. The ridge therefore is of very limited width: it extends in a general northwest direction and falls off on both sides by *erosion of the upper beds* accompanied in both cases by an increase in the thickness of the overburden. If these conclusions are correct, the amount of available stone is limited to the south, and further loss of the upper beds is to be expected in extending the quarry in that direction.

The jointing is not excessive in the greater part of the quarry and it does not interfere with the extraction of large stone, as pieces 50 to 100 feet long have been taken out from the south side. On the other hand, a peculiar yellow heading on the eastern side of the opening detracts from the value of a large quantity of stone. A strong joint enters the quarry near its southeast angle and strikes N.5°W. (mag.) across the property. At a point on the east wall 132 feet from the southeast corner another joint enters the quarry, strikes W.20° S. (mag.) and continues until it meets the first joint. In the triangular portion between the two joints all the stone is somewhat shattered (1050) and for a distance of 6 to 10 feet from the joints it presents a yellow and undesirable colour (1051).

Outwards from the two joints bounding this triangle there is no trace of discolouration. The alteration of the stone has doubtless been effected by water circulating in a fractured zone, but it seems rather remarkable that this effect has not extended for at least a short distance beyond the limiting joints.

Mr. Murray is now engaged in altering the arrangement of the tracks whereby he hopes to more advantageously handle the product of the quarry which is now being advanced towards the south and west. The waste material is being used to fill the older parts of the excavation towards the north.

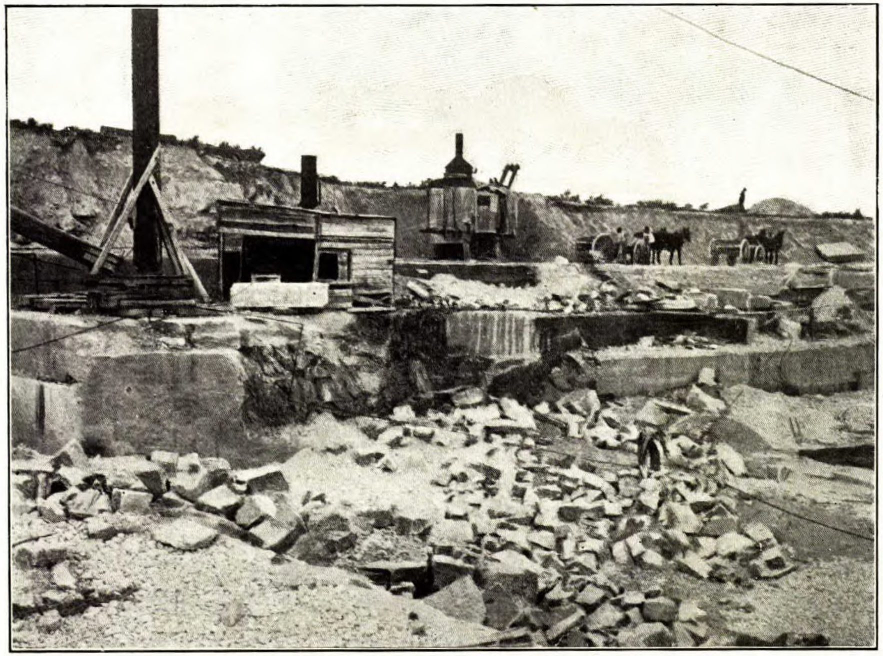
The stone.—The high grade buff and blue stones in this quarry are the same as Nos. 1047 and 1048 described on pages 48-52.

No. 1050—This example represents the fractured stone between the two joints referred to above; it does not seem very different from the good stone except for a slightly softer texture and a greyish rather than a distinctly buff colour in the dark component. It is a less "lively" stone than No. 1047.

No. 1051—This specimen is selected to illustrate the worst type of stone in the altered yellow headings. The stone is somewhat softer than the good type but not remarkably so; the most noticeable difference is the deepening of the yellow in the dark component together with a lack of uniformity in tone. The light part is rather whiter and consequently there is a sharp contrast between the two components. This stone resembles the altered variety from East Selkirk—No. 1198.

The equipment at the quarry is as follows:—

Small compressor building.
1 40-h.p. compressor delivering air at 90 lbs. per sq. in.
2 20-ton derricks with steam hoists.
1 15-ton derrick with steam hoist.
1 Ingersoll Rand steam channeller.
2 Ingersoll Rand Butterfly jackhammers.
6 Ingersoll automatic hammer drills.



Tyndall limestone. Murray's quarry, Lyall, Man.

3 Ingersoll Rand rock drills on tripods (one No. 0, one No. 2, and one No. 4).

1 steam shovel, Vulcan Steam Shovel Co., Toledo, Ohio.

4 draw kilns.

The quarry is connected with the Canadian Pacific railway by a mile of track extending to the spur of the Tyndall Quarry Co. Sixty men are employed.

At the time of my visit the production was abnormally low. I am informed by Mr. Murray that, working at the capacity of the plant, the following figures represent the general average:—

Lime—1,400 bushels per diem.

Rubble—36 cords per diem.

Quarry blocks—3,000 cubic feet per diem.

Quarry blocks are quoted at 25 cents per cubic foot, rubble at $6 per cord, and lime at 20 cents per bushel, all f.o.b.

John Gunn and Sons, 300 Bank of Nova Scotia building, Winnipeg.

This firm owns all of section 3, township 13, range 6 east, with the exception of the north half of the northeast quarter, which belongs to the Tyndall Quarry Co. No quarrying is now being done by John Gunn and Sons but it is proposed to describe here an abandoned quarry lying immediately to the east of the quarry of G. W. Murray.

The excavation extends for about 500 feet along the south side of the road; it has a width of more than 300 feet at the east and is somewhat more narrow at the west. The section exposed at the east end is as follows:—

4 ft.—Soil.

3 ft. 4 in.—Shattered beds.

1 ft. 10 in.—Buff mottled stone somewhat pitted.

3 ft. 3 in.—Buff mottled stone, in part solid but in places an upper 10-inch bed is separated from the lower part.

Below this level the quarry is filled with water. The water line shows that the beds have a slight inclination to the northward and the north face shows that the surface cracking has affected the stone down to the last bed mentioned in the section. It is evident that here we are very close to the edge of the ridge and that little is to be hoped by extending the quarry northward across the road. The prospects for enlarging the quarry are more favourable towards the south. Infrequent joints cross the formation in an east and west direction. There is no present production; I have been informed that the stone from this quarry was found to be somewhat harder than the product of the other quarries in the vicinity. A small saw shed is installed on the property.

Tyndall Quarry Co., L. Manson, manager, Winnipeg.

This company is really a syndicate of several stone supply companies in Winnipeg as below:—

Winnipeg Stone Company, office, 2314 Tribune building, Winnipeg: mill, 297 Gurney ave.

Western Stone Company, Youville and Desautels streets, St. Boniface.

Menzie and McIntyre, Erin street, Winnipeg.

Oliver and Manson, Erin street, Winnipeg.

The quarry (Plate XI) is situated on the north half of the northeast quarter of section 3, township 13, range 6 east. Unlike the quarries of Murray and Gunn immediately to the west, the opening in this instance does not lie close to the road but at a distance of about 200 yards to the south: it extends about 800 feet east and west and almost as great a distance north and south. The quarry is advancing to the south and west where the section is as follows:—

6 ft.	—Stripping.
3 ft.	—Broken buff stone used for lime burning only.
3 ft. 9 in.	Buff mottled limestone in solid beds.
2 ft. 6 in.	
2 ft. 4 in.	
1 ft. 8 in.	
1 ft. 8 in.	
2 ft.	Blue mottled limestone. These layers are not quarried over the whole extent of the opening, but in the central deeper part only.
2 ft. 6 in.	
3 ft.	
2 ft. 4 in.	
2 ft. 6 in.	
3 ft. 6 in.	

A comparison of this section with that given for the Wallace quarry on page 47 suggests that the upper broken bed is the same in both quarries. The layers are almost horizontal but they seem to have a slight inclination S.23°W. (ast.); this would indicate that the axis of the ridge has been passed before reaching the southwest face of the quarry. Towards the east end of the excavation the zone of surface cracking extends to a greater depth indicating an approach to the edge of the ridge in that direction. Towards the south the stone appears to continue to about the limit of the 80 acres, south of which there is a distinct fall-off in the level of the land. Joints are not of frequent occurrence and do not interfere with the extraction of large blocks. The major set runs N. 65° E. (mag.) vertically.[1]

Minor fractures or "dries" occur in places only and do not seriously interfere with the solidity of the formation.

[1] The magnetic variation is about 13° west.

Tyndall limestone Quarry of Tyndall Quarry Company, Lyall, Man.

The stone:—The product of this quarry in both the buff and the blue varieties does not differ from the typical examples described as Nos. 1047 and 1048 on pages 48-52.

The equipment of the company is as follows:—

Mill.

Building 80 ft. by 22 ft., with engine room annex, 14 ft. by 12 ft.

1 boiler by Stuart Machinery Co., Winnipeg.

1 12-h.p. engine by Laurie Engine and Machine Co., Montreal.

1 40-h.p. compressor, Canadian Ingersoll Rand (200 ft. of free air per minute.)

1 gang saw by New Albany Manufacturing Co., New Albany, Ind.

Quarry.

1 Ingersoll Rand rigid head stream channeller.

1 Sullivan rigid head stream channeller.

2 horse derricks.

2 steam derricks.

3 Ingersoll Rand Butterfly jackhammers.

3 tripod drills, Ingersoll Rand.

The quarry is connected by a spur with the Canadian Pacific railway and three tracks are laid in the quarry up to the working face. Traction is effected by a small locomotive made by the Montreal Locomotive Works. The company has three pot kilns for converting the waste stone into lime.

The output in 1913 was as follows:—

Quarry blocks—145,421 cubic feet.

Rubble—1803 cords.

Lime—128,000 bushels.

Quarry blocks are sold to the companies forming the syndicate at 20 cents per cubic foot.

The force at work at the time of my visit was as follows:—

20 quarrymen at 25 cents per hour.
12 lime men „ 22½ „ „ „
7 engineers „ 40 „ „ „
23 labourers „ 20 „ „ „

Each of the four independent companies forming the syndicate operates a mill in Winnipeg or St. Boniface: in accord with the practice throughout this report these mills are briefly described below.

Winnipeg Stone Co., 297 Gurney Ave., Winnipeg.

The building is 135 feet by 33 feet with two annexes—one 66 ft. by 20 ft. and the other 66 ft. by 27 ft. Crane gantrys are erected in the mill proper and in the annexes. Four hand cranes command all parts of the mill (Plate XII).

The equipment is as follows:—

1 60-h.p. motor operating—

2 Patch gangsaws.
1 double Patch planer.
1 Ingersoll Sargeant compressor.
1 30-h.p. motor operating—
1 diamond saw, General Machinery Co., St. Boniface.
1 30-h.p. motor operating—
1 small Patch diamond saw and
1 small Patch planer.
1 Ingersoll Sargeant compressor operating—
1 surfacer by the General Machinery Manufacturing Co., St. Boniface.
1 engine and boiler (not now used).

A stone yard adjoins the mill and is equipped with a travelling crane the length of the mill. The crane is operated by steam; it has a 40-ft. span and a capacity of 30 tons. Two small hand derricks are installed in the stone yard. A blacksmith shop and an office building are provided. The company operates almost entirely on Tyndall stone and employs from 30 to 35 men.

Tyndall stone supplied by this company may be seen in the following buildings:—

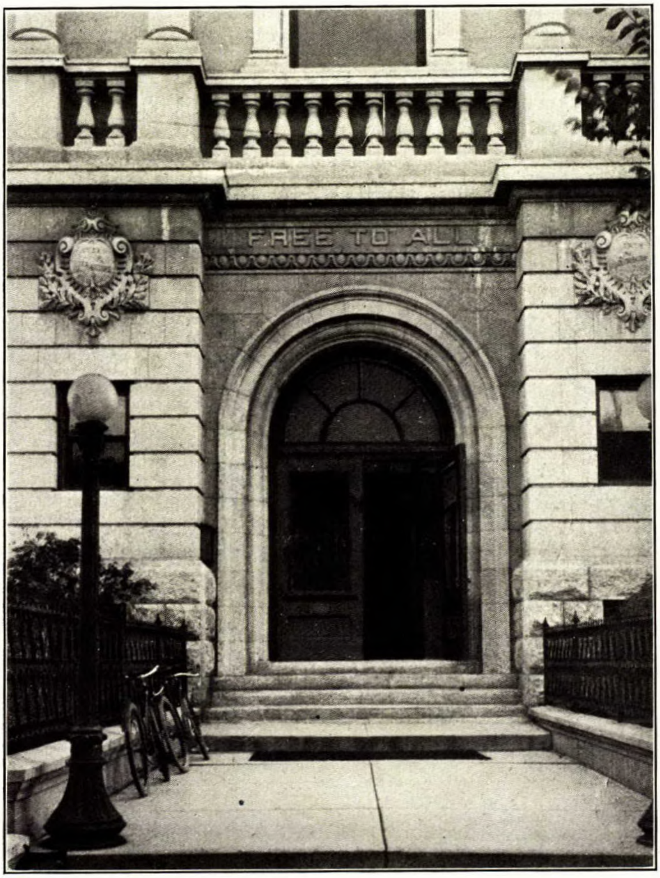
Law courts, corner of Broadway and Kennedy st., Winnipeg.
Carnegie library, Winnipeg (Plate XIII).
New parliament buildings, Winnipeg.
Land Titles building, Winnipeg (Plate XIV).
Sir Daniel McMillan's residence, Winnipeg.

Western Stone Co., Joseph Bourgeault, president, corner Youville and Désautels streets, St. Boniface.

The mill is about 250 ft. by 60 feet; it is commanded throughout by two electric cranes by the General Machinery Manufacturing Co., St. Boniface.

The chief equipment is as follows:—
1 gang saw, Patch Manufacturing Co., Rutland, Vt.
3 double blade diamond saws, George Anderson, Montreal.
1 planer, Lincoln Iron Works.
1 12-ft. rubbing bed, Patch Manufacturing Co.
1 Jenny Lind polisher, Patch Manufacturing Co.
1 lathe.
1 Canadian Rand compressor.
1 small compressor.
5 derricks and minor apparatus.
Electric power is used throughout and about 65 men are employed.

Tyndall limestone. Mill of Winnipeg Stone Company, Winnipeg, Man.



Tyndall limestone. Door of Public Library, Winnipeg, Man.

PLATE XIV.

Tyndall limestone. Land Titles building, Winnipeg, Man.

Menzies and McIntyre, Erin St., Winnipeg.

The mill building is 60 ft. by 50 ft. and contains :—

One double blade diamond saw, Geo. Anderson, Montreal.

Two planers, Patch Manufacturing Co.

One gang saw, Lincoln Iron Works.

In addition to the mill proper there is a cutting shed 70 ft. by 32 ft. equipped with a hand crane by the General Machinery Manufacturing Co. Two derricks of 5 and 15 tons capacity are installed. Twenty-five men are at present employed.

Oliver and Manson, Erin St., Winnipeg.

The mill building is about 100 ft. by 100 ft. with annexes. The chief equipment is as follows:—

2 double blade diamond saws, Geo. Anderson, Montreal.

1 diamond saw built by the owners.

2 hand cranes.

1 electric crane.

1 small Canadian Rand compressor.

1 planer, Lincoln Iron Works, Rutland, Vt.

1 planer, Patch Manufacturing Co.

The yard is equipped with two electric cranes. A machine shop is provided. Forty men are employed. The company operates chiefly on Tyndall stone but other stone is used as well.

Wm. Hazell, Lyall P. O., Manitoba.

This quarry, now abandoned, was one of the first opened in the district: it is situated on the northwest quarter of section 34, township 12, range 6 east, and is therefore about a mile south of the group of quarries already described. The formation is more disturbed than in the other quarries and there is no evidence that it is situated on the same general elevation; in fact, if our conclusions are correct as to the general character of the ridge at Lyall, the present quarry is situated on quite a separate elevation. The opening is narrow and of about 200 feet in length in a direction 20 degrees south of west (mag.). About the middle of the quarry the strata dip at a low angle to the east but at the west end they are slightly inclined to the south; on the whole the trend is southward at a low angle.

A section at the west end shows the following beds:—

3 ft.—Stripping. Varies up to 5 ft.

2 ft.—Buff mottled limestone, much broken.

2 ft. 4 in.—Buff limestone bed, somewhat broken.

2 ft. 9 in.—Buff limestone beds. Somewhat broken and inclined to split into thinner material.

——Floor of upper workings.

1 ft.—Buff mottled limestone. In part continuous with the bed above.

2 ft. 7 in.—Buff limestone of more solid character.

2 ft.—Hole filled with water.

The most pronounced joints strike W. 10° N. and dip 70° to the northward. On the whole the formation seems to be much fractured compared with the quarries at Lyall. The stone above the floor of the upper workings is of the ordinary buff variety but the lower stone shows a considerable amount of the yellow and undesirable type.

Stone is exposed or covered by a slight stripping for some distance in the neighbourhood of the quarry. The surface is broken at this point but prospecting would likely show other locations at which operations could profitably be attempted.

The proposed extension of the Canadian Northern Dundee branch will pass close to the property and should increase the value of the quarry.

This stone may be seen in the Mitchell block in Winnipeg; it was also used for the trimmings of the school at Boissevain. (See Plate XXXIV and page 180).

C. P. Malmstrom, Lyall P. O., Manitoba.

This property is the south half of the northeast quarter of section 33, township 12, range 6 east. A slight declivity runs across the property in a direction about 30° north of west (mag.). The upland is to the north and east and the lowland to the south and west of this line. Quarrying has been attempted along the face of the ridge but the formation appears to be much broken as nothing but loose blocks is to be observed at present. The stone is of the buff variety with the characteristic yellow staining observable in places. The comparative absence of soil along the edge of the upland with the consequent occasional exposure of stone indicates the possibility of future production at this point. It would appear that this outcrop lies along the same general elevation which renders the stone accessible on Wm. Hazell's farm.

Wm. Henry, Lyall P. O., Manitoba.

Mr. Henry holds the southwest quarter of the northeast quarter of section 9, township 13, range 6 east. This property is therefore along the same general direction as the Tyndall, Murray and Wallace quarries. There appears, however, to be a slight depression in the country between the Henry and Wallace properties.

A trench has been sunk through the stripping, which averages about 5 feet, for a distance of 600 feet in a north and south direction. A small opening has been made in the upper bed which is 2 feet thick and shows considerable shattering, which is common in the upper layer. The stone is the desirable buff variety and would doubtless be encountered in a solid condition at greater depth. It is stated that a well at this point shows buff stone to a depth of 50 feet, indicating probably 35 feet of good marketable stone. A good horse derrick has been erected and a siding graded to Garson station, but no stone had been shipped up to the time of my visit in June, 1914.

Alexander Murray, Lyall P. O., Manitoba.

Mr. Murray has thoroughly tested the depth of the drift over his property which is the north half of the southeast quarter of section 9, township 13, range 6 east. He found the stripping to range between 5 and 7 feet over the whole of the 80 acres. As the surface stone is the good buff variety there can be little doubt that a large amount of stone is reasonably accessible on this property.

Mr. G. W. Murray has kindly furnished the following information as to the depth of the drift on some properties in this neighbourhood as follows:—

Northwest quarter of section 10, 13, 6—the stripping is 20 feet and probably more in places.

East half of northeast quarter of section 10, 13, 6—the stripping is as great as 80 feet.

The Stringland Quarry.

This quarry, now abandoned, was opened for lime burning on the south half of the northeast quarter of section 15, township 13, range 6 east. The quarry was opened on the south side of a slight elevation which strikes in a general east and west direction. On the higher land the stripping is 4 feet, beneath which are two broken beds of 14 to 16 inches in thickness. Beneath these broken beds are two layers of about 2 feet each which appear to be horizontal and somewhat less shattered. On the lower land the stripping is 7 feet, and the underlying stone is so fractured that the bedding is not clearly perceptible. The stone is of the buff variety but it appears to have a nodular fracture and to be soft in places. Although some good blocks could undoubtedly be obtained, the formation on the whole is much too broken to compare with the quarries nearer Garson.

William Sinclair, Tyndall, Manitoba.

Mr. Sinclair's property is situated north of the railway in the same general district as the Stringland quarry.

The quarry on this property was opened for the production of stone for lime burning and it has never been worked for building stone. The exposures occur on the side of a comparatively deep ravine. The stripping is negligible and is succeeded by about 15 feet of loose, broken and dislodged blocks. Below this is a bed of 2 feet 6 inches in thickness which has scarcely been opened. This lower stone is seriously jointed and presents a considerable amount of yellowish alteration (1053).

The stone: No. 1053.—Resembles the buff Tyndall stone but is softer and with a more muddy appearance. The light parts are yellowish and the darker parts are greyish rather than buff. This stone may be compared with that from the shattered zones of the Tyndall quarries (No. 1050) but it is not as good material.

Summary—Tyndall Area.

The most important building stone produced in the three provinces is obtained from the quarries near Garson and Tyndall on the line of the Canadian Pacific railway about 30 miles northeast of Winnipeg. The stone belongs to the upper division of the Trenton formation known as the Upper Mottled limestone. To the trade the stone is known as Garson or Tyndall stone and at more distant points it is sometimes called Winnipeg stone. At the chief centre, near Lyall (Garson) post-office, three large quarries are in operation, and a number of smaller quarries or undeveloped prospects occur in the immediate neighbourhood (Fig. 3).

The stone is a soft limestone with a characteristic mottling in darker colours. Two types are recognized—a buff variety and a blue variety. The former type is generally preferred by architects but a considerable amount of the blue stone is also used. Both varieties can be quarried in large blocks and both are capable of being dressed and carved with ease. The occasional occurrence of large fossils detracts somewhat from the appearance of the stone. The buff stone is shown in Plates VII and VIII and the blue stone in Plate IX. The former variety is described in detail on page 48 and the latter on page 51.

Many of the chief buildings in Winnipeg are built of Tyndall stone: it has been used extensively in the Prairie Provinces and has been shipped into Ontario. Some of the more important buildings are indicated in the following list:—

Winnipeg, Man.

Royal Alexandra hotel.
Law courts.
Grand Trunk Pacific Railway station.
Carnegie library (Plate XIII).
Residence of Sir Daniel McMillan.
Parliament buildings.
Land Titles building (Plate XIV).
Mitchell block.
Numerous churches, schools and business blocks.

Tyndall limestone. Post-office, Lethbridge, Alberta.

Tyndall limestone. Post-office, Moose Jaw, Sask.

Regina, Sask.
Parliament buildings (Frontispiece).
King's hotel.
Post-office.
Imperial bank.
Dominion Trust Co.'s building.
Credit Foncier building.
Bank of Ottawa.
Land Titles building (part).

Prince Albert, Sask.
Armouries.

Humboldt, Sask.
Court house.
Land Titles building.

Swift Current, Sask.
Court house.
Land Titles building.

Moosejaw, Sask.
Dominion Express Co.'s building.
Dominion bank (part).
Bank of Commerce (part).
Walter Scott building.
Imperial bank (part).
Land Titles building (part).
Post-office (Plate XVI).
St. Andrew's church.

Lethbridge, Alta.
Post-office (Plate XV).
Macleod, Alta.
Bank of Commerce (part).
Edmonton, Alta.
Imperial Bank of Canada (base).
Post-office.
Sault Ste. Marie, Ont.
Post-office.
Gaol and gaoler's house.
Fort William, Ont.
Registry office.
Toronto, Ont.
Canadian Pacific Railway station, North Toronto.

Literature:—Geol. Sur. Can., Ann. Rep., Part F, Vol. XI.
Dept. Mines, Can., Mines Branch, Report on the Limestones and Lime Industry of Manitoba, 1905.
Jour. of Geol., Vol. XXI, No. 5, 1913 (R. C. Wallace—Pseudobrecciation in Ordovician Limestones in Manitoba).

Lake Winnipeg Area.

On some of the points of the east side of Lake Winnipeg and also on certain of the islands, the Upper Mottled limestone overlies the lower series and presents outcrops from which stone might be obtained. A short list of localities is given on page 40. For an extended account the reader is referred to the reports of Tyrrell and Dowling already cited. As far as I have been able to ascertain, none of these exposures present features worthy of especial attention from our point of view. The stone in each instance appears to be hard and not comparable with the stone of East Selkirk and Tyndall.

LIMESTONES OF THE RICHMOND FORMATION.

The Upper Ordovician or Cincinnatian series is represented in Manitoba by limestones and shales which are provisionally correlated with the Richmond formation of the Ohio valley. The upper strata are of limestone and are exposed at Stony mountain, Little Stony mountain and at points west of the line of the Canadian Pacific railway between Winnipeg and Stony mountain. For the most part, the rocks are thin-bedded, hard and cavernous, and are not adapted to structural purposes. The quarries have been worked almost exclusively for the production of crushed stone but some of the thicker beds have been used for building. All the quarries may be included in one area which we may designate the Stony Mountain-Winnipeg area.

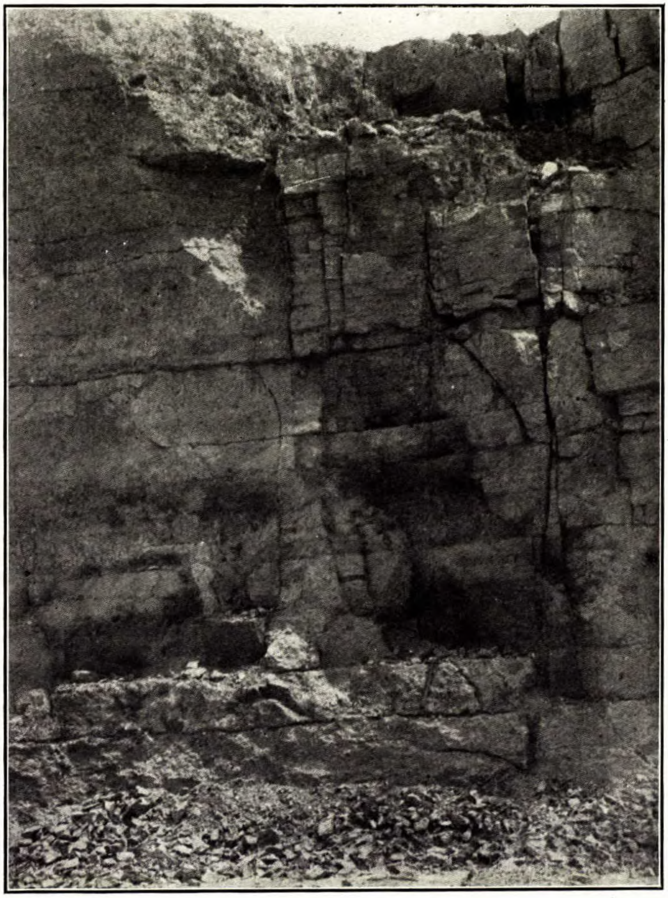
Stony Mountain-Winnipeg Area.

Corporation of the City of Winnipeg; Charles P. Kelpin, local manager, Stony Mountain, Manitoba.

The city's quarry is opened along the upper face of the escarpment to the northward of the village of Stony Mountain; its length is about 1,500 feet and its maximum width is about 500 feet. The property consists of legal subdivisions 2 and 3, less the most northerly chain and the most westerly chain. It is on the southwest quarter of section 14, township 13, range 2 east.

The floor of the quarry is uneven and shows different dips in different parts. At the southwest end the beds dip slightly to the south; a comparatively level floor is presented through the middle sections of the quarry but near the northeast end there is a sharp syncline with a north and south axis. In this part the general dip is to the northeast. On the whole it

PLATE XVII.



Stony Mountain limestone. City of Winnipeg's quarry, Stony Mountain, Man.

may be said that there is a gentle inclination of the beds east and north. The stripping is slight near the middle of the quarry but it increases to 4 feet at the northeast end (Plate XVII).

The section near the middle of the quarry is as follows:—

6 in.—Stripping; varies.

6 ft. 7 in.—Thin-bedded limestone, shaly towards top, reddish with clay streaks towards bottom. Makes good crushed stone (1060).

6 ft. 8 in.—Hard tough limestone in beds from 3 to 6 inches thick, even grained but somewhat mottled. A cavernous layer appears towards the middle. These are the only beds used for lime (1059).

15 inches.—Hard mottled limestone, cavernous towards top. This bed makes good crushed stone.

18 inches—Solid mottled limestone in persistent bed. Divided into two layers in places. Best building bed (1058).

18 in.—3 ft.—Heavy bed of variable thickness and divided into two layers where thin. This bed seems to be thicker where depressions occur in the floor; in other words, its upper surface is level, but its lower surface conforms to the undulations of the underlying stone suggesting a slight disconformity (1057).[1]

The floor of the quarry consists of soft argillaceous limestone (1061).

The general direction of the face is N.30°E. The main joints strike due northeast vertically and are about 4 feet apart. A second set strikes E.20°S. On the whole the formation is rather seriously jointed for the extraction of building stone. The section given above is somewhat variable throughout the quarry, but the heaviest stone always occurs towards the bottom. As this material is alone possible for building purposes, it is apparent that the removal of a large overburden of thin stone is necessary to expose the building beds (Plate XVII).

The stone: No. 1058.—This stone is regarded as the most adaptable to building purposes and has consequently been tested in full: it is a very fine-grained dolomitic limestone of distinctly mottled structure. The ground mass is yellowish and somewhat porous in structure. The minor element in the mottling is greyish or greenish-yellow, rather darker in tone and with a more compact structure than the ground mass. In addition to this mottling there is a secondary fine mottling in the lighter parts which is expressed by fine lines and spots of a pinkish colour. The slightly greenish cast of the stone is rather characteristic. The effect of corrosion is scarcely to be observed beyond a slight loss of the greenish cast in the darker part. Under the freezing test the angles and edges remained sharp but fine lines were observed as if from the opening of incipient flaws.

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[1] Compare the section given by MacLean in Guide Book No. 8, Pt. I, of the Twelfth International Geological Congress.

The physical properties are as follows:—

Specific gravity	2·837
Weight per cubic foot, lbs	156·822
Pore space, per cent	11·45
Ratio of absorption, per cent, one hour	2·093
" " " two hours	2·667
" " " slow immersion	3·071
" " " in vacuo	4·55
" " " under pressure	4·56
Coefficient of saturation, one hour	0·459
" " two hours	0·585
" " slow immersion	0·673
" " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	11,818·
" " " wet	10,089
" " " wet after freezing	10,795·
Transverse strength, lbs. per sq. in	1,238·
Shearing strength, lbs. per sq. in	866· / 978·
Loss on corrosion, grams per sq. in	0·015
Drilling factor, mm	13·2
Chiselling factor, grams	5·80

It must be remembered that we are dealing with a mottled and consequently variable stone; therefore, some latitude must be allowed in the above figures. In view of the remarkably high porosity the calculations for ratio of absorption and coefficient of saturation are probably but little affected.

This stone is a highly dolomitic limestone but not a true dolomite. The ratio of calcium carbonate to magnesium carbonate in a true dolomite is 1·17 to 1, whereas in this stone the ratio is 1·4 to 1. The relatively high percentage of ferrous oxide is responsible for the greenish-yellow colour and the tendency to change in colour on exposure. The large amount of insoluble matter indicates the impure and probably argillaceous character of the stone. The analysis by Leverin follows:—

	Per cent
Calcium carbonate	50·62
Magnesium carbonate	36·62
Ferric oxide	0·07
Ferrous oxide	0·32
Alumina	0·39
Soluble silica	0·16
Insoluble matter	11·60

No. 1057.—This example resembles No. 1058 in its upper part but it is rather softer and with more of the yellowish component. Towards the bottom the yellow gives place to red with an intermediate zone of red mottled with yellow.

No. 1059.—A hard, fine-grained, compact rock of fine crystalline structure, mottled in light bluish-green and yellow components. It resembles No. 1058 but its colour is more yellow and less greenish. The physical properties are doubtless similar to those of No. 1058.

No. 1060.—The actual stone substance is a fine-grained, compact, crystalline dolomite of a greyish-yellow colour; it resembles the stone from the Hudson Bay railway described as No. 1127 on page 107, but lacks the clean, slightly pinkish cast of that stone and shows mottling in shades of yellow. Like No. 1127 it is filled with large cavities which makes it useless for our purposes.

No. 1061.—A soft, apparently non-crystalline, argillaceous limestone, very distinctly mottled in greenish-white and brownish-yellow components. The lighter parts are extensively pitted. The stone is soft and muddy and of no promise as a building material.

The 15-inch and the 18-inch beds are the favourite ones for building purposes: the stone is mostly used in the form of rubble but some dressed curb stones have been cut from the 18-inch bed.

In quarrying, holes 20 feet deep are sunk 4 feet back from the face and 4 to 5 feet apart. Dynamite is used as explosive and the whole face is blown down on the floor.

The equipment at the quarry is as follows:—

Power House.

Electric current, received at 13,000 volts, passes to

1 transformer, Packard Electric Co., and is reduced to 2,200 volts. Pole transformers reduce the above to 110 volts for lighting. Penitentiary also supplied.

2 transformers reduce the initial current to 550 volts for machine shop.

1 150-h.p. Crocker-Wheeler motor, Canadian Crocker-Wheeler Co., St. Catherines, Ont.

3 boilers, 226-h.p., not now in use.

1 150-h.p. engine, Chandler and Taylor Co., Indianapolis, not now in use.

1 compressor, A.M. Well Works, Aurora, Ill., (8 in. steam cylinder, 12 in. air).

Crusher.

2 No. 3 Gates crushers, Allis-Chalmers.

1 No. 7½ Gates crusher, Allis-Chalmers.

36 Hart convertible cars.

15 iron air-dump cars, King-Lawson.

Quarry.

2 portable boilers, one 10 h.p., one 12 h.p. supplying steam to 3 Canadian Rand drills.

1 electric drill, Siemens-Schuckert Werke.

Track and 14 quarry cars, horse.

1 6-ton derrick.

Miscellaneous.

Car and blacksmith shops, offices, etc.

400 yards of siding to a spur from the C.P.R. at Stony Mountain station.

Seventy-five men are at present on the pay roll. The scale of wages is as follows:—

Labourers....................$2.25 per day of 10 hours.
Drill men....................$2.50-$2.75 per day of 10 hours.
Engineers....................$125 per month.

Crushed stone is sold to the city of Winnipeg at $1.10 per yard, f.o.b. Winnipeg. By an arrangement with other producers of crushed stone, the city quarry may sell them crushed stone at 60 cts. per ton, f.o.b. Stony Mountain.

Since the quarry was opened the production of crushed stone has been as below:—

1906—	117,195	cubic yards
1907—	55,466	" "
1908—	64,883	" "
1909—	63,529	" "
1910—	62,371	" "
1911—	89,119	" "
1912—	80,789	" "
1913—	65,927	" "

Total to 1913—599,279 cubic yards.

In addition to the above, about 500 cords of rubble have been sold since the quarries were opened. As an example of the efficiency of the mill, I am informed that 670 cubic yards were crushed on Monday, June 22, 1914.

The elevation known as Little Stony mountain lies to the west of Winnipeg and was formerly worked for stone along part of its eastern face. The city of Winnipeg opened a quarry on the southwest quarter of section 34, township 11, range 2 east. Operations were carried on until the excavation was about 1,500 feet square when they were discontinued on account of the increasing overburden to the westward. The general appearance of the section suggests the strata at Airdale as the beds are made up of alternating fine-grained limestone (1067) and cavernous stone (1068), either of which may be obtained in layers of 18 inches or even more in thickness. The stone is much fractured in all directions and the layers are separated in many places by red shaly bands.

The following somewhat generalized section was given to me by Mr. Charles P. Kelpin who was in charge of the operations for many years:—

10 ft.—Overburden (at the west).

8 in.—Hard, whitish, fine-grained limestone.

3 ft.—Hard, whitish, fine-grained limestone in thin beds.

12 in.—Mottled bed. Used for curbing. 30,000 lineal feet made in 1902.

18 in.—Heavy mottled bed. Crushed.

18 in.—Heavy mottled bed. Crushed.

6 in.—Soft, reddish, ferruginous layer.

3 ft.—Solid heavy bed of yellowish stone. Easy to work and softer than the white beds. Crushed.

12 ft.—Variable beds of yellow cavernous stone, sometimes two feet thick but usually thinner. The parting planes are very irregular and the stone does not come out in a form favorable for coursing.

45 ft.—Blue shale.

The upper 8-inch bed was used for rubble. Mr. Kelpin thinks that this bed is the same as the upper bed at Stony mountain. The favourable parts of the 3-foot bed immediately below the 8-inch bed were also employed for the same purpose. Many thousands of tons of rubble were obtained from these layers. An example may be seen in the waterworks building in Winnipeg.

It is unlikely that this quarry will again be worked, as the heavy overburden to the westward would render the cost of extraction too high.

The stone: No. 1067.—Essentially the same as No. 1064 from the quarry at Airdale described on page 74.

No. 1068.—This is a highly cavernous type like No. 1160 from Stony Mountain. It shows faint mottling and irregular lines marked by a light green argillaceous material. A rough cavernous stone quite impossible for our purposes.

Little Stony Mountain Quarry Company.

This company formerly operated immediately to the south of the city's quarry at Little Stony mountain, on the northwest quarter of section 26, township 11, range 2 east.

The excavation was not large but it was fairly deep, exposing beds similar to those in the adjoining quarry, but apparently in a more broken condition. The heavy stripping caused a cessation of operations and the quarry has not been worked for 12 years.

Manitoba Quarries, Limited; W. F. Lee, president, 409 Builders' Exchange, Winnipeg.

The quarry (old Gunn quarry) of this company is south of that of the city of Winnipeg at Stony Mountain and is separated from it by a road allowance only. The property is the east half of the east half of legal subdivision 14, in section 11, township 13, range 2 east.

The excavation has been continued east or into the mountain for about the same distance as in the case of the other workings: the length is somewhat less, probably about 1,000 ft.

The working face is now about 12 feet high and presents the following sections:—

Stripping slight.

8 ft. 9 in.—Hard, whitish, faintly mottled stone in thin beds. The same as No. 1059, page 67.

15 in.—Hard mottled limestone, cavernous towards top. This bed is persistent in both quarries and is the best horizon marker observed (1062).

2 ft.—Mottled limestone in four beds. This stone is similar to that of the 18 in. bed in the city quarry.

........—The heavy lower bed of the city quarry is not observable as a distinct stratum, but it is represented by part of the 2 feet above, or is included in the upper layers of the underlying soft rocks which are here more calcareous than in the other quarry.

It will be observed that the uppermost beds of the city quarry are entirely lacking here. The jointing is rather irregular but sets may be made out at E.15°S. and N.10°W.

The quarry is not now being worked but a crusher of 125 tons capacity (Gates No. 3) is installed and a spur connects the property with the railway.

The stone: No. 1062.—A hard, splintery, fine-grained, crystalline dolomite mottled in greenish, brownish and yellowish colours, and in places with a reddish cast. It suggests a transition between No. 1058, which is softer and greener, and No. 1123 from north of The Pas (page 108). The stone breaks with a very irregular fracture and is cavernous in places.

About a quarter of a mile directly east from this opening the company holds a small quarry which was formerly the property of the Modern Quarry Co. and was known as the Kelly quarry. The property consists of legal subdivisions 15 and 16 in Section 11, township 13, range 2 east.

The excavation is about 300 feet by 150 feet and presents a face of 12 feet. The section is as follows:—

8 in.—White mottled stone, which was quarried early and used for rubble: it may be seen in Westminster church in Winnipeg.

4 ft.—Hard white stone in thin layers.

17 in.—Hard mottled limestone with cavernous top: this seems to represent the 15-inch bed of the other quarries.

18 in.—Mottled limestone, but broken and not comparable with the stone of the similar bed on the face of the mountain.

5 ft. 6 in.—Broken, iron-stained beds of limestone with some shaly partings.

It is apparent that the upper beds of the city quarry do not occur at this point. The distinct contact of the shale and limestone, observed at the floor of the city quarry, is less marked in the old Gunn quarry, while here the contact is not to be observed.

This company also owns a 5-acre property in the southwest quarter of section 13, township 12, range 2 east; it is the most westerly 6 chains, 67 links of the most southerly 7½ chains. Stone was formerly quarried here for lime burning.

This company also has certain interests in a quarry (Airdale quarry) situated on the east half of the southwest quarter of section 23, township 12, range 2 east of the first meridian.

On this property and in its vicinity the stone is covered by a very light stripping and immense quantities could be quarried without encountering undue overburden. The beds seem to have a slight dip S.20°E.; they are more eroded towards the north where the upper beds disappear. Southward much stone is available but the greatest, easily accessible supply lies to the west of the present opening. This excavation is of very irregular shape with a length in the direction of dip (S.20° E.) of about 800 feet. The width is nearly as great at the south end but it varies in different parts of the quarry. The depth is about 6 feet. The stripping varies from 2 to 5 feet, and appears to increase towards the east, where the upper beds begin to fail as they do also towards the north.

A section at the northeast angle of the quarry is as follows:—

10 in.—Cavernous limestone (1063).

1 ft.—More uniform limestone. Often in 2 beds (1064).

14 in.—Similar to 1064. Presents 1065 in places.

1 ft.—Cavernous bed like 1063.

1 ft. 10 in.—In 2 variable beds. Stone intermediate between 1063 and 1064 (1065).

4 in.—Cavernous stone like 1063.

A section on the east side of the quarry shows:—

3 ft.—Stripping.

1 ft.—Sometimes divided into two. Cavernous limestone like 1063.

2 ft.—In 3 beds. Resembles 1064.

2 ft.—Intermediate beds like 1065.

3 ft.—Cavernous beds like 1063. Softer towards bottom.

Throughout the quarry the same general types of stone are presented, *i.e.*, cavernous layers, uniform layers and intermediate layers. There is no constant sequence and the beds seem to vary in order and to repeat. Rubble from 6 inches to 1 foot in thickness can be obtained and even heavier stone from parts of the lower cavernous beds.

The jointing is very irregular and the formation is much broken. The chief system of joints strikes S.25° W. I have no knowledge of the stone at greater depths, but, judging from the nature of the lower layers and the floor of the present quarry, it would appear that the formation becomes softer and with a greater clay content at lower levels.

The property was formerly connected by a spur, 2½ miles long, with the Canadian Pacific railway, but the rails have been removed.

A small jaw crusher by the Austin Manufacturing Co., Chicago, is still on the property as well as a boiler and derrick and 2 portable boilers with hoists. There is no production at present.

The stone: No. 1063.—A very fine-grained, crystalline dolomite of a prevailing light, pinkish-grey colour and indistinctly mottled with greenish argillaceous matter. The mottling is very fine and in consequence the stone is not comparable with the mottled stones proper. It is a rough stone and is pitted to cavernous in places; it is extremely tough and breaks with an irregular fracture.

No. 1064.—A hard, tough, fine-grained crystalline dolomite of whitish-grey colour and compact structure. This is a more uniform rock than any of the samples from Stony mountain but evidence of mottling is not altogether wanting. The stone is much too hard and tough to admit of chiselling. The bed is not continuously of this character, for places occur where the stone is much softer and fine mottled in green and red. This part still shows the fine crystalline structure, but it is doubtless argillaceous.

No. 1065.—The substance of this stone is very like that of No. 1064, but it is decidedly more cavernous and in this respect approaches No. 1063. The stone seems to be softer and less tough than No. 1064.

Kelly Bros. and Mitchell, Stony Mountain, Man.

This firm owns the quarry properties enumerated below but I have not learned that any serious attempts at quarrying have ever been made:—

(a) The most westerly 435 feet of the most northerly 1,000 feet of the southwest quarter of section 12, township 13, range 2 east.

(b) The most westerly 40 acres of the northwest quarter of section 12, township 13, range 2 east.

(c) Legal subdivision 1 in section 14, township 13, range 2 east.

(d) 31½ acres in the northeast quarter of section 11, township 13, range 2 east.

Andrew Gillies, Winnipeg, Man. (Stony Mountain, Man.)

A small amount of stone, some of which has been used for building purposes, has been taken from the eastern side of the following property:—

The most southerly 40 feet of the northwest quarter of section 11, township 13, range 2 east. (Western limit of quarter section to Alfred street, Assinawa.)

Neil Isbister, Stony Mountain, Man.

Stone has been raised on the following property for lime burning:—

The north half of the north half of legal subdivision 8, in section 11, township 14, range 2 east.

John Gunn and Sons, Winnipeg, Man.

The following properties are held by this firm but no quarrying has yet been done:—

The south half of the north half of legal subdivision 8, also a rectangular piece abutting the Andrew Gillies property on the south side and Wolesley street on the north (9½ acres; 8 chains, 97 links north and south, and 10 chains, 44 links east and west).

Ira Stratton, No. 12 Bank of Hamilton building, Winnipeg, Man.

Mr. Stratton holds quarrying rights on the southeast quarter of section 4, township 14, range 2 east. Samples have been obtained from this locality but as far as I could ascertain very little work has been done. The property was not visited.

The following analyses of three samples selected at random have been given me by Mr. Henderson of the Winnipeg Fuel and Supply Co.:—

	I	II	III
	Per cent	Per cent	Per cent
Loss on ignition	46·35	45·87	45.40
Water	0·15	0·08	0·20
Silica	0·64	0·90	2·30
Alumina and iron oxides	0·96	1·66	1·24
Lime (oxide of calcium)	31·10	30·80	30·44
Magnesia (oxide of magnesium)	21·44	20·78	20·53

Kelpin Bros., Winnipeg, Man.

It is proposed to open a quarry for crushed stone and building stone on the southeast quarter of section 4, township 14, range 2 east.

On this property about 60 acres are practically free of stripping. The upper 4 feet, as revealed in test pits, is broken and resembles Stony Mountain stone. The lower 3 feet seems to be much more solid material. The proposed line of the Winnipeg, Selkirk and Lake Winnipeg electric railway will pass close to the property.

Limestones of the Silurian System.

The Silurian system is represented in the Rocky mountains by the Halysites beds which are described as dolomites and quartzites interbedded with shales. Outcrops of these beds are of infrequent occurrence in the mountains of Alberta; I have not learned of any reasonably accessible locations.

In Manitoba, the Silurian rocks occupy a broad belt in the region immediately to the east of Lakes Winnipegosis and Manitoba. The belt increases in width to the north and west, reaching from the shore of Lake Winnipeg near the mouth of the Saskatchewan river, to beyond the line of the Hudson Bay railway north of The Pas. The most southerly exposures of any economic interest are at Stonewall and Gunton on the Arborg branch of the Canadian Pacific railway and at Inwood and Broadvalley on the Inwood branch of the Canadian Northern railway. Exposures in the more northerly parts of the province are to be seen near Fairford and Gypsumville, near The Pas along the Hudson Bay railway, along the lower reaches of the Saskatchewan river, on the adjacent Cedar, Moose, and Winnipegosis lakes, and on the shores of Lake Winnipeg.

For the most part the Silurian limestones are highly dolomitic and of fine crystalline structure; they are nearly always hard, tough, strong rocks frequently presenting an extremely cavernous structure. Four general types may be recognized—(1) a hard, rough, cavernous type; (2) a very fine-grained, massive, almost lithographic variety; (3) a type in which the crystalline structure is coarser and the stone more uniformly porous and much softer; (4) a fine-grained, greyish, dolomitic type blotched with pink, red, and chocolate colours.

The first type is common at Stonewall and Gunton and on the lower Saskatchewan river and neighbouring lakes. The second variety is seen in the lower beds at Inwood and Broadvalley, in certain layers near Fairford, and at the Grand Rapids of the Saskatchewan river. The third type occurs at Inwood and Broadvalley and also at Fairford; being a much softer stone and amenable to chiselling, it presents greater possibilities from our point of view. The fourth type was seen near Fisher Branch and along the line of the Hudson Bay railway, particularly near the narrows of Cormorant lake.

It is proposed to consider these Silurian limestones as belonging to the following, more or less distinct, geographical areas:—

Stonewall-Gunton area.
Inwood-Broadvalley area.
Lake Winnipegosis-Saskatchewan River area.
The Pas area.
Fisher Branch area.
Hudson Bay Railway area.

Stonewall-Gunton Area.

Silurian strata occur under a slight stripping immediately to the north of the village of Stonewall, within the limits of the municipality, on the southeast quarter of section 36, township 13, range 1 east of the first meridian, on the southwest quarter of section 31, township 13, range 2 east, and on the northwest quarter of section 30, township 13, range 2 east.

The available stone is determined by the amount of stripping which is scanty along the north and east sides of the elevated tract on which Stonewall is located. The quarry belt may be regarded as a strip about 1,000 feet wide, stretching in the form of a semicircle around the north and east sides of the village for a distance of about a mile. North and east of this belt, the land surface is lower, and the upper, more valuable stone is absent as the rock surface had been eroded before the present soil was deposited. Towards the south and west, the increasing overburden and the encroachment on the village must eventually put an end to quarrying operations. The accompanying plan (Fig. 4) shows in a rough way the location of the available stone and the properties of the chief operators.

A general descending section of the Stonewall strata is as follows:—

2-8 ft.—Stripping.
10 ft.—Upper, light coloured dolomites, sometimes 3 feet thick. These beds are frequently of less extent on account of surface erosion. The stone is used for lime burning and incidentally for building. (See No. 1002, page 79).
2 ft. 6 in.—3 ft.—Hard beds. (See No. 1003, page 81.)
1 ft.—Red bed. This bed is of hard, nodular, shaly dolomite; it is fairly continuous and forms the floor of the major excavations.
6 ft.—Heavy, grey, cavernous dolomite. (See No. 1004, page 81.)
8 in.—Grey shale passing into the beds below.
9 ft.—Red shaly beds. (See No. 1000, page 80.)
2 ft.—Light coloured, sandy beds. (See No. 1001, page 80.)
9 in.—Similar sandy beds but of redder colour.
30 ft.—Fine-grained, green and pink, argillaceous limestone or calcareous shale. (See Nos. 1005, 1006, 1007a, 1008a, page 81.)

The beds dip towards the southeast at about $1\frac{1}{2}°$. The jointing is very irregular but nearly vertical, it is not excessive and would not interfere with the quarrying of stone of reasonable size for building. The amount of stone available depends largely on the attitude of the municipality which has already arrested the advancement of certain quarries towards the village, as may be seen by an inspection of the accompanying sketch map (Fig. 4).

Two companies operate at Stonewall as below:—

Winnipeg Supply and Fuel Co., 298 Rietta St., Winnipeg; John Henderson, manager.

The properties of this company may be regarded as consisting of 3 sections as follows:—

1—A section between the railway and Kinsey street. In this section the stone has been largely removed over an area about 900 feet by 400 feet. At the west end of this excavation the section is as follows:—

4 ft.—Soil, increasing rapidly to the west.
18 in.—Upper white beds, (See No. 1002, page 79.)
2 ft.— " " " " " " " "
2 ft. 6 in.—Hard bed. (See No. 1003, page 81.)

The one-foot red bed of the general section forms the floor of this quarry. At the north side, near the crusher, the section is as follows:—

4 ft.—Upper white beds and hard bed.
—Main floor of quarry.
1 ft.—Red bed. Shaly limestone.
6 ft.—Grey, cavernous beds (1004).
—Floor of deeper quarry.
8 in.—Grey shale.
9 ft.—Red and shaly beds (1000).
2 ft.—Light coloured sandy stone to the bottom of the test hole (1001).

At the southeast corner of this excavation, where it passes into the quarry next to be described, the section is as follows:—

4 ft.—Stripping.
4-5 ft.—Upper white stone in thin beds. (See No. 1002, page 79.)
1 ft. 6 in.—Solid beds of white stone divided elsewhere.
2 ft. 8 in.— " " " " " " "
3 ft.—Similar white stone but less solid.
3 ft.—The hard bed. (See No. 1003, page 81.)

It will be observed that the upper beds are thicker at this point: this is due both to a rise in the land and to the southeasterly dip of the beds (Plate XVIII).

2—A property about 1,000 feet by 500 feet lying north of Lilly street. The quarry is advancing east and south and is now approximately 300 feet by 300 feet in size. The general section is the same as that last given, but

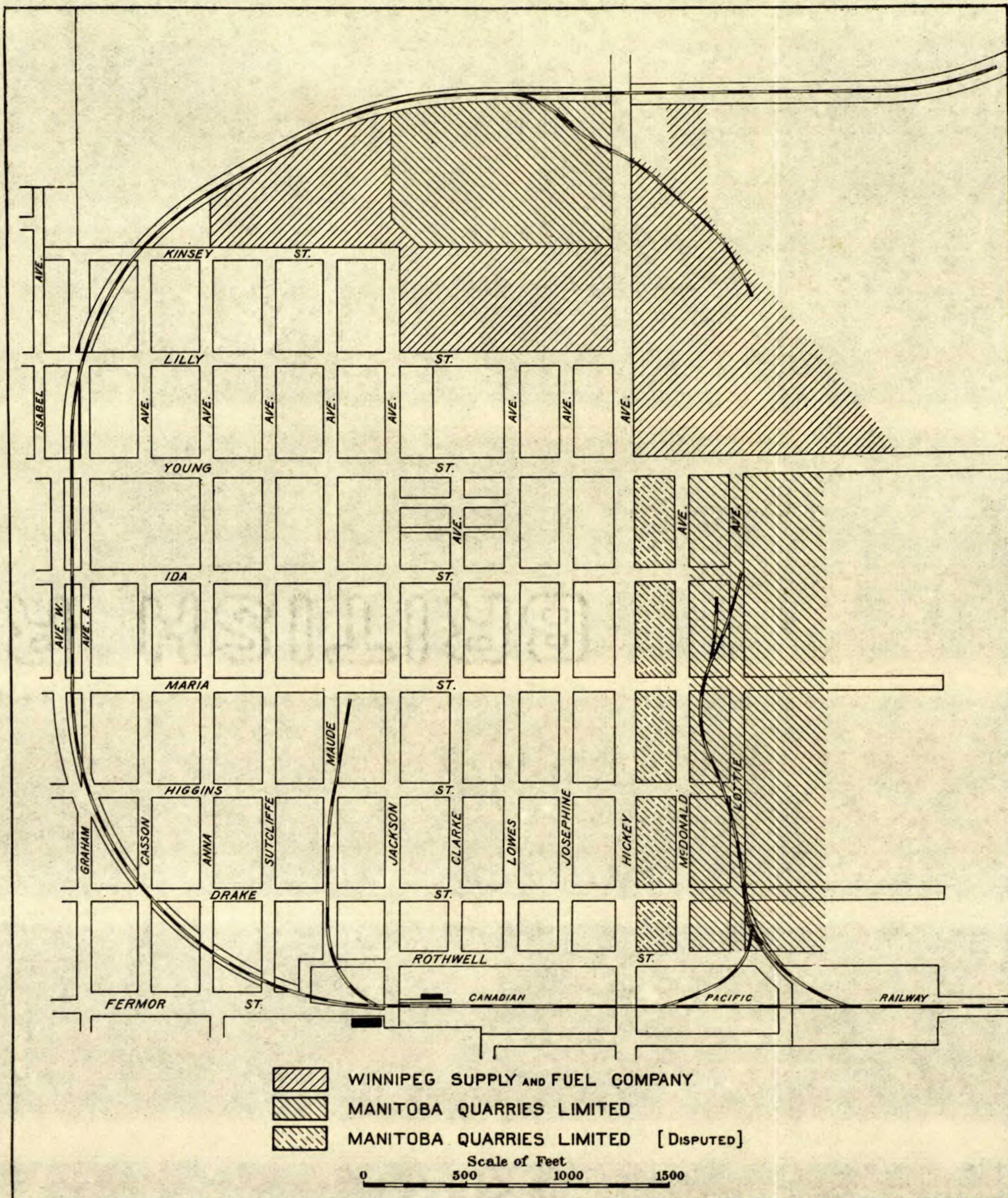


Fig. 4. Sketch map showing the quarry properties at Stonewall, Man.

PLATE XVIII.

Silurian limestone. No. 1 quarry of the Winnipeg Supply and Fuel Company, Stonewall, Man.

the dip of the rock is resulting in an increased stripping: at the limit of the quarry this stripping is now about 8 feet.

The jointing is vertical but variable in direction; sets of joints were observed, S.20°W.; S. 10°E. and in other directions.

3—A property of 16 acres lying north of Young street and east of Hickey avenue: it is of triangular shape with a frontage of 1,300 feet on Young street and 1,500 feet on Hickey avenue. The quarry reaches in a southeasterly direction along the edge of the available stone to within 50 feet of Young street: it is about 600 feet long and of a similar width.

The excavation extends only through the upper white beds and the hard 3-foot bed down to the one-foot red layer which forms the floor. The section is as follows:—

5 ft.—Stripping.

10 ft.—White beds, sometimes 3 feet thick (1002).

2 ft. 6 in.—Hard bed, thick and thin, variable (1003).

A drill hole on one of the properties shows the sequence of strata from the floor of the quarry to be as follows:—

1 ft.—The red bed.

6 ft. 6 in.—Stone like No. 1004.

9 ft.—Red shaly stone like No. 1000.

2 ft.—Sandy limestone like No. 1001.

9 in.—Similar to above, but reddish.

30 ft.—Fine-grained, argillaceous limestone or dolomites in different tints, frequently mottled with pink and green. The stone one foot down is No. 1005; 14 feet down is No. 1006; 21 feet down is No. 1007a; and 30 feet down is No. 1008a.

In all the quarries, the upper white beds (1002) and the hard bed (1003) are the only layers removed. The upper stone is used mostly for lime burning, but rubble, and occasionally, coursing stone is made from it. The hard bed is much fractured and shows skins on the fracture faces: it is useful only for the production of crushed stone. Buildings constructed of the upper stone are of a light buff colour with a tendency to become grey on exposure. Iron-staining is observed in places and the rock face has a rough appearance. The Land Titles building in Stonewall is a good example but in this structure the sills and lintels are of Tyndall stone (Plate XIX).

The stone: No. 1002.—A fine-grained, whitish dolomite with little evidence of crystalline structure: it is slightly pitted and fine cavernous. The dressed surface is greyish-white and fine mottled, with a slightly darker, more porous base and compact, lighter coloured spots. The fine pitting is conspicuous on smoothed surfaces but there is no evidence of plucking. The stone resembles No. 1160 from the Jackpine ridge near Old Gypsumville described on page 95, but it is more pitted than the average of that stone.

The corrosion test produces little or no change, a slight tendency to turn yellow being the only effect observed. No visible alteration was produced by the freezing test. The physical properties are indicated in the table below:—

Specific gravity	2·85
Weight per cubic foot, lbs	155·657
Pore space, per cent	12·51
Ratio of absorption, per cent, one hour	2·16
" " " two hours	2·88
" " " slow immersion	3·22
" " " in vacuo	4·69
" " " under pressure	5·04
Coefficient of saturation, one hour	0·43
" " " two hours	0·57
" " " slow immersion	0·64
" " " in vacuo	0·93
Crushing strength, lbs. per sq. in., dry	27,095·
" " " " wet	23,700·
" " " " wet after freezing	17,477·
Transverse strength, lbs. per sq. in	2,184·
Shearing strength, lbs. per sq. in	1,072·
Loss on corrosion, grams per sq. in	0·0088
Drilling factor, mm	10·0
Chiselling factor, grams	4·4

Mr. Henderson has kindly furnished the following analysis of this stone:—

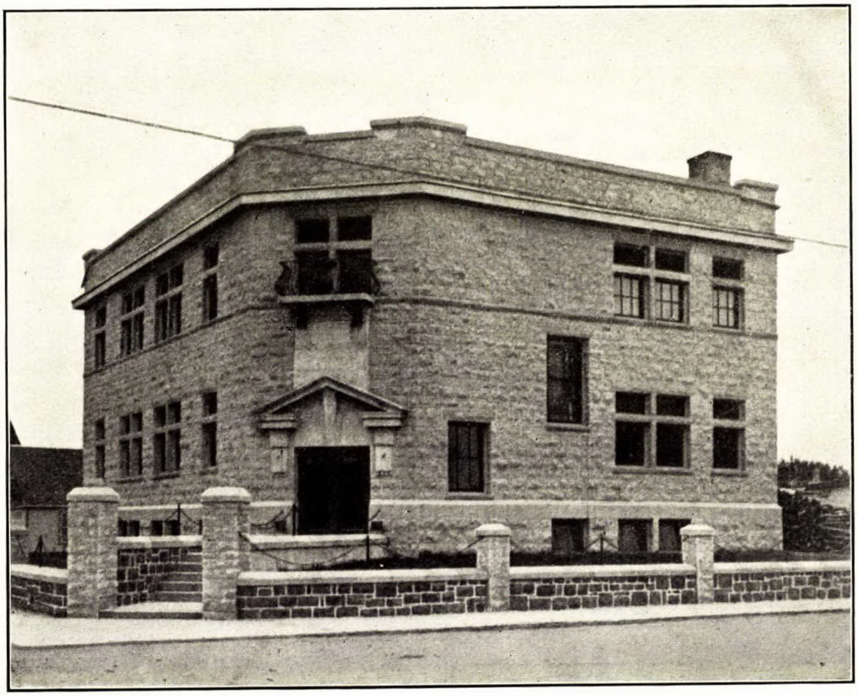
	Per cent.
Silica	0·26
Alumina and iron oxide	0·66
Carbonate of lime	52.36
Carbonate of magnesia	41·43
Water	0·44
Organic matter	4.65

This is the only stone from the Stonewall quarries of importance from our point of view as it alone has been used for building purposes. It has a tendency to turn grey on exposure, as the Stonewall schoolhouse built about 1908 is darker and more uniform in colour than the new Land Titles building.

No. 1000.—A soft, highly argillaceous limestone or dolomite of a prevailing red colour but lined and blotched with light greenish-grey.

No. 1001.—A stone of exceedingly fine grain and crystalline structure, apparently dolomitic. It has a marked banded structure parallel to the

PLATE XIX.



Silurian limestone. Land Titles building, Stonewall, Man.

stratification and shows slight differences of colour in the various bands. The dolomitic matrix holds minute grains of sand in variable amount, sometimes only scattered through the matrix, but in other parts present in sufficient amount to constitute a sandy dolomite or dolomitic sandstone.

It has been proposed to use this stone for building purposes but the layers are not sufficiently exposed to reveal the characteristics of the formation. I believe that some test pits were sunk into these beds on the opposite side of the track but none of the stone was used. The rock is fairly soft and probably could be carved but its wearing properties do not seem to be good.

An analysis of this stone shows its sandy nature in the high percentage of silica:—

	Per cent.
Silica	24·56
Carbonate of lime	38·99
Carbonate of magnesia	36·62

No. 1003.—A hard, whitish, uniform, exceedingly fine-grained, crystalline dolomite with little evidence of mottling. The stone is so hard and splintery and so filled with diagonal flaws that its possibilities as a building stone are meagre.

An analysis furnished by Mr. Henderson is as follows:—

	Per cent.
Silica	0·20
Alumina and iron oxide	1·24
Carbonate of lime	57·19
Carbonate of magnesia	39·47
Water	0·32
Organic matter	1·58

No. 1004.—A hard, fine-grained, tough, highly cavernous dolomite of fine crystalline structure: it resembles the cavernous stone from the Ordovician formations of Stony mountain. An analysis furnished by Mr. Henderson is as follows:—

	Per cent.
Silica	2·50
Carbonate of lime	55·01
Carbonate of magnesia	42·01

No. 1005.—Greenish-white, sandy limestone like No. 1001.

No. 1006.—A very fine-grained, whitish, crystalline dolomite.

No. 1007a.—Like No. 1006, but slightly blotched with pink.

No. 1008a.—Like No. 1006.

The equipment of the company, distributed at the different quarries, is as follows:—

5 draw kilns.

1 jaw crusher, capacity 70 cubic yards per day.

1 rotary crusher (Allis-Chalmers), capacity 150 yards per day.

1 compressor.

1 portable boiler.

1 drill.

Siding, track, dump cars, etc.

At the time of my visit, 25 men were employed but I understand that the force is increased to 125 at times.

The following prices are quoted:—

Rubble— $5.47 per cord, f.o.b. quarries.

Crushed stone, $1\frac{1}{2}$ to 2-in. size—90 cents per cubic yard, f.o.b.

Crushed stone, $\frac{3}{4}$ to 1-in. size—$1.15 per cubic yard, f.o.b.

Crushed stone, $\frac{3}{8}$-in. (grit)—60 cents per ton, f.o.b.

As already stated, the upper white beds are alone suitable for building purposes. This stone may be seen in the Land Titles building and in the schoolhouse in Stonewall (Plate XIX).

Manitoba Quarries, Limited, 409 Builders Exchange, Winnipeg, Man., W. F. Lee, president.

This company owns the block of land south of the railway and east of the section first described for the Winnipeg Supply and Fuel Co. The company also holds the property between Rothwell and Young streets, from McDonald avenue eastward to the limit of the workable beds of stone. Rights are claimed on the property between Hickey and McDonald avenues.

On the section first mentioned above, 2 quarries have been opened; each is about 600 feet long and 300 to 400 feet wide. They have been opened to a depth of about 10 feet in the upper beds. The stripping is light.

The opening on the second property extends north and south from Young to Higgins street and has been advanced west as far as McDonald avenue. The quarry is worked to a depth of about 8 feet in the upper beds. The product is used for lime burning and for rubble. The equipment is as follows:—

2 draw kilns.

1 drill on steam.

1 boiler.

1 derrick.

Quarry track and cars.

Crushing plant not now in operation.

This company also operates quarries farther north, near Gunton, where the Silurian strata are actually exposed or under a very slight stripping. The outcrops occur near the railway on section 28, township 15, range 2 east. A large quantity of stone has been quarried here and a considerable reserve is still available. An average section is as follows:—

———Stripping, variable.
10 ft.—Thin-bedded stone, (See No. 1015, page 86).
10 in.—Nodular red bed.
16 ft.—Thick-bedded, yellowish and reddish dolomites. (See Nos. 1013 and 1014, pages 84 and 85).
Floor of quarry proper.
17 ft.+—Reddish, chocolate coloured, and greenish, calcareous shales. (See Nos. 1010, 1011 and 1012, page 87).

This section is not strictly comparable with that at Stonewall but I am inclined to believe that the 10-inch nodular red bed is common to both localities. The strata are practically horizontal.

Under the management of George C. Le Quesne, the company operates 3 quarries near Gunton; these are known respectively as Nos. 1, 2, and 3.

No. 1 Quarry.—This opening is close to the railway on the west side of the southeast quarter of section 28, township 15, range 2 east. The excavation is 500 feet long and 300 feet wide, with a depth of 27 feet, 6 inches. The section is as follows:—

18 in.—Stripping.
10 ft. 10-in.—Yellowish, rather thin-bedded dolomites (1015).
10 in.—Red, shaly, nodular bed.
16 ft.—Reddish and yellowish, heavily bedded dolomites with the red increasing towards the bottom (1013 and 1014).
Floor of quarry.
17 ft.—Hard shales of various colours, exposed in the pit for crusher elevator (1010, 1011, 1012).

The main joints strike N.10° W. at intervals of 20 feet but they vary greatly. Indistinct sets strike N.30° E. and others nearly east and west. On the whole the formation is cut into irregular diamond-shaped blocks. The stone of the upper beds is rather thin and it does not seem to be of the same character as the upper white beds at Stonewall: it is used for rubble and is said to make a very strong lime of greyish colour. The "hard bed" of the Stonewall quarries does not appear above the red nodular layer. The red and yellow lower layers are much more heavily bedded and may be obtained in blocks 3 feet thick in places. The red element increases towards the bottom of these beds. The product is used for rubble and for crushed stone.

No. 2 Quarry.—This excavation is directly across the railway from No. 1, on the southeast quarter of section 28, township 15, range 2 east. It is about 600 feet long and 250 feet wide. The section exposed here is the same as in No. 1, but towards the south end the thickness of the upper stone is reduced to 8 feet by erosion of the surface. The stripping is about the same. Much stone is available to the west and north but it is probable that the surface lowers towards the south.

No. 3 Quarry.—This quarry is farther north and to the west of the track: it is situated on the northwest quarter of section 28, township 15, range 2 east. The length is about 400 feet, the width 200 feet, and the depth 19 ft., 3 in., exclusive of the overburden. The section at the south end is as follows:—

2 ft. 6 in.—Stripping.

2 ft. 10 in.—Medium to thin-bedded, whitish, fine-grained, mottled dolomite (1007).

5 in.—Light coloured, nodular stone.

10 in.—The red nodular bed.

9 ft. 6 in.—Whitish-yellow, dolomitic beds, in layers up to 18 inches thick.

8 ft. 6 in.—Interbanded yellowish and reddish dolomites, in layers up to 2 feet thick. The red part increases towards the bottom and passes into the underlying red shales (1008, 1009).

Distinct joints divide the formation in a north and south direction and also at S.30°E. resulting in diamond-shaped blocks.

It will be observed that the upper layers which are 10 feet thick in quarries Nos. 1 and 2 are here reduced to 2 ft., 6 in. At the north end of the quarry they have practically disappeared, indicating a falling off of the surface in that direction. Towards the west, the surface again falls off, but east and south towards the other quarries a great amount of stone is available. Test holes sunk at intervals between the quarries show that the stripping is variable, as much as 16 feet being encountered at one point (Plate XX).

The stone: No. 1013.—A hard, very fine-grained, distinctly yellowish dolomite with a faint reddish mottling. It is not much pitted or cavernous but there is a strong tendency to plucking along the wavy planes of parting between the yellow and red components: this makes the production of a smooth dressed surface of any extent almost impossible. On vertical faces the wavy stratification is very pronounced and the tendency to cleave on these lines is much in evidence throughout. In structure the stone resembles the dolomite from the Hudson Bay Railway area, described as No. 1123 on page 108, but it is a much inferior material and is not comparable as a structural stone; locally, it is known as the best yellow rubble. The corrosion test produces little effect beyond adding a slight cast of pink to the yellow. The freezing experiment produced no visible alteration. The physical properties are as follows:—

Specific gravity	2·845
Weight per cubic foot, lbs.	167·47
Pore space, per cent.	5·705

PLATE XX.

Silurian limestone. No. 3 quarry of Manitoba Quarries, Limited, Gunton, Man.

Ratio of absorption, per cent, one hour	0·918
" " " " " two hours	1·21
" " " " " slow immersion	1·712
" " " " " in vacuo	1·78
" " " " " under pressure	2·126
Coefficient of saturation, one hour	0·43
" " " two hours	0·57
" " " slow immersion	0·80
" " " in vacuo	0·83
Crushing strength, lbs. per sq. in., dry	30,980·
" " " " wet	25,831·
" " " " wet after freezing	27,833·
Transverse strength, lbs. per sq. in	759·
Shearing strength, lbs. per sq. in	943·
Loss on corrosion, grams per sq. in	0·0178
Drilling factor, mm	2·6
Chiselling factor, grams	2·7

The wet and frozen crushing strengths are anomalous and can be explained only by differences in the cubes. The very low transverse strength is occasioned by the tendency of the stone to split along the planes of stratification: this test, conducted on a larger sample, would probably give a higher result.

No. 1014.—This stone is known locally as red rubble: it is fine in grain and essentially red in colour but it passes imperceptibly into the yellow variety described above as No. 1013. Unlike that stone, however, it has but a slight tendency to pluck and it is of greater cohesion on the bedding planes. Corrosion has the effect of softening the contrast between the red and the yellow portions and of dulling the smoothed surface. Freezing produces no visible alteration.

The physical properties are as follows:—

Specific gravity	2·855
Weight per cubic foot, lbs	170·053
Pore space, per cent	4·53
Ratio of absorption, per cent, one hour	0·935
" " " " " two hours	1·18
" " " " " slow immersion	1·4
" " " " " in vacuo	1·53
" " " " " under pressure	1·66
Coefficient of saturation, one hour	0·57
" " " two hours	0·71
" " " slow immersion	0·84
" " " in vacuo	0·92

Crushing strength, lbs. per sq. in., dry	27,000·
" " " " wet	25,656·
" " " " wet after freezing	19,879·
Transverse strength, lbs. per sq. in	2,549·
Shearing strength, lbs. per sq. in	2,148·
Loss on corrosion, grams per sq. in	0·0107
Drilling factor, mm	11·6
Chiselling factor, grams	0·15

No. 1015.—This is a fine-grained, partially crystalline, dolomitic limestone with a yellow base fine mottled with chocolate coloured streaks and blotches. The stone shows a pitted structure but it is not strikingly cavernous: in this respect it resembles No. 1002 but it is a less desirable stone. A resemblance is also shown to the Silurian dolomite from Inwood (No. 1131, page 88) but the present example is less yellow and more visibly cavernous although the pore space is less. The corrosion test produces practically no effect. The freezing test causes only a slight darkening of the yellow colour.

The physical properties are:—

Specific gravity	2·85
Weight per cubic foot, lbs	160·995
Pore space, per cent	9·51
Ratio of absorption, per cent, one hour	0·5073
" " " two hours	1·195
" " " slow immersion	1·603
" " " in vacuo	3·23
" " " under pressure	3·68
Coefficient of saturation, one hour	0·137
" " " two hours	0·326
" " " slow immersion	0·435
" " " in vacuo	0·877
Crushing strength, lbs. per sq. in., dry	32,918·
" " " " wet	18,000·[1]
" " " " wet after freezing	25,140·
Traverse strength, lbs. per sq. in	1,316·
Shearing strength, lbs. per sq. in	3,030·
Loss on corrosion, grams per sq. in	0·0119
Drilling factor, mm	4·5
Chiselling factor, grams	0·18

No. 1007.—A fine-grained, crystalline dolomite of a light yellowish-grey colour with faint evidence of mottling; it is mostly compact and hard but porous patches occur throughout the harder ground mass.

[1] This result is evidently too low. The cube appeared to be perfect but it cracked far below the ultimate load and yielded gradually.

No. 1008.—Like No. 1007 but more distinctly mottled with yellowish-brown.

No. 1009.—This rock has the prevailing fine crystalline structure but it is a much softer stone than the average and shows mottling in red. It is probably somewhat argillaceous but the crystalline structure is still to be distinctly seen with the hand lens.

No. 1010.—A softer type but still of fine crystalline structure; it has a prevailing light green colour with fine mottlings in red. The stone is doubtless argillaceous.

No. 1011.—Like No. 1010 but still softer and more argillaceous.

No. 1012.—Soft, yellowish-green, highly argillaceous, dolomitic limestone.

The equipment of the company at the Gunton quarries is as follows:—

No. 1 Quarry.

1 Austin, No. 7½ crusher, with a capacity of 450 yards per day.

1 Rand drill, with portable boiler.

5 steam derricks of 4 tons capacity each.

2 sidings, quarry track and cars.

No. 2 Quarry.

1 Austin crusher, capacity 400 yards per day.

2 derricks operated from the crusher boiler.

1 drill with portable boiler.

2 sidings, quarry tracks and cars.

No. 3 Quarry.

1 crusher of 300 yards capacity.

2 sidings.

The following statement of the production of this company in the year 1913 includes the product, not only of the Gunton quarries, but the quarries at Stonewall, Airdale, and Stony Mountain.

Crushed stone....................49,287 cubic yards.
Rubble..........................10,177 cords.
Lime............................73,738 bushels.

The following prices are quoted, all f.o.b. quarry sidings:—

Crushed stone....................$1.00 per cubic yard.
Red rubble.......................$5.50 per cord.

Inwood-Broadvalley Area.

W. J. Long, Elmwood, Man.

The property is situated near the village of Inwood, on the northwest quarter of section 10, township 18, range 1 west of the first meridian. The stone is actually exposed or covered by a very thin layer of soil over a considerable area. A small quarry has been opened; it presents the following section:—

3 ft.—Rough and heavily bedded stone, in places solid, but generally divisible into two beds. Stains yellow and shows mottling on exposure (1131, 1132).

2 ft.—Soft, thin and irregularly bedded, granular dolomite, yellowish in colour but variable in this respect (1130).

10 in.—Variable and somewhat cavernous dolomite. Useless (1129).

6 ft.—Thin-bedded, splintery, white, almost lithographic dolomite. Yellow and thicker towards the top, whiter and thinner towards the bottom (1128). Cement.

Formational joints are scarcely apparent on stripped surfaces but irregular fractures occur chiefly in a direction 20 degrees north of west; these are not too closely spaced for the extraction of blocks of 5 feet in diameter. The beds apparently have a slight dip to the westward.

The upper thick bed is the only possible producer of building stone but the material is soft, cavernous in places, and variable in texture. Yellow stains are pronounced on the joint planes and yellow mottlings develop on exposure.

The stone: No. 1131.—A soft, fine-grained, decidedly yellowish stone with a crystalline structure and fine mottling in yellow and brownish-yellow; for the most part it is not visibly pitted and never really cavernous. This stone has some resemblance to the excessively altered stone of the Tyndall quarries (No. 1051, page 56); it might be considered as a transition type between No. 1015 from the Gunton quarries and the Tyndall stone. As far as the stone itself is concerned it looks like a workable material but the formational features of the outcrop must not be overlooked.

No visible effect is produced by the corrosion test and the freezing experiment resulted only in a slight crumbling of the sharp angles of the cube.

The physical properties are indicated in the following table:—

Specific gravity	2·853
Weight per cubic foot, lbs.	155·446
Pore space, per cent	12·72
Ratio of absorption, per cent, one hour	0·329
" " " " " two hours	1·425
" " " " " slow immersion	3·905
" " " " " in vacuo	5·07
" " " " " under pressure	5·12
Coefficient of saturation, one hour	0·064
" " " two hours	0·28
" " " slow immersion	0·76
" " " in vacuo	0·99
Crushing strength, lbs. per. sq. in., dry	14,325·
" " " " " wet	15,783·
" " " " " wet after freezing	12,618·

Transverse strength, lbs. per sq. in.	1,379·
Shearing strength, lbs. per sq. in.	1,238·
Loss on corrosion, grams per sq. in.	0·0094
Drilling factor, mm.	20·7
Chiselling factor, grams.	7·05

The low dry crushing strength is not to be explained by any visible imperfection in the cubes or in the manner of making the test. Duplicate experiments were made to correct this apparent error but they tended to confirm it. Further experiments would be necessary before it could be concluded that the stone is really stronger when wet.

No. 1132.—This stone resembles No. 1131 but it is of coarser crystalline structure and is less coherent; it is also moderately cavernous in places and serves to indicate that material like No. 1131 is above the general average of the bed.

No. 1130.—A compact, uniform, fine-grained, whitish-yellow, crystalline dolomite. It is scarcely to be distinguished from the "manitobite" from the quarry at Broadvalley described as No. 1144 on page 92.

No. 1129.—Very similar in grain to No. 1130 but is somewhat more yellow. The chief difference is that the present sample is full of large cavities and also has large porous patches.

No. 1128.—An exceedingly fine-grained, whitish-yellow dolomite or dolomitic limestone of uniform structure in the hand specimen. Some samples are almost white. The grain is so fine that crystalline structure can not be seen with the lens. The rock has a pronounced conchoidal fracture and belongs to the type of lithographic limestones.

Frederick Haight, Winnipeg, Man.

The quarry is situated on the northeast quarter of section 34, township 17, range 1 west, where thin-bedded stone is exposed in a small pit and in a trench which have been opened. The upper 2 feet consist of a thin-bedded laminated type (1133). The lower 4 feet is also thin and irregularly bedded but the stone is somewhat harder (1134). Much stone is accessible under a very slight covering of soil.

The stone: No. 1133.—This stone is essentially similar to No. 1129 being a fine-grained crystalline dolomite with cavernous structure: it is lighter in colour than No. 1129 and shows more evidence of stratification. The hardness of these stones and their cavernous structure does not recommend them for building purposes.

No. 1134.—An exceedingly fine-grained, light yellowish-grey dolomite. The hand lens is barely sufficient to reveal the crystalline character of the rock. Certain areas are a little coarser than others in grain and decidedly more porous than others which are very compact. It is an extremely hard and tough rock with scattered large cavities.

Manitobite Stone Works, Limited; Wm. Bruce, president, 214 Kennedy building, Winnipeg; Joseph Bourgeault, managing director, Western Stone Company, St. Boniface, Man.

This company holds quarry lands on the line of the Inwood branch of the Canadian Northern railway as follows:—

North half section 28, township 23, range 2 west of first meridian.

South half of south half of section 27, township 23, range 2 west of first meridian.

Northwest, southwest, and southeast quarters of section 22, township 23, range 2 west of first meridian.

East half of section 15, township 23, range 2 west of first meridian.

Northwest quarter of section 14, township 23, range 2 west of first meridian.

The present quarry is located at about the middle of the southeast quarter of section 22, near the line of the Canadian Northern railway from which a siding has been extended to the quarry. At this point, to the east of the track, the stone is exposed or is under a very light stripping. The exposure falls off sharply to the north in an escarpment striking about 10 degrees south of west. At the point marked "A" on the accompanying plan (Fig. 5) a test pit has been sunk and the section is continued in a second pit on the lowland at a point 25 paces N.10°E ("B"). The descending section in these two pits is as follows:—

8 in.—Bed (1139).

2 ft. 2 in.—Solid bed for most part but with indications of subdividing in places (1140).

8-10 in.—Thin-bedded and gradates into the bed above (1141).

Bottom of upper pit.

9. ft. 2 in.—Unexposed interval, including 7 ft. 6 in. of stripping in the lower hole.

2 ft. 6 in.—Thin-bedded and cavernous with fossil cavities. Less thin-bedded on the north side of hole indicating variability and the possibility of more cohesion farther in. Said to be hard to drill (1143).

2 ft.—Apparently more solid but the rock is so shattered by explosives that it is difficult to determine its bedding. The stone is hard and splintery (1142).

The joints are not well marked or continuous through the beds. The chief system seems to strike E.15°S. vertically and another set crosses at S.45°W. Other irregular joints are present, but in spite of the fracturing, blocks of reasonable size can be obtained but not without loss.

A short distance in a southwesterly direction from the opening described above a more extensive excavation has been made ("C"). The upper 8-inch bed is either absent or coalesced with the bed below resulting in a solid layer of about 3 feet in thickness. This bed apparently extends over a

Silurian limestone. Upper bed at the quarry of the Manitobite Stone Works, Broadvalley, Man.

considerable area, the extent of which can be determined only by further stripping and the sinking of test pits. The stone is somewhat variable in colour and texture: an average sample is tested in full below as No. 1144.

This 3-foot layer is the only one now being quarried; it is raised in blocks the size of which is determined by the jointing which is rather irregular in directions approximately W.10°N. and S.30°E. Blocks 4 feet square are not uncommon, while some reach greater dimensions at least in one direction (Plate XXI).

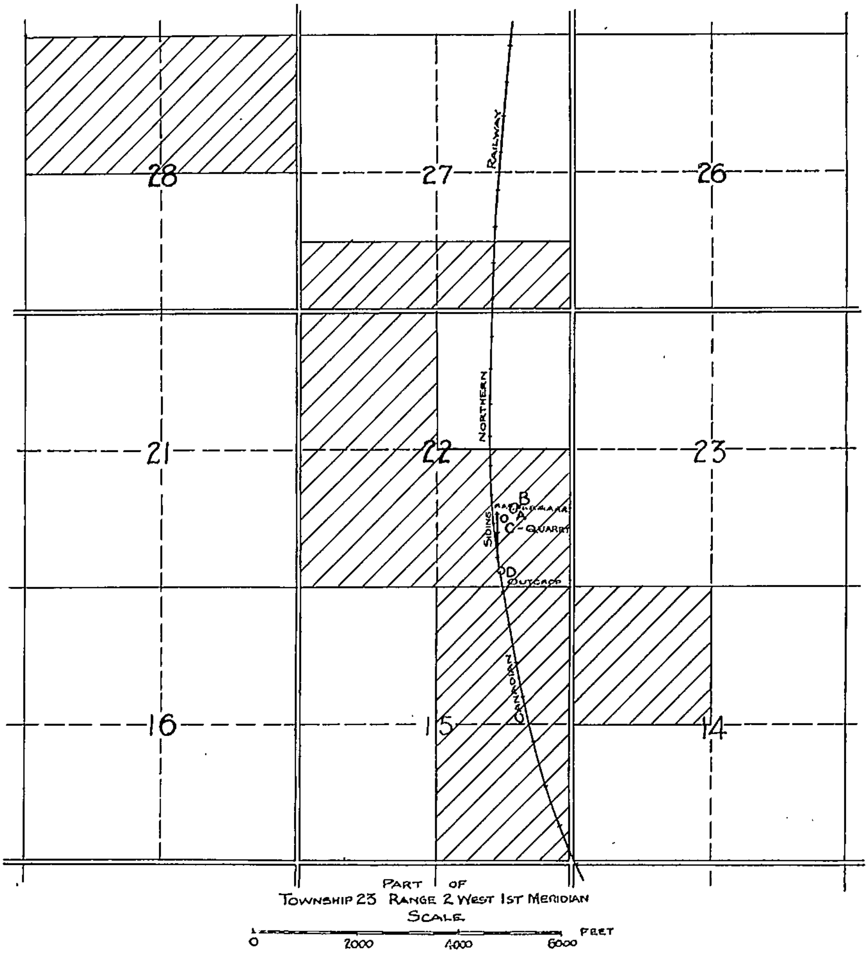


Fig. 5. Plan of the property of the Manitobite Stone Works, Broadvalley, Man.

Southward along the track, at a distance of 340 paces from the main quarry, a second rise in the rock surface brings the stone to within two feet of the grass roots ("D"). A small area here has been stripped exposing the stone which appears to be thin-bedded but further development must be done before the character of the beds can be determined (1145).

The stone: No. 1144.—A rather soft, fine-grained, distinctly and evenly crystalline stone of a whitish-yellow colour; it is distinctly porous but is neither pitted nor cavernous. It dresses to a fine smooth surface which shows no signs of pitting. The smoothed surface shows a fine and even mottling in shades of yellow and buff. The corrosion and freezing tests produce no visible result.

As it is proposed to use this stone for marble or at least for purposes of fine interior decoration, a polished sample has been prepared and is illustrated in Plate XXII.

The physical properties are as follows:—

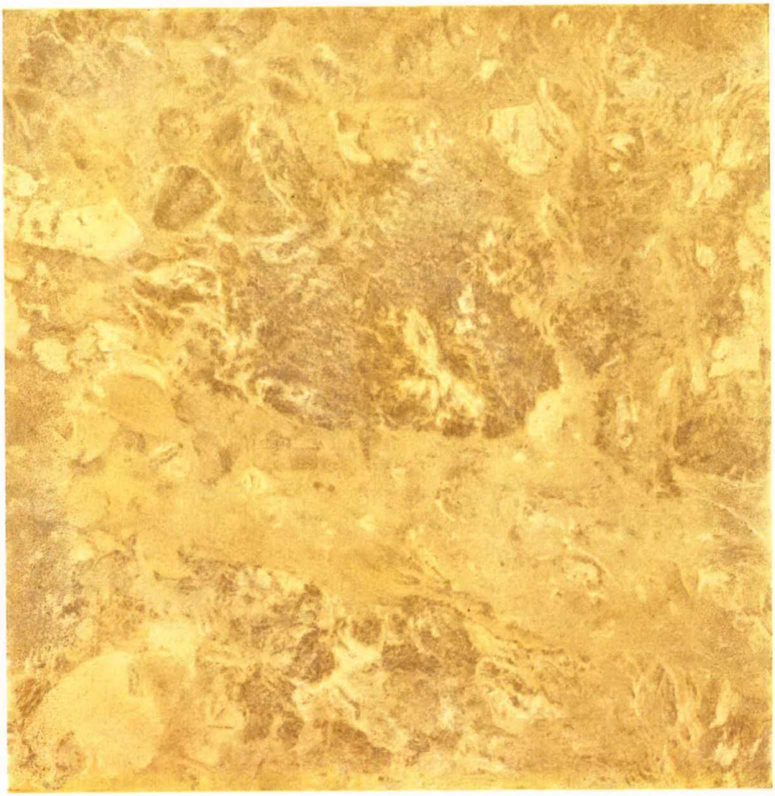
Specific gravity	2·839
Weight per cubic foot, lbs.	156·419
Pore space, per cent	11·74
Ratio of absorption, per cent, one hour	2·343
" " " " " two hours	2·355
" " " " " slow immersion	2·78
" " " " " in vacuo	4·67
" " " " " under pressure	4·68
Coefficient of saturation, one hour	0·5
" " " two hours	0·5
" " " slow immersion	0·59
" " " under pressure	0·99
Crushing strength, lbs. per sq. in., dry	30,000·
" " " " " wet	27,029·
" " " " " wet after freezing	28,977·
Transverse strength, lbs. per sq. in.	2,108·
Shearing strength, lbs. per sq. in.	946·
Loss on corrosion, grams per sq. in.	0·0108
Drilling factor, mm.	17·2
Chiselling factor, grams	9·65

The wet cube yielded under a sustained load which the construction of the testing machine required to be held for some time: it is undoubtedly a little too low.

This stone is almost a true dolomite with a small amount of foreign matter. The analysis by Leverin follows:—

	Per cent
Calcium carbonate	55·35
Magnesium carbonate	43·26
Ferric oxide	trace
Ferrous oxide	0·15
Alumina	0·11
Soluble silica	trace
Insoluble matter	1·00

PLATE XXII.



Silurian limestone. "Manitobite" cut parallel to bedding.

The following analyses by M. A. Parker of the University of Manitoba refer to (I) the thick upper beds, (II) the thin lower beds.

	I	II
	Per cent	Per cent
Ignition loss	48·34	47·40
Silica	0·14	0·18
Alumina and ferric oxide	0·20	0·65
Calcium oxide	32·16	30·64
Magnesium oxide	19·81	20·20

No. 1139.—The same type of stone as No. 1144 but differs in detail: it varies in colour, showing pinkish and yellowish bands. In places it is porous to fine cavernous.

No. 1140.—Same general type, slightly less yellow than No. 1144 and more uniform than No. 1139. Not cavernous, but hard.

No. 1141.—Almost identical with No. 1140.

No. 1143.—The same fine-grained, whitish crystalline dolomite as No. 1140 but with scattered large cavities.

No. 1142.—Exceedingly fine in grain, almost lithographic, white with a very slight cast of yellowish-grey. Hard and splintery with conchoidal fracture. Resembles the lowest beds of Long's quarry near Inwood.

No. 1145.—Essentially the same as No. 1140.

At the time of my visit one derrick had been erected at the quarry and 7 men were employed. I understand from Mr. Bourgeault that the company intends to operate on a more extensive scale, with the intention of using the stone for fine building purposes and also for interior finishings, as it is claimed that a good polish is obtainable.

Fairford Area.

The Silurian limestones of Fairford have been described by Mr. Alex. MacLean in the Summary Report of the Geological Survey for 1913 (page 167), Following Kindle, the beds are assigned to the highest horizon of the Silurian of Manitoba. A small amount of quarrying has been attempted near Fairford and on the Jack Pine ridge near old Gypsumville on Lake Manitoba. The following rather disconnected notes will serve to indicate the general aspect of the rocks of this horizon and vicinity.

Fairford, Manitoba.

East of the track and south of the crossing of the railway over the Fairford river, a slightly elevated area rises out of the lower land to the north and east. Stone is exposed or covered by a very light layer of drift over a considerable acreage. Several little pits have been made in the quarrying of a small amount of stone for local consumption. These pits are briefly described as follows:—

Pit No. 1.—Near the railway on the edge of the elevated tract. The stone is thin-bedded, horizontal, and shaly. It is a whitish-yellow dolomite with a tendency to weather still whiter (1175).

Pit No. 2.—A little farther east and farther from the edge of the hill. The stone is as much as 6 inches thick in places. It is not uniform in either grain or colour and is often cavernous with yellow stains surrounding the cavities. Pronounced joints strike E.25°S.

Pit No. 3.—A short distance southeast of No. 2. The material here is rather more heavily bedded but still too thin for other than rubble. The rock is very cavernous in places and also is much disfigured by yellow stains. The specimen (No. 1177) is selected and represents much better material than the average.

Well in the Armstrong Trading Company's building at Fairford.

Stone was encountered in sinking this well which is quite different from that of the little pits described above, and more like some of the material from Inwood and Broadvalley. The specimen was obtained at a depth of 20 feet. No information is available as to the bedding of the formation (1183).

The stone: No. 1175.—Fine-grained, whitish-yellow, thin-bedded, crystalline dolomite with numerous impressions of shells of *Leperditia.* The stone is slightly mottled and resembles the numerous similar specimens from Inwood and Broadvalley.

No. 1177.—Lighter in colour and a little more heavily bedded than No. 1175. The hand specimen is pitted but not cavernous. The exposed surface has a heavy whitish pulverulent coating and the pits are surrounded by yellowish stains.

No. 1183.—A very fine-grained, almost lithographic variety of this type of stone. It is of a light whitish-yellow colour and is almost identical with No. 1128 from the lower beds of Long's quarry at Inwood.

Jack Pine ridge, Old Gypsumville, Manitoba.

About 2 miles west of Old Gypsumville (Davis Point) an elevated ridge crosses the country in a northwest and southeast direction for a length of several miles and a width of about a half mile. Stone is accessible at many points and a small quantity was quarried where the old tram line from the gypsum quarries crossed the ridge. Stone is exposed here in layers up to a foot in thickness. Great lack of uniformity in the bedding and in the quality of the stone is to be observed. Much of the rock is porous owing to the solution of included fossils, and hard and soft streaks alternate with one another. This stone seems to possess an advantage over the other Silurian rocks of this district in being more heavily bedded, but its variability and the presence of porous streaks removes it from the class of high grade stones (1160, 1162).

The stone: No. 1160.—As already stated, the stone from this locality is extremely variable. The present sample was selected as a fair average but it will be understood that a considerable departure from the figures given below might be obtained with other specimens. When smoothed it shows a distant mottling with a compact ground mass and even more compact blebs of a lighter colour. Where weathered, the ground mass assumes a pitted appearance owing to the wearing out of fossil fragments. On the whole it is a hard and brittle stone somewhat resembling No. 1002 from the Stonewall quarries; it also resembles manitobite but it is harder, closer grained, and more cavernous. Corrosion and freezing produce no visible result.

The physical properties follow:—

Specific gravity	2·850
Weight per cubic foot, lbs	170·513
Pore space, per cent	4·16
Ratio of absorption, per cent, one hour	0·514
" " " " " two hours	0·6808
" " " " " slow immersion	1·01
" " " " " in vacuo	1·28
" " " " " under pressure	1·52
Coefficient of saturation, one hour	0·34
" " " two hours	0·44
" " " slow immersion	0·66
" " " under pressure	0·83
Crushing strength, lbs. per sq. in., dry	41,928·
" " " " " wet	28,368·
" " " " " wet after freezing	29,628·
Transverse strength, lbs. per sq. in	3,351·
Shearing strength, lbs. per sq. in	2,693·
Loss on corrosion, grams per sq. in	0·00498
Drilling factor, mm	12·7
Chiselling factor, grams	0·4

This is very strong stone for one possessing a porosity of more than 4 per cent. The slight gain in strength of the frozen cube over the wet one may be disregarded in view of the high pressure at which the cubes succumbed. The low coefficient of saturation under slow immersion is indicative of a stone with good frost resisting properties.

No. 1162.—In grain this stone is the same as No. 1160, but it is full of cavities and pitted streaks, making it a much rougher type. Neither of these stones could be used for any purposes but rough building, on account of the hardness and the generally cavernous and variable nature.

Lake Manitoba.

Silurian limestones have been excavated in making the ship channel in the Fairford river at the point where it leaves Lake Manitoba. The debris indicates a thin-bedded formation with variable colour and physical structure. A peculiar feature observed in this stone is a characteristic zonal weathering which does not argue well for its durability (1181, 1182).

Numerous exposures of Silurian rock occur along the trail to Steep Rock south of the locality described above. As far as can be ascertained in a cursory examination this stone is all thin-bedded, in places fairly solid and in others cavernous in texture (1178, 1179). At certain points inclusions of a reddish variety are observed but it was not seen in any quantity although statements to that effect are heard in the neighbourhood (1180).

The stone: No. 1181.—A hard, brittle, fine-grained type of the prevailing fine crystalline dolomite. The specimen shows an interesting zonal alteration. The centre of the block is yellow and blue banded and the outer part is bluish fading to white at the exterior. The weathered surface is dead white. This is a good hard compact rock with very few small pits and no large cavities.

No. 1182.—Fine-grained crystalline dolomite like the above but distinctly banded in yellow and white. Neither pitted or cavernous but hard.

No. 1178.—The same fine-grained crystalline dolomite but pitted, cavernous, and rough, with much iron staining.

No. 1179.—An extremely variable, rough, pitted, and even cavernous, iron stained type. In places it presents the characteristic fine-grained crystalline structure; in others, it is coarser in grain, less dolomitized, and with more resemblance to an ordinary brownish-grey limestone. The cavities are sometimes filled with white secondary matter.

No. 1180.—A brick red argillite with a small content of lime, soft and of no promise for our purposes.

Lake Winnipegosis—Saskatchewan River Area.

Silurian limestones are exposed at many points on the northeastern side of Lake Winnipegosis, on Cedar, Moose and Cross lakes, and at points on the lower Saskatchewan river more particularly at the Grand rapids.

Lake Winnipegosis.

I have heard of no attempt to utilize the stone from the outcrops on Lake Winnipegosis, nor have I found any suggestions in the literature that stone suitable for building purposes occurs. The shore line is described in detail by Tyrrell in his report on Northwestern Manitoba. It would appear that much of the shore is low-lying and without exposures and that the outcrops present little promise for the production of fine stone. The following is a summarized account of the chief outcrops mentioned by Tyrrell:—

Northwest point of Ami island—Flat-lying, thin-bedded, yellowish magnesian limestone of Niagara age.

Lat. 52° 54′ 15″—Light grey, thin-bedded, compact dolomite in a bay just north of the point. At the point, a massive, porous dolomite from 8 to 10 inches in thickness makes its appearance.

Lat. 52° 52′ 30″—Thinly stratified dolomites in undulating beds.

East side of Long point—Two feet of light yellow porous dolomites in rather thick beds, followed to the north by thick-bedded rock with nodules of chert.

Point on east side of the bay east of Long point—Yellowish-grey dolomite, more or less compact and thick-bedded. The rock contains cavities and small nodules of chert.

Points south of above—Thin and unevenly bedded dolomites.

Lat. 52° 46′—Light grey, porous, almost vesicular, dolomitic limestone, in beds from half an inch to an inch in thickness. Many exposures of similar thin stone are listed to the end of the Silurian outcrops opposite Birch island.

Cedar and Moose lakes.

At the Hudson Bay post, Chemahawin, situated on the south side of the Saskatchewan river near its entrance into Cedar lake, Silurian limestones are exposed for a considerable distance along the shore. The exposure at the wharf is low. The stone is soft and yellowish and weathers red in places (1105). A short distance up stream the cliff presents an exposure of about 10 feet with the lower 3 feet of solid but cavernous and rough stone passing upwards into more broken material. Distinct bedding can scarcely be made out in the whole 10 feet.

Still farther up stream the stone is less cavernous, particularly towards the top, and the following section is presented:—

2 ft. 3 in.—Fine-grained, greyish-yellow dolomite.
1 ft. 5 in.—Fine-grained, greyish-yellow dolomite.
1 ft. 2 in.—Very fine-grained stone but thinly bedded.
3 ft. 6 in.—Heavier but more cavernous stone, in thicker beds (1103 from different beds).

The whole exposure is characterized by the absence of distinct bedding. Thin and thick layers occur without regularity. The lower beds are heavier but more cavernous. The upper stone is finer and less cavernous but thinner bedded. Blocks of stone suitable for ordinary building could be obtained but the weathering qualities are not good and the stone would be hard to cut.

Numerous outcrops of stone occur on the islands and on the north shore near the head of Cedar lake. The cliffs are 10 feet or more in height and the stone is for the most part heavily but indistinctly bedded. Unlike the exposure at Chemahawin the thicker beds lie above. Stone at least a foot thick can be procured in quantity: it is hard, rough, fractured, and cavernous. As representing the prevailing and most desirable material on Cedar lake, this stone is described in detail below as No. 1119. Tyrrell mentions an exposure of light orange-yellow porous dolomite in heavy beds on the north point of Fort island.

Dolomitic limestones similar to those of Cedar lake are exposed on Moose lake to the northward. No geological reports have been published covering this region in detail but I understand that considerable cliffs of limestone occur at the narrows and along the north shore. An opportunity was afforded for the examination of the exposure near the old Hudson Bay post where a cliff of about 6 feet is seen. The stone is evenly bedded and comes out in slabs up to a foot in thickness but these slabs have a strong tendency to break into thinner material with a wavy parting. The ultimate layers are only one or two inches thick. The formation is strongly jointed a little north of east and shows less regular joints at varying angles. The stone is variable in quality and colour: some layers are cavernous while others are almost devoid of this objectionable feature. Certain of the bands weather whitish (1120) while darker bands occur in which the weathering is grey.

On account of the even bedding, this stone could be quarried for rough building purposes, but the tendency to differential weathering and to parting on the planes of stratification would be a drawback.

The stone: No. 1119.—This is a very hard, brittle, finely crystalline stone of a light bluish-grey colour. The dressed surface shows a fine mottling in bluish and yellowish components. While not extensively fine pitted, it is distinctly cavernous with holes often a half inch in diameter and in some cases of still greater size. It bears some resemblance to the Winnipegosan stone from Whiteaves point (No. 1086, page 126) on account of its cavernous character; it also is related to the stone from the Jackpine ridge near Old Gypsumville (No. 1160, page 95). The corrosion test produces a distinct alteration with a whitening of the surface and the accentuation of fossil fragments. The freezing test has no visible effect. The stone is remarkably hard for a dolomite.

The physical tests of this stone are necessarily very unsatisfactory on account of the extremely cavernous nature of the material. Porosity tests in particular are quite impossible, for, although apparently similar specimens were selected for duplicate testing, the results were so divergent that they cannot be regarded seriously. The total porosity, including the larger cavities which were avoided as far as possible in the experiments, must be many times in excess of the figures given. The anomalous results of the crushing strength experiments are likewise quite to be expected.

In the following table the specific gravity and the coefficients of saturation, being independent of the amount of pore space, are substantially correct as well as the corrosion and hardness tests. The extremely anomalous figures of the crushing strength tests may be regarded as illustrating the variable nature of the stone rather than as expressing the factors desired. The total pore space and the ratios of absorption apply only to the specimens and can not be regarded as reliable factors for the stone as a whole: they likewise serve to indicate the variability of the stone, and, as an extreme instance, well illustrate the difficulties which attend the determination of the constants which depend on porosity.

Specific gravity	2·843 2·846
Weight per cubic foot, lbs	175·054 173·248
Pore space, per cent	1·36 2·5
Ratio of absorption, per cent, one hour	0·188 0·275
(average)	0·231
" " " " " two hours	0·225 0·317
(average)	0·271
" " " " " slow immersion	0·1804
" " " " " in vacuo	0·379 0·787
(average)	0·583
" " " " " under pressure	0·486 0·90
(average)	0·693
Coefficient of saturation, one hour	0·38 0·31
(average)	0·345
" " " two hours	0·46 0·25
(average)	0·405
" " " slow immersion	0·36 0·2
" " " in vacuo	·78 ·87
(average)	·825
Crushing strength, lbs. per sq. in., dry	30,550·
" " " " " wet	36,320·
" " " " " wet after freezing	16,500·
Transverse strength, lbs. per sq. in	3,797·

Shearing strength, lbs. per sq. in.	3,780·
Loss on corrosion, grams per sq. in.	0·1518
Drilling factor, mm.	2·0
Chiselling factor, grams	0·5

An analysis of this stone shows that it is remarkably like No. 1123 from the Hudson Bay railway. The stone is essentially a true dolomite with a small amount of foreign matter:—

	Per cent
Calcium carbonate	53·21
Magnesium carbonate	43·62
Ferric oxide	trace
Ferrous oxide	0·26
Alumina	0·07
Soluble silica	0·06
Insoluble mineral matter	1·36

No. 1103.—(a) The same type of fine-grained crystalline dolomite. The specimen is very hard, light yellowish-grey in colour, and with numerous pits and cavities surrounded by iron staining. (b) Rather darker in colour and slightly coarser in grain. (c) Like 1103a but more mottled, in greyish and yellowish components. All these stones are extremely hard, rough, and more or less cavernous.

No. 1105.—Pitted and porous, mottled, yellowish-grey, fine-grained, hard, crystalline dolomite.

No. 1120.—A hard uniform type of this same fine-grained crystalline dolomite: it is of a slightly greyish colour and weathers a dull opaque white.

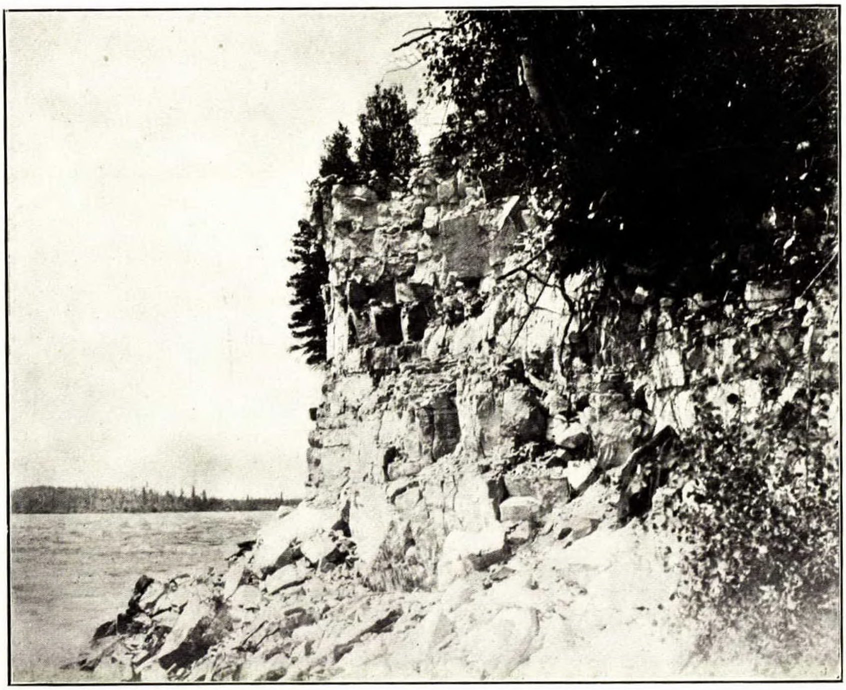
Saskatchewan River.

The points and islands near the foot of Cedar lake show exposures of light, yellowish, compact but cavernous stone in cliffs sometimes 25 feet in height. Some of the layers are thick enough to yield building stone, but the stratification is very irregular and much thin material is interbedded with the thicker stone. The better stone does not differ greatly from No. 1119.

At the demi-charge rapids into Cross lake the stone is exposed in a four-foot cliff showing thin-bedded brownish and brown and white mottled varieties (1106 and 1107).

A prominent exposure, at least 12 feet high, is seen on the south shore near where the river leaves Cross lake. The bedding is irregular but on the whole it is thick with a probable maximum of 2 ft. 6 in. The jointing is not excessive and large blocks can easily be procured. Some fallen masses 12 feet across without further jointing were observed on the talus. On vertical faces the stone shows distinct horizontal differential weathering

PLATE XXIII.



Silurian limestone. Cliff at Grand Rapids, Saskatchewan river, Man.

indicating a varying composition: in places it is much honeycombed. All the stone shows evidence of a high content of iron with a resultant low degree of resistance to weathering. The lower part of the exposure is composed of much softer and less desirable material. This is a possible site for the quarrying of heavy building blocks of very rough quality. The average stone is represented by No. 1108.

The exposures of stone on the Saskatchewan river between Cross lake and the Grand rapids present no possibilities for our present purposes. In the canyon, however, a very interesting section is afforded which has been described in detail by Tyrrell. While the beds are nearly horizontal in position, the slope of the river reveals lower strata down stream. Tyrrell divides the strata into two series which he correlates with the upper and lower Niagara. Roughly it may be said that the lower part of the gorge reveals the lower division and the upper part the upper division. From our point of view the lower series presents no possibilities and while some good stone occurs in the upper series its economic extraction is very doubtful owing to interbedding with less satisfactory layers.

The succession of beds in the lower series is given by Tyrrell on page 200E of his report on Northwestern Manitoba: the section is reproduced below. A walk through the gorge failed to impress me with the possibilities of this series as a producer of building stone.

Tyrrell's section of the lower series is as follows:—

15 ft.—White thin-bedded limestone (1117).
6 ft.—Covered.
8 ft.—Soft yellow limestone (1118).
10 ft.—Gap in section.
4 ft.—Hard yellow magnesian limestone.
8 ft.—Moderately thin-bedded white limestone.
1 ft.—Hard compact buff limestone.
2 ft.—Brecciated limestone.

The upper series is sharply defined from the underlying series and according to Tyrrell presents in all a thickness of some hundreds of feet. Tyrrell's description is as follows: "The base of this series is well shown in the gorge of the Grand rapids, where it consists of 10 feet of a hard, tough, light yellowish dolomitic limestone, rather indistinctly bedded, but conformable to the underlying series. It is generally clearly fragmental and in its lower portion contains a large number of salt crystals. This crinoid bed grades up into, and is overlaid by, from 20 to 30 feet of hard, brittle, yellow dolomite, generally thinly and evenly bedded. This compact band is overlaid by a porous yellow dolomite in moderately thin but uneven beds, and contains many impressions of salt crystals."

This upper series was examined in detail at a point on the gorge where the trail from the old tramway comes out on the river. The section is as follows:—

6 ft.—Thin and irregularly bedded stone, weathering whiter and breaking very irregularly. It is filled with masses of fossil *Stromatopora* (1115).

10 ft. 6 in.—Thin-bedded, brittle, dolomitic limestone passing into thicker bands in places. Towards the top, stone of a foot in thickness could be obtained. The layers differ slightly in texture and colour (1114, several).

2 ft. 2 in.—Hard solid bed weathering pimply. It is not very sharply defined upwards. It would yield large blocks of stone (1113).

1 ft.—Solid bed of whitish-grey stone with fossils. It is very brittle under the hammer but would yield good building blocks for rock face work (1111).

—Similar stone below the level of the water.

Vertical fissuring has greatly affected the beds. A major set of joints cuts the formation distinctly, northwest and southeast, and a set at right angles to this direction is equally well developed. Minor and local fissuring is also much in evidence. The lower bed of this section probably represents the top of Tyrrell's crinoidal layers and the rest of the section belongs to his "hard, brittle, yellow dolomite."

A gap occurs above this section, and, after an interval of 30 or 40 feet, exposures occur along the old tramway where the upper stone for a thickness of about 6 feet is thin-bedded (1109), and the lower layers are thicker but with a tendency to part into thin material like the upper portion (1110).

The stone: No. 1114.—This is probably the most uniform in structure and the finest in grain of the numerous Silurian dolomites examined: on this account it has been tested in full. The constants found for this example would probably apply, with minor modifications, to many of the non-cavernous types, *e.g.*, the fine-grained bottom stone from Long's quarry at Inwood, the stone from the well at Fairford and other similar kinds.

The colour is a uniform light greyish-white, which, together with the fine grain, gives the stone a lithographic appearance. The pore space is very low and the crushing strength remarkably high. The test cube stood a pressure of 52,708 lbs. to the square inch without any sign of crack or flaw. The wet crushing strength as recorded below is doubtless too low and is to be ascribed to instrumental error. The stone is so hard that it is scarcely abraded under the conditions of the chiselling test: it is not appreciably affected by either the corrosion or freezing tests.

The physical properties are as follows:—

Specific gravity	2·867
Weight per cubic foot, lbs	175·3939
Pore space, per cent	1·998

Ratio of absorption, per cent, one hour	0·078
" " " " " two hours	0·123
" " " " " slow immersion	0·609
" " " " " in vacuo	0·4674
" " " " " under pressure	0·7113
Coefficient of saturation, one hour	0·109
" " " two hours	0·17
" " " slow immersion	0·85 ?
" " " in vacuo	0·65
Crushing strength, lbs. per sq. in., dry	52,708·
" " " " " wet	44,430·
" " " " " wet after freezing	48,334·
Transverse strength, lbs. per sq. in	5,304·
Shearing strength, lbs. per sq. in	2,050·
Loss on corrosion, grams per sq. in	0·0089
Drilling factor, mm	7·0
Chiselling factor, grams	0·00

This stone is almost a true dolomite with a very small amount of ferrous oxide, alumina and insoluble matter. An analysis by Leverin follows:—

	Per cent
Calcium carbonate	54·20
Magnesium carbonate	43·89
Ferric oxide	trace
Ferrous oxide	0·37
Alumina	0·20
Soluble silica	trace
Insoluble mineral matter	0·30

No. 1106.—A rough, hard, cavernous, greyish type resembling No. 1179 from the Fairford-Steep Rock trail and with the same whitish inclusions.

No. 1107.—The same fine-grained crystalline stone in thin beds roughly banded in yellow and brown.

No. 1108.—This is a very much coarser and probably less dolomitic stone but with a distinct crystalline structure: it is highly impregnated with oxide of iron which gives it a mottled red appearance. The stone is pitted and cavernous and of very poor quality.

No. 1117.—This stone is softer than the average and shows very little crystalline structure. The grain is fine but quite different from the ordinary fine crystalline type. The colour is whitish-grey and there are no pits or cavities. Except for the thin-beddings this would be a possible building stone.

No. 1118.—A soft, whitish-yellow limestone of fine, non-crystalline character: it is almost a marl and of insufficient coherence to be of any value as a building stone.

No. 1115.—A very fine-grained, almost lithographic, argillaceous limestone of a distinctly yellow colour: it is hard and breaks with a conchoidal fracture. The weathering properties are not good, as it has a strong tendency to turn brown along the planes of stratification.

No. 1113.—A yellow, partially medium crystalline, partially compact limestone. It is hard and splintery and does not belong to the type of fine-grained crystalline dolomites so common in the formation.

No. 1112.—A hard, fine-grained, yellowish-white, argillaceous limestone of the lithographic type. It is not sufficiently uniform for lithographic purposes as it is filled with little specks of impurities and shows scattered calcite crystals. The stone is closely comparable with No. 1128 from Inwood and No. 1142 from Broadvalley.

No. 1111.—Very like No. 1112 but somewhat coarser and with impressions of fossils.

No. 1109.—A fine-grained yellowish limestone filled with great masses of *Stromatopora*. The presence of this fossil does not enhance the value of the stone for building purposes.

No. 1110.—Practically the same as No. 1115.

The Pas Area.

Hudson Bay Railway.

At Mile 6 of the new railway north of The Pas there is a rock cut about 6 feet deep exposing Silurian limestone for a distance of 200 yards. The stone is thin and unevenly bedded but in places shows layers of 8 to 10 inches. The upper 3 feet is finely laminated and the lower part coarser but there is little real difference. The stone weathers whitish with much iron staining in places. Thinner and less promising material is exposed in a 4-foot cut at Mile 9.

Limestones of a different type occur farther north: these are described under another area.

The stone: No. 1121.—A fine-grained, whitish, crystalline dolomite comparable with many of the same type herein described. It is a rather rough example, for thin layers of a uniform and compact structure are interbanded with coarse cavernous layers much stained with iron.

No. 1122.—A fine-grained crystalline dolomite with numerous cavities due to the solution of fossils. The abundance of yellowish staining and the cavernous structure suggest a comparison with the upper stone from Long's quarry at Inwood. The present example is harder and of finer grain but in general appearance it is very like the poorer type of Long's stone (No. 1132, p. 89).

Fisher Branch Area.

Reddish mottled dolomites are exposed in rough hills over considerable areas in the region to the east and north of Fisher Branch, Manitoba. The extension of the Canadian Northern railway from Inwood to Fisher Branch renders possible the shipping of stone from a region hitherto inaccessible. No actual attempt at quarrying has yet been made and consequently no carefully selected locality could be chosen as typical of the region. It will be understood, therefore, that the following notes are founded on exposures selected at random and cannot be expected to represent the maximum possibilities of the area.

This reddish rock from Fisher Branch and a very similar stone from the Hudson Bay Railway area were both obtained from regions in which no detailed geological work has been done. As the stone differs materially from any other of the Silurian limestones and seems to lie at a lower horizon I was inclined to ascribe it to the Ordovician system. The old geological map of Lake Winnipeg indicates a Silurian horizon for the Fisher Branch locality and Dr. E. M. Kindle has determined Silurian fossils from Fisher Branch, although a few miles to the north he recognizes Ordovician species in reddish shales. As our limestones were obtained from a region a little to the north and east of Fisher Branch it is still possible that they belong to the Ordovician. Basing the age on the fossils examined by Kindle, these rocks are provisionally ascribed to the Silurian.

Captain Humphrey Bryan, Selkirk, Manitoba.

On the northeast quarter of section 10, township 25, range 1 west, a rocky ridge crosses in a north and south direction rising about 40 feet above the lower land to the east. A considerable talus covers the base of the escarpment but 10 or 12 feet of stone are exposed along an irregular line of cliffs at the top. The stone is thin-bedded, with a maximum of about 8 inches, but I am inclined to believe that a greater coherence of beds would be found away from the zone of weathering. The general run of the stone is a hard, brittle, greyish type mottled with pink and red ; it is undoubtedly related to the stone of the Hudson Bay Railway area north of The Pas. Great variation is to be observed in the degree to which the red mottling is developed. Specimen No. 1136 is a fair average and No. 1137 shows the maximum degree of red observed at this point. The jointing is variable and irregular but fair sized slabs could be obtained. The stone is too thin, at least near the surface, for the production of mill blocks capable of being sawn into slabs as has been suggested.

The stone: No. 1136.—A hard, brittle limestone of very fine grain and splintery fracture: it is irregularly and obscurely mottled in greyish-white and yellow with a pink cast in places. The base is less clean and of a general lighter colour than that of No. 1123 from north of The Pas but the two stones are doubtless comparable.

No. 1137.—The same stone as No. 1136 but with much more red; it is very similar but a little redder than No. 1126 and considerably redder than No. 1123 from north of The Pas. This type of stone has certain possibilities for use as a marble. See remarks on page 267.

Hills west of Bryan's property.

For about 2 miles in a southwest direction from Bryan's property the road continues across the top of the ridge and shows numerous exposures of flat-lying stone in thin beds, essentially the same as that described above.

On descending the ridge on the southwest side there is an exposure of about 4 feet of stone similarly thin-bedded. Joints cross the formation at N.10°E., N.40°E., and W.10°N. Despite this fracturing it is still possible to obtain large slabs. The rock is hard and brittle (1138).

The stone: No. 1138.—This example is very similar to No. 1137: it has the same grain and structure and differs in detail only, *e.g.*, it presents a rather more distinct mottling and a purplish cast in the red.

W. H. G. Taylor, Fisher Branch, Manitoba.

A very red type of the stone occurs under a few feet of soil on the northeast quarter of section 15, township 25, range 1 west.

The stone: No. 1135.—This stone has considerably more of the red element than Nos. 1136 and 1137 described above. The increase in colouring matter (oxide of iron) is accompanied, hewever, by a somewhat coarser grain and a greater tendency to alter under the influence of the weather. A polished surface presents pleasing effects in red, pink and grey.

In this vicinity stone of a similar type is exposed on the properties mentioned below. This list is intended only to indicate localities of which I was definitely informed: doubtless a great many others might be cited in the neighborhood:—

Northeast quarter, section 18, township 25, range 1 west.
Section 28, township 25, range 1 west.
Section 19, township 24, range 1 east.
Section 24, township 24, range 1 west (in big hills).

Hudson Bay Railway Area.

Fine-grained reddish dolomites, essentially the same as those exposed at Fisher Branch, occur on the line of the Hudson Bay railway to the northward of The Pas. High cliffs of rock similar to those described below are said to occur on the shores of Rocky, Sturgeon, and Cormorant lakes.

These rocks are assigned to the Silurian system entirely on account of their resemblance to the stone from Fisher Branch, but it is by no means certain that they are not of Ordovician age. (See page 105).

Through the kindness of the engineer in charge I was afforded an opportunity of examining the rock cuts as far as the 42nd. mile. The exposures described below must be regarded, therefore, as representing the rocks of this area but it must be understood, in the absence of any literature on the region, that much more favourable localities may be found as the country is opened up.

Narrows of Cormorant lake.

Immediately north of the narrows and east of the track, a small quarry has been opened in connexion with the construction of the railway. Over several acres the surface is flat and devoid of overburden: an unlimited amount of stone is easily procurable.

The section at the little quarry is as follows:—

1 ft. 6 in.—Grey and pink mottled limestone. Essentially solid but easily divisible into thinner material.

1 ft.—Similar, but less pink and less inclined to part into thin layers.

1 ft.—Greyish and cavernous. Less desirable stone (1127).

14 in.—Greyish and cavernous. Less desirable stone.

2 ft. 6 in.—Heavily bedded and rather reddish throughout but variable in this respect (1126).

The joints are vertical at E.15°S. and N.25°E. and not too close to preventing the quarrying of large blocks. The stone seems to be very little affected by the weather as glacial striæ are perfectly preserved and the colour changes induced by the action of the elements are superficial only.

The stone: No. 1127.—A very fine-grained dolomite of light grey colour and very compact structure, but filled with large cavities which are lined with a yellow incrustation of secondary origin. The actual stone substance is doubtless hard and durable but the extremely cavernous nature of the rock renders it useless for structural purposes.

No. 1126.—This stone is essentially the same as No. 1123 which is described in detail on page 108; it differs only in a slightly greater profusion of red streaks.

Mile 41¾ Hudson Bay Railway.

A little quarry has been opened at this point on the east side of the track. The section is as follows:—

1 ft. 6 in.—Reddish, mottled and somewhat nodular and friable stone in a heavy bed but subject to wavy parting.

1 ft. 10 in.—Reddish, mottled and somewhat nodular and friable stone in a heavy bed but subject to wavy parting.

3 ft.—Similar but more solid stone in beds up to 10 inches. Much thinner material appears in places.

Pronounced joints cut the formation at S.30°E. and irregular fracturing is also much in evidence. The formation here is less promising than a little farther south and the stone is more nodular owing to a greater development of the peculiar wavy red partings. Specimen No. 1125 described below is typical of the stone from this locality and of the more nodular variety in general.

The stone: No. 1125.—This stone has the same fine-grained, greyish base shown by all the examples from this locality and from Fisher Branch. In this instance, however, the planes of stratification are extremely irregular and sharply uneven. As there is a strong tendency to part on these planes, the resulting material is seldom more than an inch thick and so irregular as to be almost nodular in structure. The red ferruginous element is present on all the planes of parting and extends with decreasing intensity for a short distance into the stone substance.

Mile 42 Hudson Bay Railway.

Close to Cormorant lake at this mileage, the reddish dolomites are exposed over a considerable area and are well seen in a rock cut a little farther north where a good section is presented. The cut is about 100 yards long in a residual ridge of almost horizontal strata (Plate XXIV). The section is as follows:—

1 ft.—Solid bed (1123).

2 ft. 2 in.—Solid bed. The upper part is pinkish, and the lower 6 inches is somewhat cavernous with yellow stains in the hollows. This lower layer is in part separable as a distinct bed. The middle part is of a typical greyish colour with a variable amount of red mottling; it may be divided into several beds but it does not cleave thin.

1 ft.—Solid bed, mostly grey, but pinkish in places, particularly towards the bottom.

1 ft.—Similar, but the pinkish part is towards the top.

4 ft.—Similar greyish and pinkish beds of variable thickness but mostly fairly heavy.

The rock cut shows a pronounced system of joints, S.40°W. with a steep to vertical but somewhat variable dip. A second equally distinct set crosses at S. 35°E. Neither set is too closely set and would facilitate rather than hinder the extraction of building blocks.

Near Mile 52 are two rock cuts in stone which is probably of a similar kind, and a ridge exposing 14 feet of stone occurs near Mile 70 in the vicinity of Limestone lake. Similar stone is said to occur on Cormorant, Rocky, and Sturgeon lakes.

The stone: No. 1123.—This example may be regarded as typical of the reddish mottled stone of this area and the description may be applied with some modifications to the Fisher Branch stone (page 104): it is also applicable to the major portion of the stone obtained from the drift near Prince Albert and Saskatoon and referred to on pages 277 and 278.

The stone is a hard, very fine-grained and very brittle dolomite, of a general greyish colour but mottled in a peculiar manner with pink and red. The mass of the rock seems to be made up of thin, irregularly wavy layers with reddish ferruginous matter irregularly developed on the parting

PLATE XXIV.

Silurian limestone. Exposure at mile 42, Hudson Bay railway, Man.

planes. In this respect it somewhat resembles the yellow rubble from the quarries at Gunton, but the tendency to part on the planes is much less pronounced in the present example. The dressed surfaces are very smooth with sharp edges and angles but with a tendency to pluck out on the wavy planes of parting. The material is susceptible of a fine polish and would make a handsome marble except for the unfortunate tendency to pluck.

Naturally weathered surfaces are whitish but the alteration is only skin deep. The corroded specimen does not show this whitening, indicating that the alteration must proceed at a very slow rate. Under this test very little colour change ensues, and, when wet, the treated and untreated specimens are scarcely to be distinguished. The freezing experiment produced no change in colour but the tendency to part on the wavy planes of stratification was accentuated. This stone is much too hard for chiselling but it would make excellent rock face work; the possibility of its use as a marble has already been referred to. The physical properties are given below:—

Specific gravity	2·856
Weight per cubic foot, lbs	177·143
Pore space, per cent	0·503
Ratio of absorption, per cent, one hour	0·0688
" " " " " two hours	0·0945
" " " " " slow immersion	0·167
" " " " " in vacuo	0·159(?)
" " " " " under pressure	0·177
Coefficient of saturation, one hour	0·39
" " " two hours	0·53
" " " slow immersion	0·94(?)
" " " in vacuo	0·9
Crushing strength, lbs. per sq. in., dry	40,549·
" " " " wet	38,100·
" " " " wet after freezing	37,714·
Transverse strength, lbs. per sq. in	2,641·
Shearing strength lbs. per sq. in	3,805·
Loss on corrosion, grams per sq. in	0·0048
Drilling factor, mm	5·3
Chiselling factor, grams	0·15

The slow immersion test for porosity was made on a separate cube and the result is out of accord with the other determinations. The ratio of absorption for slow immersion and the coefficient of saturation are undoubtedly too high. The actual amount of water absorbed is so small that a slight difference in the absorption of different examples is greatly magnified in calculating the coefficient of saturation.

This stone is a true dolomite with a small amount of impurities as the analysis by Leverin gives:—

	Per cent.
Calcium carbonate	53·21
Magnesium carbonate	43·26
Ferric oxide	trace
Ferrous oxide	0·18
Alumina	0·14
Soluble silica	0·08
Insoluble matter	1·16

The small amount of ferrous oxide indicates that the stone will not be likely to darken much on exposure.

Summary—Silurian Limestone.

An account of the general distribution and characteristics of the limestones of this formation is given in the introduction to this section on page 76. The rocks are essentially dolomites, varying in texture and colour, and in the degree to which cavernous structure is developed.

Extensive quarries are worked at Stonewall and Gunton in Manitoba. The top rock at the former place is a whitish dolomite which has been used to a limited extent for building (No. 1002, page 79). The Gunton stone, while used largely for lime and macadam, is not of high order from our point of view. Yellow and red rubble from this locality are described as Nos. 1013 and 1014 on pages 84-85.

Small quarries have been worked near Inwood, Man., and a soft crystalline, slightly mottled variety known as "manitobite" is quarried near Broadvalley. It is proposed to use this stone for purposes of finer construction and even for decoration: it is described in detail as No. 1144 on page 92.

Extensive areas of Silurian rocks occur in the northern part of the province but no quarries have been opened to date.

Literature:—Geol. Sur. Can., Ann. Rep., Vol. V, Pt. E.
Geol. Sur. Can., Ann. Rep., Vol. XI, Pts. F and G.
Dept. Mines, Canada, Mines Branch, Rep. on the Limestones and Lime Industry of Manitoba, 1905.
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Limestones of the Devonian System.

The stratigraphic position of some of the limestone formations of the eastern ranges of the Rocky mountains has been much in dispute, but at the present time the evidence points to the following formations as being of Devonian age in descending order:—

Lower Banff limestone.
Intermediate limestone.
Sawback limestone.

From a strictly economic point of view, it would perhaps be better to treat the Lower Banff limestone together with a still higher series, the Upper Banff limestone, which is regarded as of Carboniferous age. This method of treatment is desirable on account of the similarity of the stone from the two formations and on account of the difficulty of distinguishing them in the field, particularly where detailed geological work has not been done. This difficulty is so great that in many places the formations are grouped together and referred to as of Devono-Carboniferous age. In order to preserve the uniformity of arrangement adopted for these reports, the formations are separated, admittedly, with a possibility of error in certain instances.

A brief general description of the structure of the Rocky mountains has already been given in Chapter II of this volume. The outer or more easterly ranges are made up of a great series of rocks ranging in age from the Cretaceous to the Devonian. From the crests of the ranges the upper soft Cretaceous rocks have been removed by erosion and the hard Rocky Mountain quartzite now forms the summits of the mountains and helps to maintain the sharp declivity of the eastwardly directed scarped faces. Beneath the Rocky Mountain quartzite come the Upper Banff limestone and Lower Banff shale which are of Carboniferous age: these are succeeded downwards by the Devonian formations listed above.

While we are at present dealing with the Devonian formations only, the difficulty of separating the Upper Banff limestone justifies certain general remarks at this point because all the limestones of the ranges have been subjected to the same influence and consequently possess many features in common.

It is of course obvious that the limestones of these formations can easily be obtained in enormous quantities at innumerable places throughout the whole length of the eastern ranges. They are accessible along all the lines of railway that penetrate the mountains and each of the divisions could be quarried without difficulty at points convenient for shipment. Nevertheless, I know of no place where any of these stones have been quarried for building purposes, but they have been exploited to some extent for lime burning and for use in the cement industry. As far as I can learn, a small block in Blairmore is the only building constructed of these stones, if we except a few rough structures on the properties of the companies operating for lime, etc. In the Canadian Pacific hotel in Banff a few blocks of Upper Banff limestone have been used for keystones in arches.

The reason for the failure to utilize this abundant material lies in peculiarities of composition and structure and in formational features which may be enumerated as follows:—

1—Hardness.—The great bulk of the formations is much too hard to be chiselled at a cost which would permit of successful competition with other stones.

2—Nodules.—Much of the Upper Banff and some of the Lower Banff limestone is filled with nodules and thin bands of silica which absolutely prohibit its use as a fine building stone.

3—Bedding.—Throughout the formations, the original bedding of the constituent strata is obscured, with the result that the stone comes out in great irregular masses unsuitable for coursing stone. The additional cost of cutting bedding planes is a strong deterrent factor. Much variation is observed in this respect.

4—Diversity.—The various layers differ considerably in quality and structure. This objection, taken by itself, is not very serious as it applies to nearly all limestone localities, but taken together with No. 5 below it becomes of great moment.

5—Tilting.—The strata are nearly everywhere inclined at high angles and in consequence it is seldom possible to quarry an individual layer without removing contiguous less desirable material. It is to be noted in this connexion that quarrying on the eastern scarped faces of the mountains is impossible and that the back slope is covered with debris or with the Rocky Mountain quartzite and later formations. It follows therefore that quarrying can be carried on only in the crosswise valleys where the successive strata are accessible: here the difficulties due to the inclination of the strata are ever present.

6—Fracturing.—The whole mass of the mountains is greatly shattered and broken. This fact alone would not prevent and might even assist quarrying operations if the divisional planes were even and disposed in definite directions. Throughout the mountains, however, it is seldom that distinct systems of joints occur, the whole mass being traversed by irregular, ill-defined, and in places excessive partings.

In connexion with this subject it must be remembered also that the local demand for building stone is slight and that a very high grade of stone could alone stand the additional cost of freight charges to the larger centres of consumption.

In view of the enormous extent of these limestones and their variations throughout the great thicknesses exposed, and in the absence of any definite location where they are quarried for building purposes, it is impossible to present the reader with an adequate economic description. A general idea of the character of the stone in the different formations may be obtained from the quotations given below and from the description of the stone obtained from a few type localities. While the statement is doubtless based on insufficient information, I am inclined to believe that the only layers likely to prove of real economic value from the present point of view are situated in the Upper Banff series. The stone of these beds is more suitable for carving than the average, its colour is pleasing, and it presents a well-defined crystalline structure. This type of stone was seen in the rock-slide at Frank, in the talus of Mount Rundle, and near the quarries of the Summit Lime and Cooperage Works on the Crowsnest line: doubtless it is present in greater or less amount throughout the formation. In view of the relative importance of this variety it has been tested in full and is described as No. 1315 on page 143.

In Manitoba the Devonian rocks occupy a wide belt stretching in a northwesterly direction through the region occupied by Lakes Manitoba and Winnipegosis. In descending order three formations are recognized as follows:—

Manitoban.
Winnipegosan.
Elm Point.

The lower or Elm Point formation is characteristically thin-bedded, and the same structural feature is common in the two upper formations: in these, however, certain bands attain a thickness sufficient for the making of building blocks. All the Devonian rocks of this region seem to be bent into low anticlines, accompanied by much fracturing: this feature is well displayed on the points and islands of Lake Winnipegosis.

SAWBACK FORMATION.

The formation is briefly defined by Allan as follows: "The Intermediate limestone is underlain by a conformable series of massive and thinly bedded dolomitic limestones and shales which McConnell has placed in the Cambrian. These latter beds form a wedge-shaped band in the Sawback range and lie between Mount Hole-in-the-Wall and Mount Edith, with a broader exposure along the north side of the Bow valley." [1]

At the type locality north of the Bow the beds are inclined at high angles; they are much broken and seem to weather badly. The thinner lower stone is described as No. 1308 and thicker beds higher in the formation are represented by No. 1309. Allan regards these rocks as of Devonian age.

The stone: No. 1309.—A greyish, fine-grained limestone of crystalline structure and pronounced wavy lamination. The prevailing grey stone is much mixed with a dull pink variety in a manner which sometimes suggests brecciation. The whole mass is cut irregularly by veinlets of white calcite. Attempts were made to cut this stone for testing but it was impossible to make cubes owing to the shattered nature of the rock. This surface stone is quite useless for any purposes but if more solid material could be obtained

[1] Geol. Sur. Can., Sum. Rep., 1912, p. 172.

it might have a value as marble, for the polished surface has a handsome appearance in quiet tones of pink and grey, relieved by lines and blotches of white.

No. 1308.—Not essentially different from No. 1309, except that it is in a more shattered condition.

INTERMEDIATE FORMATION.

McConnell's description of this formation is as follows: "The Intermediate limestone underlies the Banff limestone conformably, and passage beds partaking of the lithological character of both groups occur at the junction of the formations. It is mainly composed of a great series of brownish dolomitic limestones, and has a thickness of about 1,500 feet. The typical dolomites of this formation are dark brownish in colour, are finely crystalline, and are often hardened by concretionary action. They have, in many places, a blotched appearance, due to small cavities becoming filled with calcspar, are cherty, and are characterized throughout by an abundance of corals. In some sections a light greyish variety is not infrequent. It is more coarsely crystalline than the dark variety, and is unfossiliferous. In addition to the dolomites, beds and bands of sandstone, quartzite, and calcareous limestone are found all through the series." [1]

The specimens described below were obtained in the vicinity of Banff—No. 1303 from the lowest exposure seen at the middle spring, Sulphur mountain; No. 1304 from the lowest ledges on the road to the spring; and No. 1305 from a still lower exposure near the Alpine clubhouse.

The stone: No. 1303.—A hard and very fine-grained crystalline, limestone of a light steel-grey colour: it weathers whitish and shows a minutely pitted surface. It is a fine-grained and more uniform stone than that described below.

No. 1304.—A hard, dark grey, crystalline limestone of varying grain; it is filled with cavities containing white calcite and is traversed in all directions by flaws which, in many cases, are filled with red oxide of iron. The stone breaks very irregularly and emits a sulphurous odour. On the whole, it is a hard, badly weathering, rough, and undesirable stone.

No. 1305.—A hard, compact, exceedingly fine-grained, almost black, argillaceous limestone, filled with diagonal flaws and cut by many veinlets of calcite. It resembles the rock on the Spray (No. 1302) much more than it does No. 1304 which I take to be typical Intermediate limestone. I am by no means sure of the geological position of the outcrop from which the specimen was obtained.

LOWER BANFF LIMESTONE.

McConnell's description of this formation is as follows: "The lowest division of the Banff limestone consists of from 600 to 800 feet of heavy-

[1] Geol. Sur. Can., Ann. Rep., Vol. II, Pt. D, pp. 19-20.

bedded, bluish, and fairly compact limestone. In composition it is mostly calcareous, but it also contains a certain amount of dolomitic matter distributed in an irregular manner through the beds, and evidently collected together by concretionary action. The dolomite is not visible on a fresh fracture, but, owing to its superior durability, it projects from weathered surfaces, over which it often forms a rough reticulation. This limestone differs from the Upper Banff limestone in being darker, more compact, and in the smaller number of crinoidal fragments and cherty concretions which it contains, although neither of these are altogether absent. It is very evenly bedded, and weathers into bold cliffs, such as are seen in Tower mountain on Devil's lake, in Cascade mountain, and in a number of other places."[1]

This formation, on the whole, is less promising from the present point of view than the Upper Banff division. All the stone that I have observed is much too hard and splintery to be of any use for purposes of finer construction. The following examples will serve to illustrate this formation.

Canadian Pacific Railway Area.

The following examples may be regarded as typical of the Lower Banff limestone in the southern part of the Rocky mountains of Alberta.

Canada Cement Company; quarry at Exshaw, Alberta.

The quarry is opened on the west face of a minor ridge on the north side of the railway: the excavation is nearly 200 yards long with a width of 30 or 40 yards. The long axis of the quarry is almost due east and west but the strike of the formation is W.30°N. and the dip 35° to the southwest. The bedding is heavy and fairly well marked showing some variation in the grain and quality of the stone. All the beds, however, conform to the general type of a hard, black, splintery limestone quite unsuitable for structural purposes other than of the roughest kind. The most prominent joints run straight down the dip, but they are cut by another series at an angle of about 45°. The latter set is very closely spaced in places and the fracturing is further increased by the occurrence of fine diagonal jointing which is excessive in some parts of the exposure. Well marked horizontal joints also occur in the face of nearly 100 feet which is exposed.

The stone: No. 1336.—This sample was carefully selected and it is above the average of the quarry. It was difficult to obtain a good specimen on account of the highly brittle nature of the rock and its tendency to diagonal fracture. Much of the stone differs from this sample in the occurrence of fine calcite stringers on the joint planes and also in the finer cracks throughout the rock. The rock is a hard, dark, splintery, greyish-blue limestone of exceedingly fine grain. The rubbed surface shows a faint brownish

[1] Geol. Sur. Can., Ann. Rep., Vol. II, Pt. D., p. 19.

mottling and fine lines of secondary calcite. The polished surface (Plate XXV) is very dark, almost black, with fine white lines and dots. The material takes an excellent polish and, if it can be obtained in large blocks, it has a positive value as a black marble.

The physical properties are as follows:—

Specific gravity	2·723
Weight per cubic foot, lbs.	169·428
Pore space, per cent	0·328
Ratio of absorption, per cent, one hour	0·024
" " " " " two hours	0·029
" " " " " slow immersion	0·083
" " " " " in vacuo	0·10
" " " " " under pressure	0·12
Coefficient of saturation, one hour	0·2
" " " two hours	0·24
" " " slow immersion	0·69
" " " in vacuo	0·83
Crushing strength, lbs. per sq. in., dry	27,174·
" " " " wet	21,429·
" " " " wet after freezing	20,072·
Transverse strength, lbs. per sq. in	1,779·
Shearing strength, lbs. per sq. in	2,975·
Loss on corrosion, grams per sq. in	0·158
Drilling factor, mm	———
Chiselling factor, grams	9·2

An analysis by Leverin shows this stone to be almost a true limestone with very little admixture of magnesium carbonate and still less of foreign matter:—

	Per cent
Calcium carbonate	95·80
Magnesium carbonate	3·38
Ferric oxide	trace
Ferrous oxide	0·13
Alumina	0·06
Soluble silica	0·04
Insoluble mineral matter	0·64

Edward Loder, Kananaskis, Alta.

The railway west of Kananaskis station cuts the base of a spur which rises into the mountain to the northwest. The formation strikes W.30°N. and dips to the southwest at a high angle. The planes of stratification are curved and the dip is lower in the main range. Mr. Loder is operating at this point for lime. The quarry is opened along the strike for a distance of downwards is well exposed. Assuming that a prominent shale formation several hundred feet in thickness is the Lower Banff shale we have a great thickness of limestone which must be ascribed to the Lower Banff or Intermediate divisions. These rocks outcrop at mile 24 and extend to the north of mile 23. The most southerly exposure shows a hard, splintery, and much fractured stone, which weathers yellow, shows a pitted surface and is cut by numerous calcite veinlets (1219). Heavy blocks could be obtained at this point but the stone is fitted only for the roughest purposes. Shaly layers extend for about 200 feet below these limestones and are again followed by limestones to mile 23. The upper part of these layers is thin-bedded but the lower part lies in heavier beds. The stone is very hard, brittle, greatly fractured and cut by small calcite veinlets; it has a tendency to weather to a dull bluish-white (1220).

The stone: No. 1219.—This stone is sufficiently described above: it differs in detail only from the stone described as No. 1239 on page 119. The varieties from this locality ascribed to the Upper Banff series are not essentially different.

No. 1220.—Differs from 1219 in detail only.

Main Line of Grand Trunk Pacific Railway.

On approaching the Yellowhead pass from the eastward, the line of the Grand Trunk Pacific railway cuts through three distinct ranges of Devono-Carboniferous strata. While admitting that some of the stone is undoubtedly of Upper Banff age, is seems advisable in order to avoid confusion and possible error to describe all the exposures together.

The first limestone exposure at mile 1003½ is a hard, black, splintery type in heavy beds; with numerous nodules arranged in bands and more apparent in some parts than in others. The dip varies and the heavy bedding is rendered useless by secondary lamination and the presence of the nodular bands (1237). This rock seems to represent the top layers of Roche Miette which is regarded as of Devonian age.[1]

The rock weathers to a dirty, yellowish-brown and is quite useless for our purpose.

Westward and ascending, the above stone is interbanded with No. 1238 and dark splintery limestone filled with stringers of calcite. Still higher in the series, at mile 1004, the beds are somewhat thicker, in places 3 to 5 feet or even more. Here, operations for lime have been conducted by the

Fitzhugh Lime and Stone Company, Edmonton.

The formation strikes S.W. (mag.) and dips at a high angle (85°). Much stone is easily accessible in a 50-foot cut near the track. The stone is

[1] Geol. Sur. Can., Ann. Rep., Vol. IX, Pt. D., pp. 29-30.

300 feet with a width of about 150 feet. The main joints cut across the strike vertically. Horizontal joints are also present. The stone on the northeast side of the ridge is rather thin-bedded but by coherence of the beds it may be obtained in small blocks. The surface shows the characteristic weathering of the formation, presenting a honeycombed appearance and fine elevated bands parallel to the strike. The walls on both the northeast and southwest sides of the quarry show a hard, dark, splintery type of stone with some calcite veinlets (1337). In the middle of the quarry is a lighter coloured zone about 30 feet wide (1338). On either side, between this light zone and the outer dark rock, occurs a band of mottled stone (1339).

The stone: No. 1338.—This stone is somewhat cavernous in places and shows spots of light coloured greenish calcite. It is said to make a high grade of lime suitable for plaster. It is of exceedingly fine grain and very light colour; in structure it does not differ greatly from the ordinary fine-grained black type like Nos. 1337, 1336 and 1239.

No. 1337.—This stone is of the hard, dark, splintery, fine-grained type like Nos. 1336 and 1219.

No. 1339.—A very hard, splintery limestone of very fine grain. It is distinctly mottled with two components—one like No. 1338 and the other like No. 1337.

Crowsnest Lake.

The Lower Banff limestone outcrops along the north shore of Crowsnest lake and is cut by the line of the Canadian Pacific railway at several points. The formation is much shattered and presents little possibility for the production of building stone. The prevailing rock is a hard, dark, splintery type with much local variation (1373, 1374, 1375).

Grand Trunk Pacific Railway Area.

Less detailed geological work has been done in the northern part of the province and consequently it is not always possible to separate the two series of limestones in the course of a cursory examination. Speaking generally, the more characteristic types of Upper Banff limestone as exposed in the southern part of the province were not observed. The average stone of the two series is so much alike in the northern area that without detailed geological examination it is almost impossible to separate the two series. The division as herein stated is subject to correction.

Coal Spur-Mountain Park branch of Grand Trunk Pacific Railway.

The line of railway north of Mountain Park in the valley of the McLeod river presents numerous rock cuts in the Devono-Carboniferous limestones. A splendid section of the formations from the Rocky Mountain quartzite

PLATE XXV.

Lower Banff limestone, Canada Cement Company, Exshaw, Alberta.

hard, dark and splintery, so much so, that it is almost impossible to break out a test block with the hammer. A description of the stone, No. 1239, is given at the bottom of this page.

The company has excavated only a small amount of rock, which has been burned in two kilns.

The hard, cherty, ribboned limestones again occur to the west and close the sequence of rocks in this exposure.

The next range westward outcrops on the track just east of mile 1011 and is represented by several types of stone, all excessively shattered and presenting no possibilities as building material. The rocks are more crystalline than those of the first range and seem to represent a different series.

The lowest or more easterly stone is a fine-grained, brownish crystalline limestone, which would make a fair building stone were it not for the excessive fracturing (1240). This stone passes upwards into a hard, greyish but crystalline type (1241) which becomes interstratified with shale and a type described below as No. 1242. Many other varieties occur in bands with shale and the exposure ends in a fine-grained, almost non-crystalline variety much shattered and broken.

The third range is exposed on the railway at mile 1014 and is represented first by a hard black type like No. 1237: this is followed by a shale and a quarter mile farther west by a hard, light coloured, semi-crystalline limestone which passes upward into the hard black variety filled with calcite veinlets. Towards the west end of the exposure fine grey types occur (1243): they are very hard and heavily bedded but part thinner on account of secondary lamination. The colour varies from grey to black. All these rocks strike W.20°S. (mag.) and dip at high angles to the northwest.

From this point the railway follows a longitudinal valley between the Devono-Carboniferous rocks and the inner ranges of greater age.

The stone: No. 1237.—A very dark—almost black—fine-grained, highly argillaceous limestone. The calcitic parts are aggregated into nodular masses in a more argillaceous base. The stone is very rough and quite impossible for our purposes.

No. 1238.—A black, somewhat calcareous slate of poor cleave and not promising as roofing slate.

No. 1239.—A hard, very dark grey, splintery, compact limestone of fine crystalline structure and with scattered larger crystals. The rock is filled with checks and flaws and is traversed by very fine stringers of white calcite. This stone is comparable with No. 1336, page 115, but it is of darker colour. I believe that it has been proposed to use the stone as a black marble as it takes a good polish; I fear, however, that the shattered condition of the formation would not permit the extraction of quarry blocks.

An analysis by Leverin shows this stone to contain very little magnesia or foreign matter:—

	Per cent
Calcium carbonate	96·36
Magnesium carbonate	1·67
Ferric oxide	0·07
Ferrous oxide	0·19
Alumina	0·08
Soluble silica	0·20
Insoluble mineral matter	0·16

A considerable amount of carbonaceous matter is present.

No. 1240.—A hard, fine-grained, distinctly crystalline limestone of brownish colour. The brown base is relieved by scattered patches of white with a slightly coarser grain.

No. 1241.—A fine to medium grained, crystalline limestone of light steel-grey colour. The stone is harder and coarser in grain than No. 1240. Another type is darker, and of uniform, medium grain and crystalline structure. Either of these stones would make good rock face work.

No. 1242.—This stone is quite different from those described above: it is medium in grain, of light greyish colour and of decidedly porous structure. It is probably a dolomite.

No. 1243.—A dark grey, finely crystalline, extremely hard limestone of uniform, compact structure.

ELM POINT FORMATION.

The lowest division of the Devonian rocks of Manitoba has been called the Elm Point limestone by Dr. E. M. Kindle.[1] The formation is typically exposed at Elm Point on Lake Manitoba whence the name is derived. The rocks are essentially thin-bedded limestone and in no case were they observed to present strata at all likely to be useful for the making of building stone. The formation, however, is being quarried at a number of places for lime and cement making, and although it is the least promising of the three Devonian formations from our point of view, it is the only one in which any quarrying operations have been attempted.

The following areas of Elm Point limestone will serve as a convenience for purposes of description:—

Oak Point area.
Moosehorn area.
Steep Rock area.
Lake Winnipegosis area.

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[1] Geol. Sur. Can., Sum. Rep., 1912, p. 251.

Oak Point Area.

David Bowman Coal and Supply Co., 667 Henry Ave., Winnipeg.

This company holds 40 acres of quarry lands connected by a siding 5,700 feet long with the Canadian Northern railway near Oak Point station.

Stone is accessible over a considerable area by the removal of a slight amount of drift. The quarry at the time of my visit was little more than a test pit, about 20 feet square, and 5 feet deep. The stone is all thin-bedded and rarely exceeds 3 inches in thickness. The bedding is wavy and irregular and the joints uncertain. The only recognizable system strikes N.35°E. with a dip of 60-70° to the northwest.

The stone is hard and distinctly mottled: it varies in colour, probably on account of the degree to which oxidation has occurred. The joints are iron stained and similarly stained pits are frequent in certain parts. The presence of numerous fossils also detracts from the value of the stone for building purposes (Plate XXVI).

The stone: No. 1148.—A hard, fine-grained, crystalline limestone, coarsely mottled in grey and yellow: in general appearance it closely resembles the more oxidized types of the Lower Mottled limestones of Lake Winnipeg.

The company proposes to utilize the stone for lime burning and intends to install a Keystone kiln. A crusher will also be erected. It is expected that 20 men will be employed.

Moosehorn Area.

Moosehorn Lime Company, Trust and Loan building, Winnipeg.

The property of this company consists of the southwest quarter of section 22, township 27, range 7 west of the first meridian: it is connected with the Canadian Northern railway at Moosehorn by a siding 4½ miles long.

Ridges of stone with a general east and west strike cross the country in this vicinity and present many places at which quarrying could easily be carried on. The northerly limit of the high land strikes about E.20° to 30°S. The company is opening the quarry at a point on this limiting escarpment where a face of from 8 to 12 feet is presented. A very pronounced difference is shown in the upper and lower stone and on tracing the edge of the escarpment towards the east it is found to break into two separate ridges of decidedly different character. I am inclined to think that the upper stone is Devonian and the lower Silurian and that they are separated by an erosion unconformity. The extension of the quarry will doubtless furnish further evidence on this point and permit the procuring of determinative fossils.

At the opening, the upper stone towards the east end is about 4 feet thick but a little farther west higher beds occur making its thickness 2 to 4 feet greater. The extension of the quarry into the hill will gradually increase the thickness of these upper beds. The stone presents two distinct systems of bedding—a major stratification in layers a foot or more in thickness and a minor stratification in layers of 2, 3 and 4 inches. In places this minor parting is so pronounced that the major stratification is obscured. I am inclined to think that as more solid stone is encountered the minor parting will disappear in part, permitting the extraction of stone at least a foot in thickness (Plate XXVII).

In a broad way, the stone of these upper beds is alike throughout, being a brownish-grey, fine-grained, semi-crystalline limestone. A close examination, however, shows two types—a fine, almost lithographic variety and a coarser and more crystalline kind. These two varieties occur irregularly throughout the exposure and may even be mottled together (1151).

The lower stone is so much decayed and iron stained that it is difficult to procure good specimens. It seems to be separated from the overlying limestones by an unconformity which, however, is obscured by the decayed condition of the lower stone. This lower stone is apparently in thick beds but further excavation is necessary before definite remarks on the nature of the stratification can be made. The stone is described here but as stated above it is probably of Silurian age (1150).

The stone: No. 1151.—A hard, fine-grained, crystalline limestone of a prevailing grey colour; it is obscurely mottled in two components differing only slightly in colour; it is a darker and less distinctly mottled stone than the Oak Point variety but it is very like the typical rock from the quarries at Steep Rock (No. 1153, page 123.)

No. 1150.—A fine-grained crystalline dolomite filled with cavities and irregularly stained yellow with oxide of iron. The weathered stone is soft, and yellow but fresher specimens show the typical fine-grained whitish dolomite so common in the Silurian of Manitoba. The stone belongs to the cavernous type of Silurian limestones and resembles specimens from Fairford, Broadvalley, and other localities.

The company uses the stone for lime burning and has erected three Keystone kilns by the Steacy-Schmidt Manufacturing Co., York, Penn. These kilns have a capacity of 90 to 140 barrels of lime per 24 hours. A steam hoist, a drill, and a Canadian Rand compressor were being installed at the time of my visit. I am informed that a satisfactory business has been built up since that time.

Steep Rock Area.

Canada Cement Company; Louis de Tilleul, superintendent, Steep Rock, Manitoba.

The large quarry of this company near Steep Rock is operated solely for cement making and it presents no possibilities for the production of

Elm Point limestone. Quarry of David Bowman Coal and Supply Company, Oak Point, Man.

PLATE XXVII.

Elm Point limestone overlying Silurian limestone. Quarry of the Moosehorn Lime Company, Moosehorn, Man.

building stone except for those rough purposes to which any stone may be applied. As typical of the lowest division of the Devonian rocks of Manitoba a short description will not be out of place.

The quarry is about 800 feet long east and west by 120 feet wide. Its depth is about 9 feet and the present floor is 20 feet above the level of Lake Manitoba. It has not been extended to a greater depth owing to an influx of water but arrangements for drainage are being made, after which it is proposed to remove another 9 feet.

The stone is all thin-bedded and usually does not exceed 4 inches in thickness. By the coalescence of beds it is possible to obtain thicker stone but it is very liable to part on handling. This stone, No. 1153, has been tested in full as typical of the Lower Devonian limestone of Manitoba. The beds below the present floor are said to be harder than the upper stone now being quarried: a sample is described below as No. 1154. It can not be inferred that the next 9 feet is all heavily mottled like this specimen; in fact, I am informed that its average as revealed by drill cores is more like the darker part or ground mass of No. 1154.

About a half mile from the quarry is Steep Rock on the shore of Lake Manitoba. Here a cliff of 20 feet exposes stone essentially the same as that at the quarry: it is thin-bedded, brittle, nodular, full of incipient partings, and with a tendency to break diagonally under the hammer (1156).

At the power house which is situated on lower ground about half way between the quarry and the point, a very different kind of stone was encountered in digging the foundations. This rock is of reddish colour and apparently lies below the characteristic limestone: I was unable to see it in place but a specimen from the refuse from the foundation is described as No. 1155.

The stone: No. 1153.—A hard, whitish, fine-grained, semi-crystalline limestone with a slight greyish-pink cast. The dressed surface is coarse mottled and resembles in this respect the stone from Tyndall. The rock contains fossils which have been converted into crystalline calcite, or rather cavities left by the solution of fossils which have later been filled with calcite. The rock has some resemblance to the stone from Point Wilkins but the comparison cannot be carried far.

The corrosion test has considerable effect as the surface is etched and whitened all over with the fossil fragments standing in relief. The greyish-pink cast is entirely lost. The freezing test also produces visible results with an accentuation of the fossil fragments and a darkening of the darker portions of the mottling.

The physical properties are:—

Specific gravity	2·701
Weight per cubic foot, lbs	167·41
Pore space, per cent	0·595

Ratio of absorption, per cent, one hour	0·1193
„ „ „ „ „ two hours	0·1551
„ „ „ „ „ slow immersion	0·156
„ „ „ „ „ in vacuo	0·218
„ „ „ „ „ under pressure	0·222
Coefficient of saturation, one hour	0·54
„ „ „ two hours	0·7
„ „ „ slow immersion	0·7
„ „ „ in vacuo	0·98
Crushing strength, lbs. per sq. in., dry	31,507·
„ „ „ „ wet	29,452·
„ „ „ „ wet after freezing	23,318·
Traverse strength, lbs. per sq. in	2,202·
Shearing strength, lbs. per sq. in	1,706·
Loss on corrison, grams per sq. in	0·1178
Drilling factor, mm	8·0
Chiselling factor, grams	1·1

No. 1154.—The darker part of this stone is exactly like that of No. 1153. The mottling, however, is much more distinct in the present case as the lighter parts are quite yellow and stand in strong contrast to the pinkish-grey component. This stone probably occupies a position intermediate between No. 1153 and the lighter and more oxidized type from Oak Point (No. 1148, page 121.)

No. 1156.—Not essentially different from No. 1153.

No. 1155.—A soft red argillaceous stone resembling a red brick.

Quarrying is effected by drilling holes at intervals of 9 feet and in rows 9 feet apart. These holes are extended through the 9 feet forming the present face of the quarry: 10 to 30 of them are charged with 20 sticks each of Olympic explosive, and are fired simultaneously by battery. This discharge so breaks up the whole mass that it may be removed by steam shovel.

The broken stone is loaded by a Marion No. 7 steam shovel into dump cars of 6 yards capacity by the Kilbourne and Jacobs Co., Columbus, Ohio. The cars are lifted by hoist up an inclined tramway to the crusher floor. A very complete crushing plant is installed but a description of the operations scarcely falls within the scope of the present work.

Lake Winnipegosis Area.

Since the Elm Point limestone was separated by Kindle from the Winnipegosan series of Tyrrell no detailed survey of Lake Winnipegosis has been made and in consequence it is impossible to state to what extent this lower series may be exposed on the lake. According to Tyrrell the dolomites of Birch island are the lowest Devonian rocks definitely determined in

Manitoba. It is very doubtful, however, if these rocks can be correlated with the Elm Point beds as the lithologic characters are quite different and no palæontological evidence is at hand. It seems reasonable, however, to expect the occurrence of Elm Point beds towards the margins of the Devonian rocks on the east side of Lake Winnipegosis.

Birch island, Lake Winnipegosis.

"On the northeastern extremity of Birch island, a vertical cliff of Devonian dolomite, several hundred paces long, looks out over the lake across a shelving beach of rounded pebbles. The top of the cliff at its highest point is level and ten feet above the water. There is here exposed in all twelve feet of yellow argillaceous limestone in nearly horizontal beds from two to eight inches in thickness, but often broken by fractures to such an extent that the stratification is greatly obscured. The rock is porous and semi-crystalline, and often traversed by holes or cavities which at one time probably held fossils which have since been dissolved........

"The Birch Island dolomite is the lowest series of beds that have been definitely determined in Manitoba to be of Devonian age.[1]"

The stone: No. 1091.—A thin-bedded, whitish, crystalline dolomitic limestone, without any evidence of mottling but with numerous small pits or cavities: it does not resemble the other rocks ascribed to the Elm Point series and is placed here provisionally.

WINNIPEGOSAN FORMATION.

LAKE WINNIPEGOSIS AREA.

Whiteaves point, Dawson bay, Lake Winnipegosis.

Whiteaves point lies across Dawson bay, Lake Winnipegosis, from the mouth of the Red Deer river. This point and an island in its vicinity present the best exposures of the Winnipegosan or middle member of the Devonian formations of Manitoba. Tyrrell thus describes the exposure on the point. "Whiteaves point is a cliff, twenty-one feet in height extending for a mile along the shore and rising to a total height of thirty-one feet above the water....The rock is a white compact, uncrystalline dolomite, not very thickly or evenly bedded, but breaking readily into irregular fragments. Though the stratification is essentially horizontal, it is cut by numerous jointage planes, along which the rock appears to have slidden to some extent. It probably represents the highest beds seen at the island (see below) or possibly beds somewhat higher." This point was visited with the object of securing specimens for testing but the whole formation is so badly broken that I found it difficult to obtain a block of sufficient size for the purpose. No distinct bedding it to be observed; in fact the whole

[1] Geol. Sur. Can., Ann. Rep., Vol. V, Pt. E, p. 168.

cliff seems to be one bed, but broken horizontally and irregularly into thin material. Towards the bottom the stone is heavier and it might be possible to obtain material of sufficient size for our purposes, but the heavy overburden of thin and broken material would render the quarrying of the lower stone commercially impossible. The specimen described below as No. 1086 represents a fair average sample and it has been tested in full as an example of the Winnipegosan stone. No. 1087 represents different varieties showing the variability of the stone on the point.

Lower beds of the Winnipegosan are exposed on an island off Whiteaves point. The cliffs here form such a striking topographic feature that Tyrrell has selected a photograph of the island as a frontispiece for his report (*op. cit.*). "On the west side of this island the waves beat against the foot of a vertical cliff of white dolomite that overlooks the lake with a total height of forty-one feet.... The cliff is composed of a very thick-bedded or massive, white, exceedingly tough dolomite, occasionally somewhat crystalline, but never harsh or rough. The bedding is not always distinctly marked, but the hill is clearly shown to be brought up by a rather sharp anticline with a strike S.85°W., and the rock dips off towards each end at angles varying from 25° to 30°. In the middle of the cliff, where the stratification is horizontal, thirty-nine feet of rock in all are seen. The rock is cut by numerous jointage planes that run from the top to the bottom of the exposure. A number of faults have occurred along these jointage planes, so that it is difficult to measure the exact thickness of the beds exposed....The lowest beds, about ten feet in all, are not so thick-bedded as the rest, break down readily, and contain a large number of the stems of crinoids. Above this are ten feet rather barren of fossils, and then there is a very massive band from which large angular masses have fallen and are lying at the foot of the cliff."[1]

Little is to be added to the above excellent description by Tyrrell, I can only remark that the exposure was a severe disappointment, for despite the thick bedding of the stone, the excessive shattering would render its exploitation as building material almost impossible. Of course some thick and large blocks might be obtained but the waste would be enormous. There is nothing to warrant an optimistic view of the possibilities here. The upper rock resembles that at Whiteaves point; No. 1089 is the lower crinoidal layers of Tyrrell; and No. 1090 is a fair sample of the stone lying above the crinoidal layer.

The stone: No. 1086.—A warm, greyish-white, fine crystalline dolomite with a very slight pink cast, and fine mottled in greyish and lighter tones. It dresses to a smooth finish but is fine-pitted throughout and in places is really cavernous—occasional cavities as great as one inch by a quarter inch occurring. It resembles No. 1160 from near Old Gypsumville but it is much more cavernous; it resembles also No. 1119 from Cedar lake but it is

[1] Geol. Sur. Can., Ann. Rep., Vol. V, p. 173 E.

much less bluish in colour. The corrosion test occasions a slight loss of the greyish-pink colour with the assumption of a yellowish tint. Under the freezing test no general colour change was noted but a darkening of a zone around the pits was observed.

The stone being of a highly cavernous nature, most of the figures given below must be regarded as approximate only: this is particularly true of the porosity tests. Including the larger cavities the total porosity must be much in excess of that determined. The hardness of the stone makes chiselling practically impossible.

The physical properties follow:—

Specific gravity	2·849
Weight per cubic foot, lbs.	170·777
Pore space, per cent	3·978
Ratio of absorption, per cent, one hour	0·268
" " " " " two hours	0·381
" " " " " slow immersion	0·734
" " " " " in vacuo	1·137
" " " " " under pressure	1·484
Coefficient of saturation, one hour	0·18
" " " two hours	0·26
" " " slow immersion	0·49
" " " in vacuo	0·77
Crushing strength, lbs. per sq. in., dry	47,883·
" " " " " wet	31,423·
" " " " " wet after freezing	35,972·
Transverse strength, lbs. per sq. in.	3,186·
Shearing strength, lbs. per sq. in.	1,756·
Loss on corrosion, grams per sq. in.	0·00685
Drilling factor, mm.	7·0
Chiselling factor, grams	0·15

This stone is a highly dolomitic limestone, practically a true dolomite, with a very small amount of foreign matter as indicated by the following analysis by Leverin:—

	Per cent
Calcium carbonate	54·85
Magnesium carbonate	43·54
Ferric oxide	trace
Ferrous oxide	0·13
Alumina	0·04
Soluble silica	0·04
Insoluble mineral matter	0·10

No. 1087.—(a) A harder and finer grained stone than No. 1086: it is also more cavernous and has more tendency to break with conchoidal fracture. The colour is slightly more yellow, and pinkish stains appear in places. (b) A softer, whitish, non-cavernous, fine-grained type of yellowish-white colour. (c) A whitish stone, spotted with yellow, porous and cavernous with numerous fossils.

No. 1089.—Like No. 1088 c, but more fossiliferous with large crinoid stems. A whitish-yellow dolomite of porous and even cavernous structure. It is not at all a desirable stone from our point of view.

No. 1090.—Very like No. 1089 but less cavernous.

Similar stone is well exposed at Salt point on the opposite side of Dawson bay (see page 180, Tyrrell's report, *op. cit.*).

Weston point, Lake Winnipegosis.

Just south of the point the strata of the Winnipegosan member rises about 4 feet above the level of the water and according to Tyrrell dips 3° to 5° in a direction S.60°W. The beds are fairly even and thick but with a tendency to part into thinner material. The jointing is irregular but less excessive than in many of the exposures. Fair sized stone could be obtained but the low height of the exposure and its westwardly dip limit the amount of stone available (1100).

The stone: No. 1100.—A whitish, comparatively soft, very fine-grained stone, of decidedly porous structure. Certain parts are compact but these are scattered through a very porous matrix making a stone of variable structure; it could be used for rough purposes only.

Island west of Weston point.

"To the westward of Weston point an island about half a mile in length extends nearly north and south parallel to the shore. Along its eastern side is a cliff 10 feet in height of white thick-bedded limestone, the upper 6 feet being very compact and massive, while the 4 feet below are more friable, and break easily into irregular fragments. The bedding is almost horizontal but undulates slightly. On the north end of the island a cliff of similar limestone rises to a height of 8 feet abruptly out of the lake, the beds dipping S.40°W. at an angle of 10°." These beds seem fairly solid and are doubtless capable of yielding building blocks. The lower stone, while reasonably coherent, has a tendency to part into thinner material. The upper bed is quite solid without this tendency to parting.

MANITOBAN FORMATION.

The Manitoban or upper division of the Devonian of Manitoba is well developed on the shores and islands of Lake Winnipegosis. Exposures are much too numerous to allow a visit to all of them for the purpose of this report; in consequence, a few typical and better known localities were examined as follows:—

Winnipegosis village Snake island Point Wilkins. Brabant point	Lake Winnipegosis area.
Lower part of Red Deer river	—Red Deer River area.

In addition to the above occurrences a few localities in the Lake Winnipegosis area were examined incidentally, particularly Kettle hill to the south of Swan lake.

Lake Winnipegosis Area.

John Henderson, 298 Rietta Street, Winnipeg.

Mr. Henderson has acquired quarry lands near the village of Winnipegosis on the northwest quarter of section 9, township 31, range 18 west. The actual exposure of stone on the neighbouring road is 65 paces wide with a strike of S.25°E. magnetic. The exposure may be traced for about a half mile along the strike to the southward of the road across Mr. Henderson's property. North of the road the rock is hidden under drift of unknown thickness.

No developing work has been done beyond the making of a few shallow test pits. The stone exposed in these pits is a hard, whitish and apparently thin-bedded limestone (1070) with many fossils. No evidence is available as to the thickness of the beds at depth, but inferences may be drawn from the stone exposed in the river near the village (*vide postea*).

The stone: No. 1070.—An extremely fine-grained, almost lithographic limestone of a very light yellowish-grey colour. Minute crystals of calcite are scattered through the fine-grained base. The stone is splintery and with a tendency to break in all directions when struck with the hammer.

An analysis of the stone by A. Gordon Spencer is as follows:—

	Per cent
Insoluble matter	1·20
Alumina and ferric oxide	0·40
Calcium oxide	53·09
Magnesium oxide	1·01
Loss: carbonic acid, etc	43·45
	99·96

Mossy river, Winnipegosis village.

An exposure 8 feet thick is presented for a distance of about 100 yards along the west side of the river below the bridge at Winnipegosis. The stone is a hard, whitish, fine-grained limestone, brittle, and with a tendency to conchoidal fracture; it is disposed in thin beds throughout. The strike is S.15°E. and the dip is 12° eastwardly. This strike and dip is local only, as a short distance down stream it is quite different, indicating that the beds are considerably folded. Half a mile below this outcrop is another in which the beds strike due east and west and dip south at an angle of 55°. There is no hope here for the production of a high grade building stone.

Snake island, Lake Winnipegosis.

Snake island lies in Lake Winnipegosis, about five miles east and south of the village of Winnipegosis at the mouth of the Mossy river. This locality has received much attention as a prolific source of the fossils characteristic of the formation and is described in detail by Tyrrell.[1]

The extent and disposition of the beds is fully given in the report cited and need not be repeated here, as little or no possibility exists for the use of the stone as a building material. The highest point of the cliff presents a section of 19 ft. 2 in. (17 ft. 6 in., Tyrrell) in descending order as follows:—

3 ft.—Thin layers, rather soft and brownish with irregular fracture (1072).

——Strong parting.

11 ft. 8 in.—Thin layers like above, but with very fossiliferous bands (1073).[2]

4 ft. 6 in.—Thin layers, harder, whiter, and more splintery (1074).

The dip of the beds varies and the summit of a gentle dome is located near the point of section. The jointing is strong but variable in direction, E.10°N. and due N. and S. being the prevailing strikes. These well marked joints are responsible for the vertical faces shown in Plate XXVIII.

The variability, the fossils, the thin-bedding, and the splintery fracture make the stone of little use as a structural material.

The stone: No. 1072.—A soft, brownish-grey, rather dark limestone of fine grain but with scattered crystals of calcite. It is rather rough and is filled with fossils. The thin-bedding and the presence of fossils make it impossible for purposes of fine construction.

No. 1073.—The same type of stone as No. 1072 but extremely fossiliferous.

No. 1074.—A lighter coloured stone of more compact grain: it is soft and apparently is more argillaceous. Fossils are present in less abundance. The stone does not weather well and presents no possibilities.

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[1] Geol. Surv. Can., Ann. Rep., Vol. V, Pt. E, pp. 162-163.

[2] Three feet above the base of this series is the ripple marked horizon described by Kindle (*op. cit.*).

PLATE XXVIII.

Manitoban limestone. Cliffs on Snake island, Lake Winnipegosis, Man.

Point Wilkins, Dawson bay, Lake Winnipegosis.

This point presents one of the finest sections of the Manitoban limestone to be found in the province. The section has been described in detail by Tyrrell[1] and is referred to by Kindle in his summary report on the Silurian and Devonian of Manitoba.[2]

The highest part of the cliff is at the northeast angle where it attains an altitude of more than 80 feet above the lake. From this point the level of the rock surface decreases gradually to the west and south resulting in the failure of the cliff at a distance of about a mile in each direction. The actual level of the country declines less rapidly with the result that the overburden, which is insignificant at the northwest angle, increases in the directions mentioned above. For more than a mile, however, immense quantities of stone are easily available. The following quotation from Tyrrell's report indicates the general section through the formation:—

"It consists of horizontal strata, with the following characters considered in descending order:—

"Forty feet of light grey, very compact, fine-grained, thick-bedded and in places oolitic limestone which breaks readily into polygonal fragments when struck with a hammer.

"Thirty-three feet of a light grey argillaceous limestone, running down into a hard, compact, cavernous limestone, interbedded with clay shale.

"Ten feet of red calcareous argillite without fossils."

For the purposes of this report, the lower red beds may be neglected: we have to consider, therefore, the upper and lower limestones only.

The upper limestone:—This stone is heavily bedded with a probable maximum thickness of about 4 feet but these beds are by no means solid throughout as there is a well marked stratification whereby the beds part into much thinner material. Most of the heavy blocks lying at the foot of the cliff do not exceed 10 inches in thickness and the heavier ones can easily be split. It would be possible, however, to quarry blocks as great as 3 feet thick, but care would be necessary to prevent parting. The peculiar tendency to diagonal fracturing under the hammer makes it difficult to procure a block of sufficient size for testing, and this same property would militate strongly against the use of the stone for building purposes (1082).

The lower limestone:—The upper part of these beds gives little promise for use as building stone on account of the thin-bedding and argillaceous partings (1084). Towards the bottom, the beds are thicker and some layers of a foot or more are obtainable. Nos. 1083 and 1085 were taken from the lowest bed at different points and represent the "sonorous" limestone of Tyrrell. This stone breaks much better than that of the upper beds and is probably the best stone for structural purposes.

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[1] Geol. Sur. Can., Ann. Rep., Vol. V, Pt. E., p. 183.

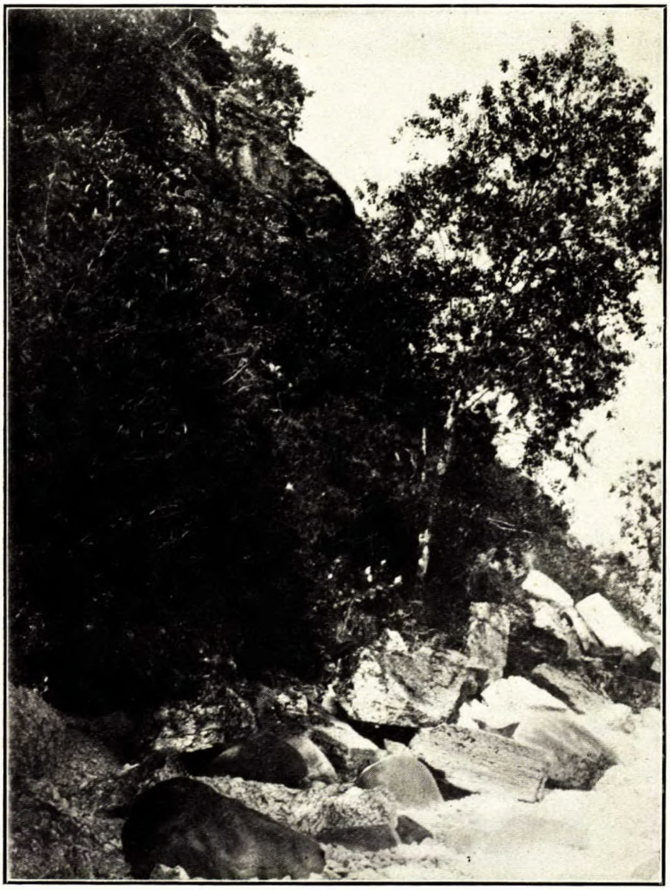
[2] Geol. Sur. Can., Sum. Rep. for 1912, p. 255.

In both series the main joints run at E.40°S. and E.10°N. and do not seem to be too frequent for the extraction of blocks of reasonable size. It must be remembered also that the exposed cliff does not permit of accurate determination of the jointing nor does it favour the obtaining of specimens representing the best products of the formation (Plate XXIX).

The stone: No. 1082.—This stone is hard, fine-grained, brittle, and of a slightly buff colour; it contains fine aggregations of calcite crystals in spots and lines. Smoothed surfaces reveal a distinct mottling in two shades of buff. The lighter portion or ground mass is much more porous than the darker parts. Fine lines of crystalline calcite frequently occur at the borders of the two components but also traverse both. The stone is not generally pitted but there is a tendency to pluck on the lines of separation between the two elements. The stone somewhat resembles No. 1083 from the same locality but it is more plucky and differs considerably in detail. The corrosion test produces a serious etching and whitening of the surface; the mottling is obscured and the fossil fragments show more distinctly. Freezing accentuates the planes of parting and produces a greenish cast in the lighter component. The chiselling factor is high on account of the plucky character of the stone.

The physical properties are as follows:—

Specific gravity	2·77
Weight per cubic foot, lbs.	166·47
Pore space, per cent.	3·73
Ratio of absorption, per cent, one hour	0·819
" " " " " two hours	0·973
" " " " " slow immersion	1·156
" " " " " in vacuo	1·244
" " " " " under pressure	1·4
Coefficient of saturation, one hour	0·58
" " " two hours	0·69
" " " slow immersion	0·82
" " " in vacuo	0·88
Crushing strength, lbs. per sq. in., dry	17,422·
" " " " wet	13,068·
" " " " wet after freezing	11,439·
Transverse strength, lbs. per sq. in.	1,458·
Shearing strength, lbs. per sq. in.	890·
Loss on corrosion, grams per sq. in.	0·313
Drilling factor, mm.	11·0
Chiselling factor, grams	12·55



Manitoban limestone. Cliff at Point Wilkins,
Lake Winnipegosis, Man.

An analysis by Leverin shows that this stone, as well as No. 1285 from the same locality, is a true limestone with very little magnesia:—

	Per cent
Calcium carbonate	96·87
Magnesium carbonate	0·88
Ferric oxide	trace
Ferrous oxide	0·13
Alumina	0·02
Soluble silica	0·04
Insoluble mineral matter	1·54

No. 1083.—A hard, fine-grained and brittle stone full of little round but crystalline dots. A distinct mottling is present in whitish and greyish components of which the former is more absorbent and with fewer of the little spherules. When wet both components have a yellowish cast. Calcite and fine-grained pyrite occur in cracks. The chiselling factor is lower than in No. 1082; nevertheless, this stone is more satisfactory to chisel as the tendency to pluck is much less pronounced.

The corrosion test entirely obscures the mottling and produces a whitish and etched surface with fragments of shells standing in relief. The freezing test accentuates the fossil fragments and produces incipient flaws.

The physical properties are as follows:—

Specific gravity	2·711
Weight per cubic foot, lbs	163·415
Pore space, per cent	3·44
Ratio of absorption, per cent, one hour	0·786
" " " two hours	0·980
" " " slow immersion	0·870 (?)
" " " in vacuo	1·283
" " " under pressure	1·31
Coefficient of saturation, one hour	0·6
" " " two hours	0·74
" " " slow immersion	0·66 (?)
" " " in vacuo	0·98
Crushing strength, lbs. per sq. in., dry	21,297·
" " " " " wet	22,045·
" " " " " wet after freezing	19,470·
Transverse strength, lbs. per sq. in	2,790·
Shearing strength, lbs. per sq. in	2,415·
Loss on corrosion, grams per sq. in	0·1833
Drilling factor, mm	20·0 (?)
Chiselling factor, grams	5·74

The slow immersion test for porosity is evidently low; judging by the similarity of this stone to No. 1082, the ratio of absorption for slow immersion should probably be about 1·0. The wet crushing strength is evidently high or the dry strength low: I have no explanation except a variation in the material.

No. 1085.—A hard, fine-grained, slightly pinkish-grey limestone. Indistinct mottling is present but it is obscured by large fossil fragments and by prevalent red streaks and dots. The grey, slightly mottled matrix, with darker fossil fragments and white crinoid joints, together with the reddish lines and dots give the stone a handsome appearance when polished (Plate XXX). It may have a possible application as marble, as it polishes easily, although the surface is not as uniform as might be desired.

The corrosion test deadens and whitens the whole surface with considerable etching but it does not entirely destroy the red component. The freezing test produces a slight general darkening and the reddish parts assume a purplish cast.

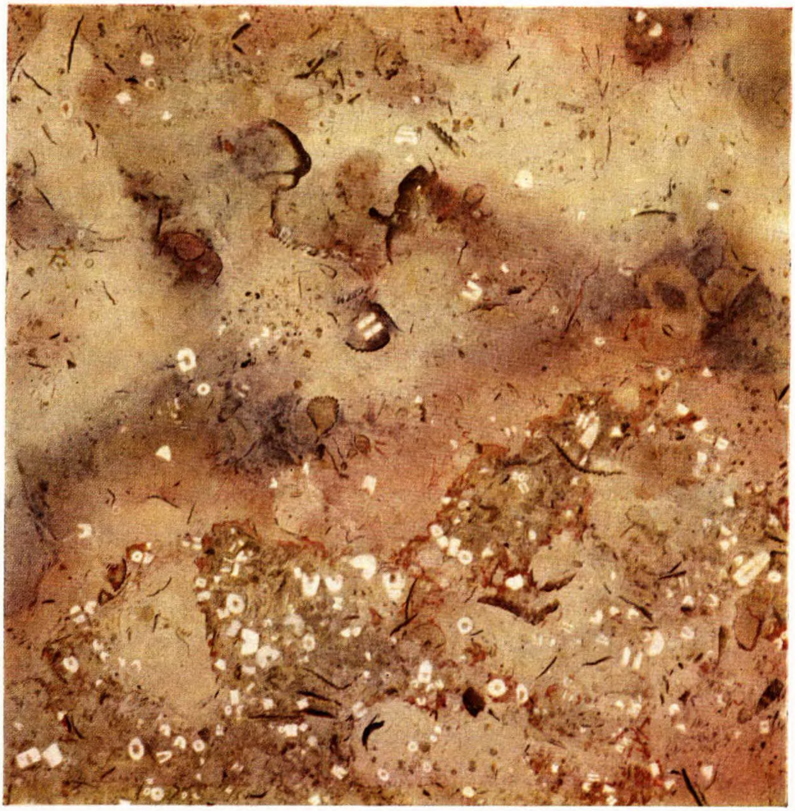
The physical properties are:—

Specific gravity	2·696
Weight per cubic foot, lbs	168·3
Pore space, per cent	2·74
Ratio of absorption, per cent, one hour	0·435
" " " two hours	0·576
" " " slow immersion	0·86
" " " in vacuo	0·95
" " " under pressure	1·04
Coefficient of saturation, one hour	0·41
" " " two hours	0·55
" " " slow immersion	0·86
" " " in vacuo	0·95
Crushing strength, lbs. per sq. in., dry	19,682·
" " " " " wet	14,427·
" " " " " wet after freezing	13,645·
Transverse strength, lbs. per sq. in	802·
Shearing strength, lbs. per sq. in	1,649·
Loss on corrosion, grams per sq. in	0·2077
Drilling factor, mm	9·0
Chiselling factor, grams	8·65

Like No. 1082 this stone is a true limestone with very little magnesium carbonate. The insoluble matter is high as shown by the following analysis by Leverin:—

	Per cent
Calcium carbonate	89·55
Magnesium carbonate	1·15
Ferric oxide	0·07

PLATE XXX.



Manitoban limestone, Point Wilkins, Lake Winnipegosis, Man.

	Per cent
Ferrous oxide	0·13
Alumina	0·02
Soluble silica	0·04
Insoluble mineral matter	7·50

No. 1084.—This stone resembles both No. 1082 and No. 1083; it is somewhat softer and more muddy in appearance and shows stains of a purplish-red colour. The stone is less desirable than the other varieties.

Brabant point, Lake Winnipegosis.

Among the numerous exposures of the Upper Devonian limestones on the shores of Lake Winnipegosis that at Brabant point on the east side of the lake is one of the most important. The outcrop has been described in detail by Tyrrell who estimates that the more northerly part of the exposure represents 50 feet of strata consisting of 30 feet of dolomitic limestone covered by 20 feet of red and grey shale.[1]

The rocks are folded and somewhat broken and faulted with a maximum height of 36 feet above the level of the lake. "At the first good exposure (from the north) the lower 16 feet of the cliff consists of a hard, compact, light yellowish-grey dolomite resounding when struck and breaking with an irregular fracture." A recent landslip at this point had exposed the rock in a fairly fresh condition: it lies in heavy beds up to 3 feet in thickness and presents a distinctly mottled aspect. The jointing and fracturing are very irregular and greenish calcite films have been developed on many of the planes of parting as well as an excessive amount of stylolite. The stone weathers rapidly and in a honeycombed manner. Some large blocks could undoubtedly be obtained here, but the overburden, the shattered nature of the stone, and its tendency to break irregularly do not recommend the location as a site for a quarry (1092). The upper 10 feet of this section is essentially the same but it appears to be even more broken and more seriously weathered to a dirty yellow colour. The limestones are covered by 3 feet of reddish and green shale which is followed by No. 1093.

"For the next 300 paces southwards the beds decline slightly to the south, parallel with the decline in the top of the cliff. In the next 110 paces the beds of dolomite dip 15 feet to the south. In this latter stretch the beds are very hard and compact, but much broken by little joints, so that they have been worn into caverns by the waves." I found this stone to be very thin-bedded (1098) and to be underlaid by a rock like No. 1097 (*vide postea*). "In the next 15 paces the cliff is 15 feet high, and the rock is considerably broken, but it appears to be rather shaly towards the top. In the next 25 paces the rock dips 6 feet and here shows a cliff 20 feet high, the beds being white magnesian limestone, occasionally stained with dull pink." These

[1] Geol. Sur. Can., Ann. Rep. Vol. V., p. 159 *et seq.*

beds present the most promising stone of the exposure. The beds are more clearly defined but they are still considerably broken. The stone itself is of finer grain and more even texture than in other parts of the exposure: it is described in detail below as No. 1097.

"For about 200 paces the shore is rather low to an exposure of yellowish semi-crystalline dolomite. For the next 200 paces the bank is composed entirely of till and boulders, and is about 3 feet in height. At this point it rises to a height of 10 feet, consisting at the bottom of 6 feet of yellow argillaceous limestone, overlaid by 4 feet of white limestone. For 100 paces similar rock is practically horizontal, at the end of the distance the cliff consists of 4 feet of brittle argillaceous limestone overlaid by 6 feet of thick-bedded white limestone." This particular exposure is much shattered. The lower stone is described below as No. 1094. "Continuing down the shore for 40 paces a sharp anticline suddenly brings up 4 feet of a light yellowish-red calcareous argillite. Ten paces farther the cliff is 12 feet high and is composed of 8 feet of yellow and pink, hard, compact, often thin and irregularly bedded argillaceous limestone. For the next 35 paces the beds are difficult to follow, as they are a good deal crumpled, but they appear to have a light dip of about 3 feet to the north. Here there is an almost vertical fault striking S.65°E., with a downthrow to the south, probably not more than 5 feet. On the south side of it is a cliff of limestone 11 feet in height with the friable limestone at the bottom while on the north side are 6 feet of light grey argillaceous limestone, becoming almost a clay shale at the top, where it is also of a pinkish colour." The upper argillaceous stone of this stretch is quite impossible for our purpose. The lower friable limestone is hard, thin-bedded and of little promise (1096).

"Sixty paces farther the cliff consists of 6 feet of hard limestone, overlaid by 3 feet of a light, pink, hard calcareous shale. Twenty-five paces farther, the section is terminated in 2 feet of a white, thick-bedded limestone."

Owing to the height of the cliff and the thickness of the strata revealed, this section at Point Brabant is one of the most important on Lake Winnipegosis in which the beds of the upper division are to be seen. An analysis of the conditions shows that certain beds, particularly that described as No. 1097, would furnish stone of fair quality for building purposes. The variability in the beds, the poor weathering qualities of most of the stone, and above all the excessive fracturing throughout the formation, lead to the conclusion that quarrying for shipment could not profitably be carried on under present economic conditions.

The stone: No. 1092.—A fairly hard, light greyish limestone with a slightly mottled appearance in yellower and greyer components: it is not cavernous or distinctly porous but contains scattered larger crystals of calcite in a fine-grained crystalline base. It would make a fair quality of stone for rock face work.

No. 1093.—A soft, yellowish, muddy limestone filled with fossils: it looks like an altered type of the stone described from Snake island.

No. 1094.—Somewhat like No. 1092 but it is more distinctly crystalline, more uniform and lighter in colour. It should make a fair quality of stone for rock face work.

No. 1096.—A highly fossiliferous greyish limestone like the examples from Snake island. All natural pieces show a deep zone of weathering which is soft and of a pronounced dirty yellow colour.

No. 1097.—This stone, which seems to be the most promising exposed on the cliff, is a dolomite of fine crystalline structure and very light yellowish-grey colour; it is not of a marked cavernous nature but scattered cavities with a yellowish zone of alteration are found in places. The stone is not at all comparable with the fossiliferous types from this locality. Smoothed surfaces show evidence of an indistinct mottling: it dresses to fine edges but shows scattered spots and small cavities with yellow stains. Fine crystals of pyrite are common on all cracks and joint planes. The stone is very hard and would be difficult to chisel.

Under the corrosion test there is no etching or pitting but the fine mottled character of the stone becomes apparent. The only colour change is a slight assumption of yellow. Under the freezing test a slight intensification of the oxidized zones around the small cavities was observed.

The physical properties are as follows:—

Specific gravity	2·85
Weight per cubic foot, lbs.	169·6788
Pore space, per cent	4·293
Ratio of absorption, per cent, one hour	0·495
" " " " " two hours	0·681
" " " " " slow immersion	0·368(?)
" " " " " in vacuo	1·433
" " " " " under pressure	1·493
Coefficient of saturation, one hour	0·33
" " " two hours	0·46
" " " slow immersion	0·24(?)
" " " in vacuo	0·94
Crushing strength, lbs. per sq. in., dry	45,587·
" " " " wet	25,400·
" " " " wet after freezing	37,332·
Transverse strength, lbs. per sq. in.	2,991·
Shearing strength, lbs. per sq. in.	3,065·
Loss on corrosion, grams per sq. in.	0·00703
Drilling factor, mm.	3·0
Chiselling factor, grams	1·15

The low wet crushing strength is due to the fact that a cavity in one side of the cube caused a yielding at that point far below the ultimate load. The ratio of absorption and the consequent coefficient of saturation under slow immersion is contradictory and is due to the irregularly cavernous nature of the stone. Such mistakes can be avoided only by averaging a large number of experiments.

No. 1098.—A soft altered type of rock of a dirty yellow colour: it appears to be argillaceous and to have been originally of a bluish colour: it is of no possible value for our purpose.

No. 1099.—Very like No. 1097.

Swan Lake.

Tyrrell mentions exposures of Devonian limestone at several points on Swan lake, particularly on Rose island and the points near the mouth of Swan river. Concerning Rose island he states: "Rose island lies towards the northern end of the lake, and consists almost entirely of beautifully glaciated limestone which at the western end rises to a height of 10 feet above the water, showing at the same place a dip of 8° to the south. The rock is a fine-grained, compact limestone of the upper portion of the Manitoban series. In places it is brecciated, with a matrix of more or less soft argillite, but it is not improbable that the broken character is due to the occurrence of fissures or slight faults."

On the east shore south of the mouth of Swan river is an exposure thus described by Tyrrell: "The rocky point consists of a little cliff 8 feet in height. The rock is a thin-bedded, grey limestone, breaking readily into small polygonal fragments, and is generally very similar to that composing Rose island. It appears to be raised in a low anticline, striking southeast and northwest." The stone from this point, which may be regarded as typical of the Devonian rock on Swan lake, is described below as No. 1080.

The stone: No. 1080.—A very fine-grained light yellowish-grey dolomite with scattered large crystals of calcite. The stone is remarkably cavernous with the cavities partly filled with secondary white calcite. It is an extremely rough rock quite impossible for our purposes.

Kettle Hill, Swan Lake.

Kettle hill south of Swan lake rises to a height of 274 feet above the lake. On the top of this hill are numerous, large angular masses of dolomitic limestone, presumably of Devonian age. The stone is rather thin-bedded but in places it is fully a foot in thickness. While this stone presents no immediate economic possibilities, it represents a type not elsewhere seen in the Devonian and in consequence it was thought advisable to test it in full.

The stone: No. 1079.—An exceedingiy fine-grained, crystalline, dolomitic limestone of prevailing yellowish colour but blotched with purplish, ring-like markings. Fine pitting is present to a slight extent but no large cavities were observed: it seems to be a very even and fine-grained type of stone. Corrosion produces a general yellowing of the surface and somewhat obscures the purplish mottling.

The physical properties are:—

Specific gravity	2·841
Weight per cubic foot, lbs.	167·02
Pore space, per cent	5·82
Ratio of absorption, per cent, one hour	0·996
" " " " " two hours	1·114
" " " " " slow immersion	1·27
" " " " " in vacuo	2·108
" " " " " under pressure	2·14
Coefficient of saturation, one hour	0·46
" " " two hours	0·52
" " " slow immersion	0·6
" " " in vacuo	0·98
Crushing strength, lbs. per sq. in., dry	37,275·
" " " " " wet	28,109·
" " " " " wet after freezing	30,013·
Transverse strength, lbs. per sq. in.	2,571·
Shearing strength, lbs. per sq. in.	1,990·
Loss on corrosion, grams per sq. in.	0·0095
Drilling factor, mm.	4·0
Chiselling factor, grams	1·42

The crushing strength tests appeared to be satisfactory in every way and I have nothing to offer in explanation of the anomaly in the wet and frozen tests except variation in the stone. The slow immersion tests were made on a separate cube and appear to be low; if wrong, this result could result only from variation in porosity.

Red Deer River Area.

At several points along the Red Deer river within a short distance of its mouth, isolated exposures of the Manitoban division of the Devonian are encountered. These exposures all show a variable strike and dip—in some cases quite high—indicating an undulating disposition of the beds. Tyrrell has described these outcrops in some detail.[1]

Most of the stone is thin-bedded but some layers of a foot or more were observed. Doubtless a certain amount of stone could be obtained for rubble or even for coursing but neither the quality of the stone or the condition of the formation gives any promise as a quarrying centre.

[1] Geol. Sur. Can., Ann. Rep. Vol. V, Pt. E, pp. 186-187.

The first exposure is about two miles from the lake: it shows only thin-bedded and much broken layers. "A short distance farther up the river, on the same side, is a hill consisting of 11 feet of limestone overlaid by 6 feet of unstratified till. The rock is grey, yellow-weathering limestone of the Manitoban series, and dips N.60° E. at an angle of 16°. The upper 5 feet is a whitish limestone breaking readily into fragments and containing a number of fossils; while below it is a thicker bedded, but not very compact, argillaceous limestone, containing but few fossils." A cliff about 100 yards long is exposed a little farther up the river. The beds dip at a low angle to the southwest. The upper 8 feet consist of thin-bedded calcareous shale beneath which are 6 feet of clayey limestone of little use from the present point of view. The lowest stone is a light grey limestone, much broken, but possibly thicker bedded away from the zone of surface alteration. Tyrrell mentions a hard, whitish limestone at a still lower level. The light grey limestone is again seen in an exposure about 9 feet high on the south side of the river. The upper part shows stone as much as a foot in thickness (1081) but the greater portion of the exposure is of very thin-bedded material. The stone weathers in a peculiar nodular manner and breaks with an irregular fracture.

The stone: No. 1081.—A whitish, comparatively soft, thin-bedded limestone filled with fossil fragments. Though lighter in colour, this stone resembles the Snake island stone more closely than the stone at Point Wilkins.

Summary—Devonian Limestones.

A general account of the distribution of the Devonian formations in the Rocky mountains of Alberta is given on page 110, *et seq.*, and of the Manitoba formations on page 113. There is no quarry operated primarily for building stone in the Devonian strata of either province. Thin bedding is the chief deterrent factor in Manitoba, while hardness and excessive fracturing render most of the Devonian limestones of the mountains unsuitable for our purposes.

In Manitoba, quarries are operated for lime and cement in the region east of Lake Manitoba. Some of the strata of the upper part of the Devonian of Lake Winnipegosis may have an application as building stone and possibly also as marble. (See No. 1085, page 134).

The Lower Banff limestone of Alberta is quarried for cement making and for lime at Pocahontas on the line of the Grand Trunk Pacific railway and at Exshaw and Kananaskis on the Canadian Pacific railway. While the stone is much too hard for structural work, it is susceptible of a good polish and may have an application as a black marble. (See No. 1336, page 115.)

Literature:—Manitoba:

Geol. Sur. Can., Ann. Rep., Vol. V, Pt. E.
Geol. Sur. Can., Ann. Rep., Vol. XI, Pts. F and G.

Geol. Sur. Can., Sum. Rep., 1912 and 1913.
Dept. Mines, Canada, Mines Branch, Limestones and the Lime Industry of Manitoba.

Literature:—Alberta:

Geol. Sur. Can., Ann. Rep., Vol. III, Pt. D, 1187.
Geol. Sur. Can., Ann. Rep., Vol. XI, Pt. D, 1900.
Geol. Sur. Can., Cascade Coal Basin, Pub. No. 949, 1907.
Geol. Sur. Can., Bighorn Coal Basin, Pub. No. 1130, 1911.
Geol. Sur. Can., Sum. Rep., 1910 (Lake Minnewanka Section)
Twelfth Int. Geol. Cong., Guide Book No. 8, Parts I and II, 1913.

Limestone of the Carboniferous System.

Rocks of this system do not occur in Manitoba, for the Devonian strata are immediately overlaid by members of the Cretaceous system. In the Rocky mountains, all the Carboniferous limestone is embraced in one great formation—The Upper Banff limestone. The position occupied by this formation in the great series of rocks which form the outer ranges of the mountains has been referred to on page 33, and its general structural features have been discussed, together with those of the Devonian limestones on page 111.

UPPER BANFF LIMESTONE.

McConnell's general description of this formation is as follows: "The Upper Banff limestone usually occurs as a greyish, purely calcareous and well crystallized rock, but is also found under a number of other forms. It is often dolomitic, and hard, bluish, compact beds are not uncommon, nor are shales and sandstones altogether absent. Its most characteristic features, however, are the abundance of crinoidal remains which it everywhere shows (some of the beds being wholly composed of the broken stems of crinoids), and the cherty concretions which are distributed through it, either irregularly or arranged in lines along the bedding."[1]

As already stated, this formation extends throughout the eastern ranges of the Rocky mountains and is accessible at many points. The localities described below were selected on account of accessibility only and may be regarded as typical of the formation.

Crowsnest Area.

Frank rockslide, Frank, Alberta.

The enormous mass of rock which fell from the eastern face of Turtle mountain in 1903 affords a ready means for the examination of the lime-

[1] Geol. Sur. Can., Ann. Rep., Vol. II, Pt. D, p. 18.

stones of the Upper Palæozoic. The exact horizon from which the individual blocks were obtained is not determinable. Brock states that Devonian limestones were included in the slide but later authors ascribe the bulk of the rock to the Carboniferous.[1] I am inclined to think that much of the material in the slide is Upper Banff limestone. In a general way, three types of stone are to be seen:—

(1) A crystalline limestone presenting varying grain: it is quite comparable with the stones described elsewhere as Nos. 1315, 1376 and 1377.

(2) A cherty limestone with dark blotches (1383).

(3) A light, banded limestone. This rock is so subject to diagonal fracturing that a hand specimen is prepared with difficulty (1384).

The stone: No. 1383.—A rough banded stone with light-coloured siliceous limestone irregularly interbanded with black chert. Quite useless for our purposes.

No. 1384.—A light greyish, fine-grained, crystalline limestone with a distinctly banded structure. The banding is probably due to the development of dolomitic streaks. This rock approaches the uniformly crystallized type described as No. 1315, page 143.

One mile east of Blairmore.

The dark cherty beds described as No. 1383 above are cut by the railway at this point. They appear to lie low in the Upper Banff series and present no possibilities.

Rocky Mountain Cement Co., Blairmore, Alberta.

A quarry was opened east of Blairmore for the production of stone for lime burning; more recently it has been worked in connexion with the cement plant. The formation strikes E.40°S. and dips 70° to the southwest. The quarry extends 200 feet along the strike with a width of 100 feet. The bedding is fairly well-defined permitting a clean hanging wall on the southwest side of the excavation. The stone varies greatly in texture but a general average is described as No. 1385.

The stone: No. 1385.—This stone is the most promising of the Upper Banff limestones. Except for a slightly darker colour, the specimen is quite comparable with No. 1315 described in detail on page 143.

The L. B. and M. Company's block in Blairmore was probably built of stone from this quarry. The rock face stone is of good appearance but the cut work (tooled margins only) shows that the stone is too hard and plucky for fine chiselling.

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[1] Dept. Mines, Can. Mines Branch, Pub. No. 2, 1903.
Geol. Sur. Can., Pub. No. 1211 (Memoir 27), 1912.

Summit Lime and Cooperage Works, E. G. Hazell, manager, Lethbridge, Alberta.

The quarry of this company is situated on the Crowsnest line near the summit. In the present quarry and in adjoining excavations to the east which were formerly worked for lime burning, and for some distance farther east along the track, fairly heavy beds of the crystalline type of limestone are exposed in great amount. The formation dips to the southwest and is very irregularly jointed. The beds vary greatly, particularly in grain, but it would be possible to obtain in quantity stone of the general type of Nos. 1376 and 1377 described below. The irregular jointing and the variation in the beds would entail a large amount of cutting in the making of coursing stone.

Eastward from these exposures and in descending series there is an increase in the amount of chert, rendering the stone useless for our purposes.

The stone: No. 1376.—This stone belongs to the type of light-coloured, fairly coarse crystalline stones like Nos. 1315, and 1385. The present specimen is rather softer than No. 1315 and emits a distinctly fœtid odour on breaking.

No. 1377.—This specimen is finer in grain and more compact but otherwise like No. 1376. The two specimens are but examples of many variations of this type of light-coloured crystalline stone.

Canadian Pacific Railway Area.

Kicking Horse pass, main line Canadian Pacific railway.

Near Banff are numerous exposures of the Upper Banff limestone, in Cascade mountain, Mount Rundle, Sulphur mountain, the Vermilion Lake range, etc. The best stone observed was in the talus at the foot of Mount Rundle (1315). The highly cherty type is illustrated by an example from the exposures along the road leading to Edith pass (1306, 1307)[1].

The stone: Nos. 1306 and 1307.—These are both dark limestones of variable grain and with a considerable clay content: they show numerous crinoid joints and scattered crystals of calcite in a dark fine-grained base. They are interbanded with chert and are so filled with cracks that it is almost impossible to break out a properly shaped specimen. These stones are not comparable with types like No. 1315, described below.

The stone: No. 1315.—A medium-grained, highly crystalline, crinoidal limestone. The smoothed surface has a light bluish cast when dry and greyish when wet. Throughout the stone are small pits with slightly stained margins; the presence of these cavities would prevent the use of the stone for decorative purposes. While more or less variable in grain, this material

[1] Geol. Sur. Can., Ann. Rep., Vol. II, Pt. D.
Geol. Sur. Can., Sum. Rep., 1910, p. 145 *et seq.*

should make a good structural stone but it is too hard to permit of chiselling without prohibitive cost. The corrosion test produces a decided change in appearance, as the stone assumes a mottled aspect with a dead white base in which greyish crystalline fossil fragments stand in relief. The frozen cube shows a somewhat dirty colour but this may be due to causes not inherent in the stone.

The physical properties are:—

Specific gravity	2·706
Weight per cubic foot, lbs.	167·44
Pore space, per cent	0·88
Ratio of absorption, per cent, one hour	0·15
" " " two hours	0·15
" " " slow immersion	0·189
" " " in vacuo	0·301
" " " under pressure	0·329
Coefficient of saturation, one hour	0·45
" " two hours	0·45
" " slow immersion	0·57
" " in vacuo	0·91
Crushing strength, lbs. per sq. in., dry	17,772·
" " " wet	18,369·
" " " wet after freezing	14,660·
Transverse strength, lbs. per sq. in	1,969·
Shearing strength, lbs. per sq. in	1,600·
Loss on corrosion, grams per sq. in	0·154
Drilling factor, mm	14·
Chiselling factor, grams	4·75

This stone is almost a true limestone with very little magnesia or foreign matter. An analysis by Leverin follows:—

	Per cent
Calcium carbonate	97·94
Magnesium carbonate	1·17
Ferric oxide	trace
Ferrous oxide	0·09
Alumina	0·12
Soluble silica	0·08
Insoluble mineral matter	0·94

Mountain Park Area.

The line of the Grand Trunk Pacific railway between Coal Spur and the Mountain Park colliery exposes an excellent section of the Palæozoic limestones (see page 117). I am inclined to ascribe the upper part of the section to the Upper Banff formation, although the stone is very little different from that of the lower part, which has been included in the Lower Banff series.

The first limestone (from south to north on the railway) is seen near the gorge of the McLeod river at about mile 25. This stone underlies a series of quartzites and thin-bedded rocks which appear to represent the Rocky Mountain quartzites and which are described elsewhere. The limestone is at first thin-bedded, nodular, and very friable under the hammer. Below mile 25 it passes down into thicker, cavernous beds of coarse, hard, cherty stone (1216). In places these beds show red streaks and possess a tendency to weather red (1217). Bands of shale follow and are succeeded by a hard, dark, friable limestone (1218). Beneath these strata are heavy layers of a hard, banded type of limestone with numerous fossils and with geodes filled with quartz crystals. The formation here is very much shattered.

The stone: No. 1216.—A light grey, very hard and splintery, fine-grained limestone, filled with checks: it weathers yellowish and shows skins of white and yellowish calcite on joint planes. The hand specimen does not show the cavernous nature presented by the bed as a whole.

No. 1217.—A very rough cavernous type of limestone. The base is fine-grained and grey but it is mottled in shades of red. The stone is filled with large cavities which have been partially filled with secondary white calcite.

No. 1218.—A very hard, fine-grained, almost black limestone comparable with No. 1239.

Summary—Carboniferous Limestones.

Limestone of this age occurs only in the mountains of Alberta, in the formation known as the Upper Banff limestone which forms the steep upper part of most of the eastern ranges.

The stone is hard, much fractured, and frequently filled with nodules and streaks of chert. In places the formation consists of a light-coloured limestone, of crystalline structure owing to the presence of fragments of fossil crinoids. This variety has some value as a building stone: it has been used at Banff and Blairmore to a very limited extent and is described in full as No. 1315 on page 143.

Limestone of Permo-Triassic Age.

The great shale formation which succeeds the Rocky Mountain quartzite is in places sufficiently calcareous to constitute impure limestone. Although the quality of the stone is not of a high order, the evenness of the bedding and jointing greatly facilitates quarrying and allows the extraction of blocks of a size and shape suitable for rough masonry. Stone of this type was observed near Banff and on the Canadian Northern railway near the coal mining village of Nordegg.

Canadian Pacific Railway Area.

Banff, Alberta.

On the Spray river, a short distance above its junction with the Bow, the uppermost layers of Mount Rundle form a steep cliff about 75 feet high dipping 70° towards the river. The beds are remarkably even and in consequence a wall-like exposure is presented extending several hundred yards along the river. The layers are easily separable and may be obtained in thicknesses up to about 15 inches. Well defined joints run straight down the dip as well as a set at right angles which is developed at intervals of 4 to 6 feet. This jointing facilitates the quarrying of stone of a size and shape suitable for building. Between two of the vertical joints, 50 feet apart, has been opened the only serious quarry for building stone in the whole of the Rocky mountains of Alberta. The stone is hard and of a black colour when freshly quarried. On weathering it becomes lighter at first, but afterwards assumes a brownish-red and unattractive colour. The remarkably even bedding and jointing and the accessible location give a certain value to this occurrence although the stone itself is not of high grade and is suitable only for rubble and rock face coursing. The Canadian Pacific hotel and the buildings of the Government swimming pool at Banff are constructed mainly of this stone. The general effect is rather dark and there is a lack of uniformity in colour (Plate XXXI).

I am informed by Dr. J. A. Allan that this stone belongs to the Upper Banff shale and is therefore of Permian or Permo-Triassic age.

The stone: No. 1302.—A hard, bluish-black, compact, fine-grained stone. The rubbed surface is distinctly dark blue—darker than the Lower Banff stone described as No. 1336 on page 115. No mottling is shown but a distinct fine lamination parallel to the bedding is to be observed throughout. The corrosion test produces a marked result as the dark blue colour entirely disappears and is replaced by a light yellowish-grey. No apparent change results on freezing. This is a remarkably strong stone in both crushing and transverse strength: it is very hard and suffers scarcely any abrasion under the chisel.

The physical properties are as follows:—

Specific gravity	2·764
Weight per cubic foot, lbs.	172·04
Pore space, per cent.	0·292
Ratio of absorption, per cent, one hour	0·018
" " " two hours	0·022
" " " slow immersion	0·091
" " " in vacuo	0·091
" " " under pressure	0·106

Permo-Triassic limestone. Government swimming pool, Banff, Alberta.

Coefficient of saturation, one hour	0·17
" " " two hours	0·20
" " " slow immersion	0·86
" " " in vacuo	0·86
Crushing strength, lbs. per sq. in., dry	50,000·
" " " " " wet	50,669·
" " " " " wet after freezing	40,937·
Transverse strength, lbs. per sq. in	6,657·
Shearing strength, lbs. per sq. in	5,222·
Loss on corrosion, grams per sq. in	0·0363
Drilling factor, mm	1·0
Chiselling factor, grams	0·01

The crushing strength after freezing should probably be disregarded in view of the great pressure under which the tests were made; it is questionable if so low a figure is to be accepted as literally correct.

This stone is a highly argillaceous magnesian limestone; its resistance to colour changes on weathering is low owing to the high content of unoxidized iron. An analysis by Leverin follows:—

	Per cent
Calcium carbonate	49·01
Magnesium carbonate	8·52
Ferric oxide	0·29
Ferrous oxide	1·54
Alumina	1·06
Soluble silica	0·25
Insoluble mineral matter	38·56

Considerable carbonaceous matter is also present.

Nordegg Area.

Nordegg, Alberta.

In the valley of a little stream close to the coal mining village of Nordegg is an outcrop of argillaceous limestone in layers 8 to 12 inches thick and in almost horizontal position. As the beds are unusually even and well-jointed it would be possible to obtain stone for rough purposes (1272). This stone undoubtedly occurs high in the Palæozoic series and I am provisionally referring it to the Upper Banff shale.

A little to the west of Nordegg the line of the Canadian Northern railway cuts other limestones which are also high in the series but which can not be referred to any definite horizon. These stones offer no economic possibilities: for the sake of convenience they are considered here although they are probably to be ascribed to the Carboniferous system.

At mile 169½, hard, dark, and fine-grained limestones occur (1269, 1270). At mile 171 a peculiar mottled rock is observed (1271), and several other outcrops of hard, splintery, dark-coloured, light weathering stones occur between this point and Nordegg,

The stone: No. 1272.—A close-grained, compact stone of a very dark brownish-black colour: it is much darker than No. 1302 from the Spray river and No. 1336, the typical Lower Banff limestone from Exshaw. Corrosion causes a loss of bluish and an assumption of brownish colour. The specimen was found to be so filled with flaws that no cube was prepared for the freezing test. The dry test cube stood a strain of 52,400 lbs. to the square inch without breaking. The stone is so hard that no abrasion whatever resulted from the chiselling test.

The physical properties are:—

Specific gravity	2·683
Weight per cubic foot, lbs.	164·14
Pore space, per cent	1·88
Ratio of absorption, per cent, one hour	0·291
" " " two hours	0·39
" " " slow immersion	0·55
" " " in vacuo	0·551
" " " under pressure	0·715
Coefficient of saturation, one hour	0·4
" " " two hours	0·54
" " " slow immersion	0·77
" " " in vacuo	0·77
Crushing strength, lbs. per sq. in., dry	52,400·
" " " " wet	46,388·
Transverse strength, lbs. per sq. in.	6,302·
Shearing strength, lbs. per sq. in.	5,720·
Loss on corrosion, grams per sq. in.	0·0354
Drilling factor, mm.	4·0
Chiselling factor, grams	0·00

Like No. 1302 from Nordegg, this stone is a highly argillaceous magnesian limestone with considerable ferrous oxide and a large amount of carbonaceous matter. An analysis by Leverin follows:—

	Per cent
Calcium carbonate	33·03
Magnesium carbonate	12·62
Ferric oxide	0·14
Ferrous oxide	0·57
Alumina	0·45
Soluble silica	0·36
Insoluble mineral matter	47·36

No. 1269.—A very hard fine-grained limestone of almost black colour and massive structure.

No. 1270.—This stone is a fine-grained limestone of a very dark colour. It is splintery and filled with flaws, and in places with calcite veinlets. The stone is quite comparable with Nos. 1215 and 1239.

No. 1271.—A hard, rough rock consisting of a dirty yellow fine crystalline dolomite blotched with dark bluish patches apparently of an argillaceous nature. It is a rough stone of poor weathering properties.

Limestone of the Cretaceous System.

The strata of the Cretaceous system as exposed in the three provinces contain very little limestone and none that may be seriously regarded as a source of building stone.

In Manitoba the Niobrara division of the Cretaceous consists of light grey calcareous shales passing into bands of limestone. Some of these limestone bands might be used for purposes of rough local construction but I have learned of no place where a serious quarrying industry could be attempted. Typical exposures in northern and southern Manitoba are described below.

Northern Manitoba Area.

A section of this formation was examined on the north branch of Pine river where the strata are exposed on the lower flanks of Porcupine mountain. Tyrrell has described this section in full (*op. cit.*, p. 102 E): he regards it as quite typical of the Manitoba Niobrara. It may be briefly stated that there is no hope of procuring building stone here but that detached blocks of a thin layer about 15 feet up in the section might be gathered from the bed of the stream and used for purposes of the roughest construction (1075, 1076).

The stone: No. 1076.—A medium grey, highly argillaceous limestone containing immense numbers of shells of *Foraminifera:* it is soft and weathers a dirty yellow colour.

No. 1075.—Similar to No. 1076 but darker in colour: it contains other fossils than the minute *Foraminifera* shells. Neither of these stones is of any practical value.

Southern Manitoba Area.

Mr. Alex. MacLean who has recently been engaged in geological explorations in the Pembina mountains of southern Manitoba informs me that the middle of the Niobrara formation is marked by a limestone layer which crops out to a thickness of 3 feet on the Valley river to the east of Gilbert Plains, and also in excavations in Morden. In these instances the heavy overburden makes quarrying impossible. The same stone outcrops on the Assiniboine river, on section 36, township 8, range 11 west of the first meridian. About 8 feet of stone are exposed in beds from 6 inches to a foot thick. A limited use has been made of this stone for foundations in local buildings.

The stone: For the most part, this stone is fine-grained and distinctly crystalline and with a greyish-white colour. The general appearance is darker owing to thin, interbanded, shaly layers. White fossil shells are abundant in certain bands.

CHAPTER IV.

SANDSTONES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Sandstones of more or less economic promise occur in different formations in the three provinces, but only in one instance have they been exploited on a commercial scale. The following table gives a rough idea of the characteristics and distribution of these stones.

Eocene	Fort Union	Soft and hard sandstones in the Souris river valley in southern Saskatchewan. The soft stones are very friable and probably of no economic value. The hard stone could be used for rough purposes.
	Paskapoo	Soft sandstones exposed at many places in Alberta and extensively employed for building purposes.
Upper Cretaceous	Edmonton	Hard thin sandstones passing into sandy shales. No economic possibilities are presented by the exposures in river valleys distant from the mountains. On approaching the foot hills the softer stones are more indurated and are of possible local value.
	Boissevain	This sandstone appears to lie between the Millwood and Odanah formations of Turtle mountain, Manitoba. The stone is hard and for the most part thin-bedded but it is employed successfully for building.
	Belly River	Mostly soft sandstones of southern Alberta, the foothills, and river valleys farther east. Some possibilities are presented, but nothing of proved value has yet been found.
	Dakota	Hard greenish sandstone in the foothills; suitable for rough building. Soft friable sandstone in Manitoba.
Lower Cretaceous	Kootenay	Hard argillaceous sandstones in thin beds. Common in the foothills associated with coal beds. They present no possibilities beyond local use for rough purposes.
Ordovician	Winnipeg sandstone	Soft and friable sandstones exposed on the shores and islands of Lake Winnipeg.

In accord with the practice hitherto followed these formations will be considered in ascending order beginning with the Winnipeg sandstone.

Sandstone of the Ordovician System.

WINNIPEG SANDSTONE

Lake Winnipeg Area.

The lowest member of the Palæozoic formations exposed in Manitoba consists of a basal sandstone which is known as the Winnipeg sandstone and is ascribed to the upper part of the Black River formation by Dowling, who estimates the thickness of the beds at 100 feet or more.[1]

These sandstones outcrop only in the basin of Lake Winnipeg but they have been pierced by deep wells in the vicinity of Winnipeg.

The more important localities in the Winnipeg basin are described by Tyrrell and Dowling (*op. cit.*). The following list indicates the more important outcrops:—

Black island.—Largely composed of this stone. Soft and also moderately hard white and yellowish sandstone up to 25 feet thick in places.

Big island.—Small exposures. At the north end the sandstones appear at a point 25 feet above the water but the face is covered with debris.

Punk island (Deer island in Dowling's report).—This exposure is described in detail below.

Little Grindstone point.—Seven feet of sandstone beneath thin-bedded limestone.

Grindstone point.—Thirty-five feet of sandstone. (See page 155).

Little Bull head.—Friable red and yellow sandstones.

Bull head.—Similar stone but less exposed.

The Winnipeg sandstone, for the most part is thin, friable, cross-bedded, and much stained by iron and interlaminated with shale. The possibilities of the formation from our present point of view are not great. The only point at which quarrying operations have been attempted is on Punk island. This locality was visited as well as the exposures at Grindstone point. The following account together with the excellent descriptions given by Dowling will serve to indicate the economic possibilities of the Winnipeg sandstone as a building material.

Punk island, Lake Winnipeg.

The section at the northeast point is as follows:—

6 ft.—Blue laminated shale.

12-15 ft.—Very soft crumbling sandstone, with interlaminated streaks of shale. The stone is locally stained by iron, but the whiter parts consist of very pure silica which has been suggested as a glass-making material. No possibilities as a building stone.

18 in.—Soft, whitish, yellow stained sandstone.

[1] Geol. Sur. Can., Ann. Rep., Vol. XI, p. 36 F.

2 ft.—Soft, brown, somewhat mottled sandstone in a heavy bed. A possible building material.

2 ft.—Similar to above.

Proceeding westward along the north shore, some thin layers of harder stone occur in the upper soft layers which also show a greater amount of interlaminated clay. Still farther west, in a small bay just east of the north point, the lower beds are more solid. The following section is presented here:—

5-6 ft.—Stripping which would increase inland.

2 ft.—Solid bed of sandstone (1020).

14 in.—Yellow and somewhat mottled stone in solid bed.

——— Soft ferruginous sandstone at water level.

At this point a quarry has been opened and some blocks removed from the upper solid bed. These blocks are now piled near the site of the quarry and present a grey appearance owing to the imbibition of dirt consequent on the porous nature of the stone. The resistance to weathering is much better than the soft nature of the stone would lead one to expect. This power of resistance is due to a superficial hardening on exposure which is very pronounced. To break a fair sized piece from one of these old blocks requires repeated blows of the hammer, although the interior of the stone is soft—almost pulverulent—in character.

In places, this stone shows rusty streaks owing to the decomposition of pyrite. The jointing is irregular but not close enough to prevent the extraction of blocks of reasonable size.

At the north point the lower heavy sandstones are not seen. The section is as follows:—

15 ft.—Thin-bedded limestones. (See No. 1021, page 40).

8 ft.—Soft sandy beds.

12 ft.—Shale with sandstone bands.

5-6 ft.—Talus covered.

A section, originally described by Hind in 1859 and quoted by Dowling in 1900, shows that the lower heavy beds do not occur on the northwest face of the island although a bed of sandstone of one foot in thickness is interlaminated with the soft, friable stone.

The stone: No. 1020.—On fresh fracture this sandstone shows the white to whitish-yellow, somewhat mottled appearance illustrated in No. 1, Plate LV. The mottling appears to be due to an irregular distribution of the cementing material which has a yellowish colour while the grains are chiefly of pure white quartz. In addition to this white and yellow mottling there is a secondary mottling of a more pronounced type in brown due to the oxidation of pyrite. Frequently the brown spots are hollowed into cavities. The fresh stone is soft and friable but the specimen after being a year in the laboratory has hardened considerably. The corrosion test renders the smoothed surface rough and adds a yellow tinge to the colour. The freezing test produces less effect than might be expected as only a slight crumbling of angles was observed. The darker spots became still darker under the test.

The physical properties are as follows:—

Specific gravity	2·635
Weight per cubic foot, lbs	140·558
Pore space, per cent	14·55
Ratio of absorption, per cent, one hour	3·352 3·
" " " " " two hours	3·549 3·544
" " " " " slow immersion	5·87
" " " " " in vacuo	6·01
" " " " " under pressure	6·465
Coefficient of saturation, one hour	0·518
" " " two hours	0·549 0·548
" " " slow immersion	0·9
" " " in vacuo	0·93
Crushing strength, lbs. per sq. in., dry	6,438·
" " " " wet	6,798·
" " " " wet after freezing	5,941·
Transverse strength, lbs. per sq. in	575·
Shearing strength, lbs. per sq. in	599·
Loss on corrosion, grams per sq. in	0·0068
Drilling factor, mm	High
Chiselling factor, grams	Failed.

An analysis by Turner shows this stone to be a fairly pure sandstone with a small amount of cement composed chiefly of iron oxides and carbonates of lime and magnesia. It is interesting to note that the total amount of carbonic acid is less than that required to make carbonates of the lime and magnesia present. It may well be that the hardening of the stone on exposure is due to the conversion of other lime and magnesia salts into carbonates by the carbonic acid of the atmosphere. The analysis follows:—

	Per cent
Insoluble residue	96·34
Soluble portion	3·66

Partial analysis of soluble portion:

Lime	0·89
Magnesia	0·13
Ferric oxide	1·51
Ferrous oxide	0·12
Carbonic acid	0·45
Total of soluble constituents determined	3·10[1]

[1] See introductory chapter, page 20.

PLATE XXXII.

Winnipeg sandstone. Grindstone point, Lake Winnipeg, Man.

Grindstone point, Lake Winnipeg.

On the north side of Grindstone point the following section is presented:

5 ft.—Thin-bedded mottled limestone. (See 1026, page 40).

40 ft.—Thin, friable, nodular, iron-stained, cross-bedded sandstones with shale parting towards top and bottom.[1]

18 in.—Very ferruginous soft sandstone.

2 ft.—Highly ferruginous sandstone, very soft and much decomposed.

2 ft.—Irregularly bedded and somewhat firmer sandstone with a mottled aspect (1027).

———At water level is a somewhat similar stone (1028).

The formation is rather persistently jointed northeast and southwest at reasonable intervals for quarrying. A less pronounced series of joints crosses the above set at right angles. The soft and ferruginous nature of the stone and the very heavy overburden would render impossible the application of this material as a building stone (Plate XXXII).

The stone: No. 1027.—A soft, greyish sandstone, composed almost entirely of quartz grains: it contains considerable pyrite, the oxidation of which has resulted in a mottling of the stone. Weathered pieces show a deep zone of yellowish, soft, iron-stained stone.

No. 1028.—A firmer and more uniformly grey stone than No. 1027; it is a rather more coherent stone than No. 1020 and differs also in its darker colour.

Bull Head, Lake Winnipeg.

The sandstones (1043) are well exposed near the water line at this point (see page 39).

The stone: No. 1043.—The stone is very soft and pulverulent in a general way, but where altered to a yellow colour by oxide of iron, it is considerably harder. In addition, the stone has some extremely hard streaks and irregular spots. In consequence of this mixed structure the rock is hard to break with the hammer although it pulverizes at the point of impact and the softer portions may be rubbed out with the finger point. It would make a very poor building stone.

Sandstones of the Cretaceous System.

KOOTENAY FORMATION

The lower part of the Cretaceous system is represented in the Rocky Mountain region by a series of shales interbedded with hard sandstones and coal seams. Authors recognize three subdivisions—the Upper Ribboned sandstone, the Kootenay coal measures, and the Lower Ribboned sandstone. For our purposes it is well to include all these members under the term

[1] A more detailed section of interest to geologists only is given on page 61F, Vol. XI, Geol. Sur. Canada.

"Kootenay." An excellent, short, and generalized account of the Kootenay is given by Dowling as follows: "The lower member of the Cretaceous, the Kootenay, is found resting upon the Jurassic in the Rocky mountains. In Manitoba it has not been recognized, and is supposed to have formed but a very thin sheet to the east. It is recognized in the southern part of Dakota and in Montana. In the Rocky mountains the base of the formation is a heavy bed of sandstone, which is succeeded by sandstones and shales containing many coal seams. The maximum deposition during this period was near the axis of the Rocky mountains. In the Elk River escarpment the formation measures 3,600 feet. East of this, at Blairmore, it is reduced to 740 feet. North, near Banff, it has a thickness of 3,900 feet; and in Moose mountain east of the main range, there are only 375 feet. Northward, on the Bighorn, the thickness is about 3,600 feet. It would seem that east of the mountains the formation was not of great importance, owing to thinning of the beds."[1]

The frequent references to the occurrence of sandstone in this formation prohibit a complete disregard of the Kootenay series for our present purposes, but a careful examination of the literature and the inspection of a few typical localities do not lead to the conclusion that it presents any serious possibilities as a producer of building stone. Briefly it may be stated that all the sandstone bands are extremely hard and possessed of very poor weathering qualities.

The distribution of the series is extensive; in fact, it is to be found all along the foothills and in many of the valleys west of the first great range of the Rockies. The importance of the subject does not justify further remarks on distribution in a work on building stone; readers desirous of such information are referred to the many geological reports on the foothills and particularly to those dealing with the various coal fields of the Kootenay formation. An excellent bibliography may be found on page 123 *et seq.* of Mr. Dowling's report on the Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia (Publication No. 1363 of the Geological Survey of Canada).

Typical exposures of the Kootenay sandstones were examined near Hillcrest and Coleman on the Crowsnest line and near Cascade mountain and Canmore on the main line of the Canadian Pacific railway, also at Mountain Park south of the line of the Grand Trunk Pacific railway.

Crowsnest Area.

Hillcrest, Alberta.

Immediately east of Hillcrest the upper Kootenay sandstones are well seen in a wall-like exposure on the north side of the railway. The stone is in part massive, in part thin-bedded, extremely variable in structure and of little economic importance. The stone is hard and yet weathers very

[1] Geol. Sur. Can., Pub. 1363 (Memoir 53), 1914.

readily, presenting dirty brown, reddish and yellowish colours. Owing to rather even bedding, the heavier layers may be broken out in blocks of suitable thickness for rough coursing. The varying composition of the different beds does not admit of an account of the stone as a whole. Three different types are described below as Nos. 1380, 1381 and 1382. The last mentioned variety is probably the best and as it occurs in beds of reasonable thickness it might be quarried for rough coursing.

The stone: No. 1380.—A fairly coarse-grained sandstone consisting principally of quartz grains but with some darker fragments giving the stone a speckled appearance with a general brownish-grey colour. There is an abundant white cement which does not effervesce with acids. The stone is hard but it could be used for rock face work.

No. 1381.—Similar to the above but with a banded structure in lighter and darker grey, also with yellowish altered bands.

No. 1382.—A hard, uniform, light grey sandstone without lime in the cementing material. The grains are nearly all of quartz and are closely pressed together. The grey colour is due to scattered specks of a darker colour.

Coleman, Alberta.

Immediately west of Coleman, a characteristic section of the upper part of the Kootenay may be observed. The formation is disposed at high angles and consists essentially of sandstones with a less amount of shale. As at Hillcrest, the stone is hard and of poor weathering properties. The one redeeming feature is that many of the layers are even and are separated by shaly parting permitting their easy extraction. The stone might be used locally for foundations but it presents no further possibilities. Nos. 1366, 1367, 1368 and 1369 may be considered typical: they were obtained in order from the west to the east, *i.e.*, in descending series.

The stone: No. 1366.—A hard, grey, medium grained sandstone with a fine, white-speckled appearance on fresh fracture. The grains are mostly of quartz but other rock particles are present. The matrix is siliceous and argillaceous and appears to be partly recrystallized. The stone is very hard and weathers badly.

No. 1367.—Very like No. 1366 but shows some variation in grain and colour.

No. 1368.—A finer grained type of sandstone of very dark colour. The quartz grains are cemented in an abundant argillaceous matrix giving the stone an almost black colour. It is softer than Nos. 1366 and 1367.

No. 1369.—This is of the same type as Nos. 1366 and 1377: its colour is slightly darker and the general appearance is more "muddy." Bright red and yellow stains are common on the joint planes.

CANADIAN PACIFIC RAILWAY AREA.

Main line, Canadian Pacific railway.

The Lower Ribboned sandstones are well exposed in the valley of Cascade creek and on the road between Bankhead and Lake Minnewanka. The stone stands at high angles and is thin-bedded for the most part. No. 1310 was obtained at the gorge about 2 miles from the lake and may be regarded as typical.

Four miles east of Canmore on the road down the south side of the Bow river the Cretaceous strata are well exposed in a vertical cliff which abuts against the face of the Carboniferous fault block. Numerous places, at different levels, present possibilities for the quarrying of the sandstone layers. The strata are almost horizontal and although the sandstone is much mixed with shale it occurs in defined layers up to 10 inches in thickness. Prospecting in this vicinity might reasonably be expected to result in the locating of a favourable place for quarrying (1335)[1].

The stone: No. 1310.—A very hard greyish stone of fine laminated structure. The matrix is fine crystalline limestone in which a small percentage of very small quartz grains are embedded.

Under the microscope the stone shows a ground mass of extremely small crystals of dolomite or calcite of about ·05 mm. in diameter. Scattered through this matrix are minute fragments of quartz having about the same diameter as the calcite crystals.

No. 1335.—A hard, very dark grey, fine-grained sandstone with an argillaceous cement; it resembles No. 1366 but is rather darker in colour: it is lighter than No. 1368 and may be said to be intermediate between these two (see page 157). The microscope shows closely set grains of about ·2 mm. diameter; these are nearly all quartz. The grains are smaller in certain laminae and larger in others.

MOUNTAIN PARK AREA.

Railway, Coal Spur to Mountain Park.

Typical exposures of the Kootenay formation are to be seen in the valley of the McLeod river and along the line of railway north of Mountain Park.[2] Hard sandstone layers are not uncommon but they are mixed with much shale and present no possibilities. The stone is very hard and siliceous and weathers rapidly to a characteristic dirty brown colour. Brief notes on this locality follow:—

One mile north of Mountain Park, thin-bedded sandstones, bent into a sharp anticline, are seen in the valley of the river (1207).

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[1] For a full account of the distribution of the Kootenay in this area, see Geol. Sur. Can., Pub. No. 949 (Cascade Coal Basin).

[2] The miles on this branch are numbered southward from Coal Spur to Mountain Park.

One half mile farther north are exposures of a similar rock but with a greater amount of shale.

Two miles north of Mountain Park, a heavy-bedded, coarse conglomerate strikes with the railway and dips 45° to the westward. At mile 28 south of Coal Spur, this band crosses the track (1208).

North of this point are further exposures like 1207.

At mile 27½, the sandstones are thin-bedded and more shaly: they weather black with bright yellow stains on the joints (1209).

At mile 26¾, thin beds of sandstone lie in a shale formation. The whole series is wonderfully folded and contorted.

At mile 26½, hard-banded sandstones underlie heavy masses of thin-bedded material (1210).

At mile 26, is an exposure of rough calcareous sandstone with fossils; this is probably of Fernie age and is useless for our purposes.

An interval ensues in which an excellent section is seen of the Palæozoic rocks. (See page 117).

At mile 22⅞, are further exposures of Kootenay shales and thin sandstone quite comparable with those observed farther south.

The stone: No. 1207.—A hard grey sandstone essentially the same as No. 1366 but slightly darker. It shows scattered flakes of mica.

No. 1208.—A coarse rough conglomerate with pebbles as great as one inch in diameter. The matrix shows no lime. The pebbles are mostly quartzite.

No. 1209.—Dark, fine-grained, highly argillaceous sandstone: it shows the transition to a shale. The rock is full of flaws with bright yellowish-red coatings. This type is quite useless for building purposes of any kind.

No. 1210.—A dark grey, distinctly ribboned sandstone closely resembling the specimen of the Lower Ribboned sandstone from the Cascade basin described as No. 1310 on page 158. Unlike No. 1310, the present specimen has no lime in the cementing material.

West fork of McLeod river, Alberta.

A good exposure of Kootenay sandstone occurs on this stream in township 47, range 24 west of the 5th. principal meridian. The stone occurs in fairly heavy beds and is easily accessible at the water level (1226).

The stone: No. 1226.—A very hard, grey, laminated, fine-grained sandstone with a calcareous cement: it resembles No. 1310 very closely but is less distinctly laminated. The original colour is dark grey but all pieces show a deep zone of oxidation which is of a dirty brownish colour. The rock shows vertical dark lines due to organic matter derived from the decay of roots. Both the original stone and the oxidized zone are very hard but they might be used for rough building.

DAKOTA FORMATION.

The Dakota formation is the basal member of the upper division of the Cretaceous system: as it consists largely of sandstone, this formation is of considerable interest from the present point of view. In Manitoba where the Lower Cretaceous and all other intervening formations are absent, the Dakota rests immediately on the Devonian limestone. The following description by Tyrrell indicates the general characteristics of the formation in this area. "This formation resting unconformably on the limestones of the Devonian, is composed of white or reddish sandstone, either cemented by a calcareous matrix or often quite incoherent, being then an even-grained white quartzose sand. It grades up into a light green and rather hard sandstone, commonly interstratified with thin bands of shale.[1]"

Outcrops of this formation in Manitoba are to be seen only in the northern part of the province, *e.g.*, on the Red Deer, Armitt, Kematch, Pine, and Swan rivers, and on Kettle hill south of Swan lake. None of the exposures give any promise of yielding building stone on account of the soft and friable nature of the rock and the interbedding with shales.

On the western side of the great plains, in the foothills of the Rocky mountains, the Dakota sandstones are again exposed where the mountain making forces have brought to the surface rocks which are hidden beneath later accumulations and are nowhere to be seen across the prairies.

The first or eastern range of the Rocky mountains is essentially a great block of the earth's crust, separated from the prairie region by an enormous fracture and forced upward by tremendous pressure. The upthrust of this mass has necessarily bent and elevated to a less extent the rocks lying east of the great break. Thus were the foothills formed and in them we find, practically throughout the whole length of the mountains, the upturned edges of the Dakota sandstone. Doubtless these sandstones were lifted in their natural position, together with all the other formations when the first range was formed, but subsequent erosion has removed them from the tops of the mountains. In the valleys west of the first range, however, where more protection has been afforded, we again encounter beds of sandstone of this age overlying the coal-bearing strata of the Kootenay formation. The strata of the formation doubtless differ greatly in different localities, but as the great majority of recorded outcrops are difficult of access and consequently of no immediate economic importance for our present purposes, the following quotations will serve to indicate the general character of the formation. Cairnes thus describes the formation in the Moose Mountain district of Southern Alberta:—

"The upper beds consist of light coloured sandstones, shales and clays. . . . . Greens, blues and greys are the most noticeable colours, but there are a few very persistent red bands, about 2 feet wide, which occur near the top of the Dakota and form good horizon markers in certain localities. The

[1] Geol. Sur. Can., Ann. Rep., Vol. V, p. 209 E.

rocks of this formation are well bedded and are chiefly fresh water, particularly the upper light coloured beds.

"Below these upper beds, are some which are darker and harder, which in turn overlie some coarser, lighter coloured, and somewhat more massive beds of sandstone. These again are followed by 300 or 400 feet of thinner, harder, darker strata. . . . The sandstones as a rule present the general appearance of a dark green or greenish-blue colour. Below these again are a few thicker beds of sandstone which are very fine-grained, quartzitic, and grey in colour; the lowest one being very noticeable and almost white in colour, and averaging from 10 to 50 feet in thickness. This latter bed is very persistent and was traced for over 30 miles, nearly the entire distance from Bow river to the south branch of Sheep river. Below this is the conglomerate forming the base of the Dakota.[1]"

The Dakota formation in the Bighorn coal basin is described by Malloch as follows:—"The boundary between the Kootanie and Dakota is quite distinct lithologically. The Dakota begins with a bed of white quartzose sandstone, which has a peculiar greenish cast. The grains of the sandstone are not so firmly cemented as those of the siliceous sandstones in the Kootanie, which weather either to reddish or blüish-grey colours. The shales which follow the sandstones are even more easily distinguished, for they weather to reddish and yellowish tints, showing in places a purplish cast, whereas the shales of the Kootanie are almost invariably carbonaceous, to some extent at least, and seldom lose their black colour on weathering. Higher up in the Dakota the sandstones often weather brown, but are usually grey on fracture.[2]"

Dowling gives the thickness of the formation in the foothills as 900 to 1,700 feet in the Sheep Creek district; Cairnes makes the thickness in the Moose Mountain district 900 to 1,700 feet; and Malloch records 1,799 feet in the Bighorn coal basin.

Most of the geological reports dealing with the foothills as well as the special reports on the coal fields of the Kootenay record the occurrence of Dakota sandstone. It is to be inferred therefore that sandstones of the formation could be obtained at a great number of places along the mountains. It is to be regretted that authors have not expressed opinions as to the suitability of the stone to structural purposes, as it was found impossible for the present report to visit any localities except a relatively small number accessible by railway. From what has been observed, it would appear that the upper layers are too thin and too much mixed with shale to present great possibilities as building material. In all instances observed, the only stone at all promising, is seen in some of the lower beds. This stone is hard, tough, greyish or greenish in colour, usually much shattered, and of poor weathering qualities: it is suitable only for foundations and other structural purposes of a rough kind. It must be admitted that

[1] Geol. Sur. Can., Pub. No. 968, p. 31, 1907.
[2] Geol. Sur. Can., Memoir 9E, p. 35, 1911.

the formation may contain much better material but it is safe to state that at no accessible point is any stone to be procured superior to the typical examples described in this report.

Manitoba Area.

The characteristics and distribution of the Dakota sandstone in Manitoba have been referred to already in as much detail as their importance justifies.

Crowsnest Area.

Hillcrest, Alberta.

The valley of the Old Man river east of Hillcrest station shows a number of parallel ridges of rock striking about southeast and presenting numerous outcrops on which quarrying could easily be carried on. The more southerly ridge exposes a face of 30 feet with the strata dipping 25° or 30° to the southwest. The rock is rather thin-bedded and the exposed surfaces are severely weathered with a dirty yellowish-grey appearance and with red and yellow stains on the joint planes. Where opened, the beds appear to be thicker and quite capable of yielding rough stone for structural purposes (1378).

The second ridge to the northeast presents a similar stone with a strong tendency to weather red (1379). This ridge gradually rises into a great hill towards the southwest and would be capable of yielding enormous quantities of this type of stone. Three more parallel ridges of similar rock occur between this point and the river, on the opposite side of which the Dakota formation is cut off by a smooth wall of rock belonging to the Kootenay series. A little west of this point the railway curves to the south and cuts across the nearer ridges of Dakota sandstone. Rock cuts here show that the stone is shattered and much mixed with shales. North of Hillcrest station and west to beyond the Frank rockslide, similar rocks are accessible at many points. The hard green stone is in places associated with a coarse conglomerate towards the base of the series.

The stone: No. 1378.—This stone is similar to No. 1364 described on page 163 but it is of light brownish rather than of greenish colour. The hand specimen shows much more reediness than No. 1364.

No. 1379.—This example also resembles No. 1364 but it is yellowish rather than greenish in colour and is somewhat softer.

Coleman, Alberta.

A short distance west of Coleman a prominent band of Dakota sandstone is crossed by the roadway where a small amount of quarrying was done by Wm. Sandvidge of Silverton, B.C. The product was used for foundations in Cranbrook and for the coke ovens at Hosmer, B.C.

The formation strikes a little west of north and dips 30° to the westward. The exposure is about 200 feet wide at the road but it rises into a pronounced hill to the north. The actual face where quarried is 15 feet high but this would increase if the workings were extended. The stone is mostly thin-bedded but with thick lenticular bands which would yield stone of sufficient size for ordinary rough building which is the only purpose to which the material is adapted. Pronounced joints cross the formation N.20°W. with a dip of 80° northeasterly. On the whole the formation is rather severely jointed. The average stone is described below as No. 1364. This rock is probably the result of the oxidation of an original rock of bluish colour as specimens may be obtained with a greenish external zone and a blue centre (1365). In places a deep brown alteration is observed in spots with defined borders, but the stone, when broken, does not show any essential difference from the general run of the rock. On the eastern side of the ridge the sandstone is underlaid by a clay conglomerate.

The stone: All the stone mentioned above is very hard and tough; it all shows a colour between dead green and greenish-yellow, and none of it presents any possibilities except for use in foundations and in the roughest kind of walls.

No. 1364.—A hard, greenish-blue, medium to fine-grained sandstone. The general appearance is rather muddy and without the clean "pepper and salt" effect of No. 1224 from the McLeod river. This specimen has more of a bluish cast than No. 1233 from the Grand Trunk Pacific Railway area and it is darker than No. 1221 from the Mountain Park area (No. 4, Plate LV).

Under the microscope the stone shows a close set aggregate of mineral grains averaging ·25 or ·3 mm. in diameter but occasionally reaching a diameter in the greater direction of more than ·5 mm. The fragments are both rounded and sharply angular and consist chiefly of orthoclase in an advanced stage of decomposition. A small amount of plagioclase is present in a less altered condition and quartz grains occur to a number which would not exceed one-fifth the number of the feldspar grains. The cementing matter is green in transmitted light and is evidently recrystallized in the form of some mineral of the mica group. This stone is the hardest of the various Dakota sandstones examined.

The physical properties are as follows:—

Specific gravity	2·712
Weight per cubic foot, lbs	163·24
Pore space, per cent	3·58
Ratio of absorption, per cent, one hour	0·559
" " " two hours	0·63
" " " slow immersion	1·23
" " " in vacuo	1·37
" " " under pressure	1·37

Coefficient of saturation, one hour	0·41
" " two hours	0·46
" " slow immersion	0·9
" " in vacuo	1·
Crushing strength, lbs. per sq. in., dry	22,500·
" " " wet	20,789·
" " " wet after freezing	19,534·
Transverse strength, lbs. per sq. in	3,081·
Shearing strength, lbs. per sq. in	3,630·
Loss on corrosion, grams per sq. in	0·0017
Drilling factor, mm	9·1
Chiselling factor, grams	0·5

No. 1365.—Very hard and tough. The outer part of the specimen resembles No. 1364, but the inner unaltered part is of bluish colour. Oxidation produces a yellow ingredient which alters the blue tone to a green.

Crowsnest lake.

Another band of Dakota sandstone is seen at the point where the railway first touches Crowsnest lake. The formation is rather thin-bedded and severely jointed but the ridge would furnish an unlimited quantity of stone similar to No. 1364. Natural blocks broken from the formation show a centre of the hard green stone surrounded by an oxidized zone of brownish colour.

Canadian Pacific Railway Area.

Main line of Canadian Pacific railway.

The chief reports dealing with this district do not record the occurrence of the Dakota formation but sandstones of the underlying Lower Cretaceous are mentioned at numerous localities.[1]

Southward of this region, however, the Dakota formation is well exposed in the Moose Mountain district (*op. cit.*).

Highwood River Area.

Highwood river, Alberta.

Dakota sandstones are exposed along the Highwood river on section 35, township 18, range 3 west of the fifth meridian. Mr. Dowling informs me that the upper beds are thin and interstratified with shale and that the lower stone presents the same features that have been described for the stone from the Crowsnest pass.

[1] Geol. Sur. Can. Vol. 1, Pt. B; *ibid*, Vol. II, Pt. D.; *ibid.* Sum. Rep., 1903; *ibid*, Sum. Rep., 1904; *ibid*, Pub. No. 949, 1907; Jour. Can. Min. Inst., Vol. VIII.

Grand Trunk Pacific Railway Area.

Mile 984, Grand Trunk Pacific railway, Alberta.

At the above mileage, east of Dyke station, is a rock cut about 100 yards long in greenish sandstones which are probably referable to the Dakota formation but which may possibly be of Edmonton age.

The railway is about 100 feet above the Athabaska river and the formation is exposed in a vertical cut to a height of 30 feet. Westward from the cut the ridge is more or less exposed for a distance of fully a quarter mile and is probably continuous with a second outcrop at mile 986½ where it seems to be underlaid by a coarse conglomerate.

The bedding is rather indistinct in the whole mass, but in places it is thin, showing a practically horizontal position for the strata.

The main set of joints cuts the formation in a north and south direction but numerous other joints occur, as well as much lenticular parting. Although the loss would be considerable, it would be possible to obtain fair sized building pieces, but not large quarry blocks.

The overburden would increase with development, but a large amount of stone might be obtained along the ridge before the stripping would become excessive.

The stone is fairly uniform and weathers a rather pleasing olive-green colour. An average sample is described below as No. 1233. Some of the stone from the deeper part of the cut has a bluish appearance (1234) and it is quite possible that this type represents the original rock and that all the greenish material is the result of oxidation. Both varieties alter on exposure—the green rock becoming darker and the blue rock assuming a greenish colour. The sandstone near the western edge of the outcrop is more laminated (1235), and is apparently underlaid by a coarse conglomerate (1236).

The stone: No. 1233.—A dark greenish, hard, fine-grained but rather muddy sandstone; it is rather darker than No. 1221 from Mountain Park. The grains consist of quartz of different colours, feldspar, and black fragments; the latter are sometimes one mm. in diameter. The quartz and feldspar fragments seldom exceed ·5 mm. The cement is abundant, reacts very slightly for carbonate of lime, and shows an indistinct development of secondary mica. The test cubes show very little alteration under the corrosion and freezing tests. As in the case of all the Dakota sandstones tested, the coefficient of saturation is high and the stones may be regarded as in danger of injury by frost.

The physical properties are as follows:—

Specific gravity	2·714
Weight per cubic foot, lbs	154·85
Pore space, per cent	8·602

Ratio of absorption, per cent, one hour	1·2
" " " " " two hours	1·6
" " " " " slow immersion	3·11
" " " " " in vacuo	3·29
" " " " " under pressure	3·383
Coefficient of saturation, one hour	0·35
" " " two hours	0·47
" " " slow immersion	0·92
" " " in vacuo	0·94
Crushing strength, lbs. per sq. in., dry	17,880·
" " " " wet	13,074·
" " " " wet after freezing	9,477·
Transverse strength, lbs. per sq. in	1,765·
Shearing strength, lbs. per sq. in	1,680·
Loss on corrosion, grams per sq. in	0·013
Drilling factor, mm	14·
Chiselling factor, grams	3·65

No. 1234.—Similar in grain to No. 1233 but with a decidedly bluish rather than yellowish-green colour. It is a muddy stone, nevertheless, and has not the clean "pepper and salt" appearance of the stone from McLeod river, No. 1224. The microscope shows quartz fragments up to ·5 mm. in diameter, determinable feldspar grains, numerous muddy indeterminable fragments, cementing matter with iron oxides and greenish chloritic material.

No. 1235.—A greenish, dirty, micaceous, laminated type of no promise.

No. 1236.—A coarse rough conglomerate resembling that near Coleman, and on the Mountain Park railway. This stone is hard and resistant: it might be used for purposes of rough construction.

Mountain Park Area.

Railway, Coal Spur to Mountain Park.

On the railway between Bickerdike on the Grand Trunk Pacific railway and Mountain Park, at mile $21\frac{7}{8}$ south of Coal Spur, is an exposure of greenish sandstone which I am inclined to believe is of Dakota age. The formation strikes N.60°E. and dips 70° or 80° to the northwest. The exposure measures 150 feet across the strike and rises into a considerable ridge. The beds vary in thickness up to 2 feet and are somewhat interlaminated with shale. It would not be difficult to obtain blocks of sufficient size for purposes of ordinary construction. The stone weathers a dirty, yellowish-green, and zones of this altered material surround all the natural fragments (1221). Across the McLeod river similar stone crops out along the line of strike.

The stone: No. 1221.—This sandstone is hard and compact and of a dark dirty greenish colour like No. 1233 from the Grand Trunk Pacific railway. The present example is somewhat lighter in colour and with more of a "peppery" effect. The corrosion test dulls the surface and oxidizes some of the mineral grains with the production of red and yellow specks. No alteration was observed after freezing.

The physical properties are as follows:—

Specific gravity	2·708
Weight per cubic foot, lbs	158·37
Pore space, per cent	6·32
Ratio of absorption, per cent, one hour	1·06
" " " " " two hours	1·15
" " " " " slow immersion	2·34
" " " " " in vacuo	2·42
" " " " " under pressure	2·491
Coefficient of saturation, one hour	0·42
" " " two hours	0·46
" " " slow immersion	0·94
" " " in vacuo	0·97
Crushing strength, lbs. per sq. in., dry	19,362·
" " " " wet	14,114·
" " " " wet after freezing	11,481·
Transverse strength, lbs. per sq. in	2,243·
Shearing strength, lbs. per sq. in	679·(?)
Loss on corrosion, grams per sq. in	0·0116
Drilling factor, mm	17·
Chiselling factor, grams	4·75

West fork, McLeod river.

A good exposure of Dakota sandstone occurs on section 5, township 48, range 24 west of the fifth meridian. The sandstone outcrops on both sides of the river in cliffs 50 to 75 feet high. The beds strike nearly east and west and dip about 80° to the north: they vary greatly in thickness but are fairly solid and would yield a large amount of stone suitable for building. The best exposures are on the right bank of the stream where quarrying could be carried on for some time without encountering an excessive overburden. The beds occupy a position near the bottom of the Dakota and show an interesting contact with the underlying Kootenay. The stone seems to be fairly uniform in grain and colour but it has the usual tendency to alter superficially under the action of the weather. No. 1224 is a good average sample: No. 1225 illustrates the changes effected by the weather.

This point is quite inaccessible for quarrying at the present time but coal claims have been located in the vicinity and should a railway be constructed the sandstone may find a use for building purposes. An indication of the possibilities is afforded by a chimney and fireplace in a cabin constructed on the ground by Mr. James McEvoy.

The stone: No. 1224.—This is a hard, medium to fine-grained compact sandstone of blue rather than green cast (No. 3, Plate LV). In structure it is cleaner than the other Dakota sandstones tested and shows a distinctly speckled or "pepper and salt" effect which adds much to its appearance.

Under the microscope the stone shows a close set aggregate of mineral grains averaging about ·5 mm. in diameter and occasionally reaching a diameter of nearly 1 mm. The grains are nearly all orthoclase in a seriously decomposed condition. Scattered grains of quartz are present but there is very little plagioclase fresh enough to be determined as such. The cementing matter is scanty and of a brownish colour. This stone is rather coarser and with more rounded grains than No. 1364 from near Coleman. The cementing matter is not converted into chloritic or micaceous minerals as in that example. The corrosion test removes the bluish cast and induces a slightly red-speckled appearance. The freezing test produces no visible effect.

The physical properties are as follows:—

Specific gravity	2·669
Weight per cubic foot, lbs	161·25
Pore space, per cent	3·22
Ratio of absorption, per cent, one hour	0·85
" " " " " two hours	0·98
" " " " " slow immersion	1·17
" " " " " in vacuo	1·17
" " " " " under pressure	1·24
Coefficient of saturation, one hour	0·68
" " " two hours	0·79
" " " slow immersion	0·94
" " " in vacuo	0·94
Crushing strength, lbs. per sq. in., dry	20,186·
" " " " wet	15,600·
" " " " wet after freezing	17,042·
Transverse strength, lbs. per sq. in	1,510·
Shearing strength, lbs. per sq. in	1,260·
Loss on corrosion, grams per sq. in	0·0082
Drilling factor, mm	7·8
Chiselling factor, grams	3·63

The chemical analysis confirms the microscopic examination as to the small amount of cement which is evidently argillaceous and ferruginous, with a very slight amount of carbonates. The high percentage of ferrous oxide does not speak well for the colour durability of the stone. The analysis follows:—

	Per cent
Insoluble residue	92·29
Soluble portion	7·71
Partial analysis of the soluble portion:	
Lime	1·12
Magnesia	0·67
Ferric oxide	0·71
Ferrous oxide	1·40
Carbonic acid	0·49
Total constituents determined	4·39

No. 1225.—This altered stone shows the colour characteristic of the greenish types of Dakota sandstone. It is quite possible that all the green stones are the result of the oxidation of an originally bluish type.

Other Areas of Dakota Sandstone.

In addition to the previously described areas which I was enabled to visit, the literature contains many references to the occurrence of Dakota sandstones in the foothills. The following brief notes may be of some value:—

Shunda Creek coal area (Brazeau range).

Dowling records the occurrence of sandstone of Dakota age in this district but I was unable to learn of its occurrence in any accessible position along the railway from Rocky Mountain House to Nordegg.[1]

George creek, Alberta.

Mr. James McEvoy informs me that Dakota sandstones occur on George creek near the southwest corner of section 35, township 41, range 19 west of the fifth meridian. The formation is exposed in beds of 6 inches to 2 feet in thickness. The stone is of an olive green colour and is available in quantity.

Bighorn Coal Basin.

Numerous exposures of Dakota sandstone are recorded by Malloch in his report on the Bighorn basin (Publication No. 1130 of the Geological Survey of Canada).

Summary—Dakota Sandstone.

This formation is known in Manitoba by soft, pulverulent sandstones of no possible value as building material. In Alberta the formation is of considerable extent (see page 160) and is represented by hard greenish stones which give evidence of originally possessing a blue colour. These

[1] Geol. Sur. Can., Sum. Rep., 1909, p. 142.

stones are hard and tough with poor weathering qualities but they are useful for rough construction. The probability of their use for such purposes, rather than the prevailing limestones of the mountains, lies in the fact that they may be quarried in thicknesses suitable for coursing whereas the limestones usually require bedding. The stones examined show a paucity of quartz grains but a large amount of feldspar and dark ferromagnesian minerals in an altered condition. The stones are compact with a low porosity. The cementing matter is argillaceous rather than calcareous and in some cases it is rather scanty. The four stones tested are alike in their physical properties, *i.e.*, they are all hard, tough, fairly strong and of low porosity. Nevertheless, there is considerable difference in the specimens when compared with one another. They all agree in possessing a low power of resistance to frost action as indicated by a coefficient of saturation exceeding ·9 in each instance.

The average of the chief physical properties of 4 stones is given below:—

Specific gravity	2·701
Weight per cubic foot, lbs.	159·43
Pore space, per cent.	5·43
Coefficient of saturation	0·925
Crushing strength, lbs. per sq. in., dry	19,982·
" " " " " wet	15,914·
" " " " " wet after freezing	14,384·
Transverse strength, lbs. per sq. in.	2,149·
Shearing strength, lbs. per sq. in., (3 only)	2,190·
Drilling factor, mm.	12·1
Chiselling factor, grams	3·13

BELLY RIVER FORMATION.

Crowsnest Area.

Coleman, Alberta.

The Allison Creek formation of the Belly River series occurs to an estimated thickness of 2,000 feet in the Crowsnest coal field: it overlies the Dakota sandstones and includes the latest strata exposed in this region. The formation is described as consisting of soft, light-coloured sandstones with small coal seams near the top. The rocks of this series form the lower slopes of Crowsnest mountain and occupy a considerable area in the surrounding less elevated region, *e.g.*, on Allison and McGillivray creeks. No attempt has been made to work the formation for building stone and little was learned of its possibilities.

East of the town of Coleman the base of the formation is exposed in a ridge about 25 feet high. The stone is soft, thin-bedded and much jointed but a considerable quantity could be obtained in thin rectangular blocks.

The formation is not well exposed but a very little work would better reveal the character of the beds (1386).

The stone: No. 1386.—A fine-grained, greyish, laminated sandstone showing much mica among the constituent grains. The stone is fairly hard but not as hard as the Dakota sandstone. The cement is calcareous. Other samples are less laminated and are softer.

Sentinel, Alberta.

About a mile west of Sentinel station on the Crowsnest line is a small exposure of soft sandstone which probably belongs to this series. The stone is of fair quality but it is very thin-bedded in the rock cut. Prospecting along the ridge might reveal the same type of stone in thicker beds (1372).

The stone: No. 1372. Quite the same type of stone as No. 1386 but of rather cleaner and more bluish colour and with less lime in the cementing material. A microscopic examination shows that quartz grains, not exceeding ·25 mm. in diameter make up about one-third of the stone. Other mineral grains of about the same size occur in rather greater abundance; some of these are sufficiently fresh to be definitely determined as feldspar. Brownish mica is also present. Actual cement is relatively small in amount but in places the cement is not separable from decomposed mineral grains. The cloudy matter, made up of cement and decomposed mineral grains, shows spots of oxide of iron. On the whole, this stone is cleaner and fresher than the average sandstone of the Paskapoo formation.

Milk River Area.

Coutts, Alberta.

Sandstones are exposed in the valley of the Milk river and in variou coulées near the Alberta-Montana boundary. Dr. Dawson ascribed these sandstones to the Fox Hill division.[1] At a later date, in the Report of the Geological Survey for 1882-84, he gives a full account of this region, to which the reader is referred for the localities of occurrence. In this report Dr. Dawson states that some of these sandstones may belong to the St. Mary River series.

The best and most accessible exposure of these sandstones is in a coulée on the Montana side of the line immediately south of the boundary and a little west of the line of the Northern Pacific railway which connects at Coutts with the Canadian Pacific line to Lethbridge. These rocks are known locally as the "Ruins of Jerusalem." On the Canadian side the most accessible exposure of these castellated sandstones is about 20 miles northeast of Coutts. Owing to the heavy rains at the time of my visit I found it difficult to obtain a conveyance to the Canadian locality and ex-

[1] Geol. Sur. Can., Rep. 1880-82, Pt. B, p. 7.

amined instead the exposures in Montana which, as far as I have been able to ascertain, are precisely similar in their general features and doubtless will serve equally well to illustrate the formation for our present purposes. As already stated, the localities of occurrence are numerous and may be found in Dr. Dawson's report (*op. cit.*).

The "Ruins of Jerusalem" extend for nearly a mile along a deep valley which at this point presents steep scarped cliffs for the upper 50 feet, where the sandstones are exposed, more particularly on the north side. Beneath the sandstone the valley is cut in the Pierre shales (Claggett formation) and presents more sloping banks to the bottom. In a general way it may be said that these sandstones are thin-bedded, soft and grey, with a tendency to weather yellow. Where fresh scarped the thin bedding is less perceptible and stone of considerable thickness might be obtained. The thin bedding seems to be emphasized by weathering and in consequence it might be concluded that stone of greater coherence would be found if the outer surface were removed. The beds are so variable that a detailed section will not apply throughout the exposure. Nevertheless, the section given below is departed from only in detail, and it at least indicates all the types of stone observed along the escarpment.

10-15 ft.—Soft sandstones. Mostly thin-bedded and variable. Where freshly scarped, apparently thicker. Exposed stone (1390). Stone from a more protected position (1391).

10-15 ft.—Shale with hard nodular concretions.

5 ft.—Soft sandstones in beds up to a foot thick. The fresh stone is greyish, but yellow zones of oxidation are found on all bedding and joint planes (1392).

——Thin sandstones with an increasing amount of shale.

Systematic joints are not well developed and there is no evidence of jointing of the excessive nature that would prevent quarrying.

At a somewhat higher level than the above section, some stone is exposed in little buttes between this point and the boundary. It occurs in beds up to a foot thick interstratified with much thin material. The stone is hard and presents no possibilities (1393).

In coulées near the boundary, probably at a lower level than the "Ruins", a hard flinty sandstone interstratified with shale crops out at a number of points: it is of no possible use.

No attempt has ever been made to quarry any of these stones on either side of the boundary. As far as I have observed there are no beds of sufficient coherence to justify such a venture. It is of course possible that a systematic examination of all the outcrops might result in the discovery of more valuable material but such an investigation is beyond the scope of the present work.

The stone: No. 1390.—A soft, light yellowish-grey, fine-grained sandstone of porous and bibulous nature. The cementing matter is deficient and of a calcareous composition. This stone is lighter in colour, less yellowish, and somewhat harder than the less exposed stone described below. This hardening on exposure increases the possibility of using the material for structural purposes.

No. 1391.—Like No. 1390 but softer and more yellow. It seems to have little or no lime in the cementing matter.

No. 1392.—Like No. 1390 but softer and with no lime in the cementing material.

No. 1393.—A greenish-grey, medium to fine-grained sandstone of laminated structure and with a calcareous cement. It is much harder than the stones described above and might be used for rough purposes but its manner of occurrence is not favourable.

BOISSEVAIN SANDSTONE.

Turtle Mountain Area.

Sandstone more or less suitable for building outcrops at various places along the base of Turtle mountain in southern Manitoba. The chief locations are south of Boissevain, Ninga and Deloraine, where the rock appears in ravines and hillsides. The formation is thin and variable and does not seem to be continuous but rather to occur in more or less extensive lenses which appear and disappear at an horizon which Dowling places at the base of the lignitic Tertiary (Fox Hill)[1].

My own observations in the field indicate a position between the Millwood and Odanah of Tyrrell. While of interest geologically, the exact horizon of the beds matters little for the purposes of this report. Provisionally, I am placing the sandstones in the Upper Cretaceous as indicated above.

The stone is a fair quality of sandstone which, in a region devoid of other building stones, deserved attention. It has been employed with success in Boissevain and Ninga but in recent years none has been quarried. The cessation of production is in part due to the competition of other building materials and in part to the broken character of the stone and the heavy overburden which is encountered over many of the outcrops. It must be remembered, however, that no quarrying on a large scale has been attempted and that the stone hitherto obtained is surface material only.

The following locations which were visited are arranged in order from east to west and will be further described later:—

John Hawkins.—Section 2, township 3, range 19 west.
James Shannon.—West half of section 34, township 2, range 19 west.
William Shannon.—East half of section 34, township 2, range 19 west.
Peter Robinson.—North half of section 7, township 3, range 19 west.

[1] Geol. Sur. Can., Ann. Rep., Vol. XV, p. 200A.

Archibald Smith.—West half of section 18, township 3, range 19 west.
John Robinson.—North half of section 12, township 3, range 20 west.
John Shorey.—South half of section 11, township 3, range 20 west.
E. B. Chambers.—South half of section 10, township 3, range 20 west.
Dugald Taylor.—Northeast quarter of section 7, township 3, range 20 west.
Thomas Wilson.—Section 5, township 3, range 21 west.
William Steadman.—Southeast quarter of section 22, township 2, range 23 west.
John Rutherford.—Southeast quarter of section 15, township 2, range 23 west.

Information received from well borers in Boissevain and Deloraine indicates that the sandstone does not continue to the north and that its occurrence is local, as a well on one property may encounter the stone while the neighbouring section shows none of it. The following notes on wells are of interest:—

Boissevain. Alexander O'Neill.

Well at Boissevain.—140-150 feet clay; 20 ft. shale, soft above, harder below.
Well two miles north of Whitewater.—90 feet clay; 80 feet shale with hard sandy layers.
Well four miles south of Whitewater.—60 feet soil; shale.
Well five miles northeast of Boissevain and northwest of Ninga.—90 feet soil; shale.
Well on section 20, 2, 19.—38 feet soil; hard shale.
No sandstone found in any well sunk near Boissevain.

Deloraine. J. B. Le Barron.

Well at Deloraine.—90 feet drift. (This drift is shallower towards the north and the shale is near surface); 200 feet, hard shale. This shale is said to disappear about 14 miles north and a "soapstone" occurs under the soil.

Wells two miles south.—The hard upper shale is said to be absent and the "soapstone" comes to the surface.

Well at Whitewater.—80 feet drift; 50 feet soft shale; 165 ft. hard shale.

Well on section 22, township 2, range 23 west.—40 ft. drift; 6 in. reddish sandstone; soft greasy shales.

Well on section 10, township 2, range 23 west.—Sandstone at 38 feet.

Well on section 32, township 2, range 22 west. Sandstone under 32 feet of soil.

Well on northwest quarter of above.—Sandstone under 40 feet of soil.

PLATE XXXIII.

Boissevain sandstone. John Hawkins' quarry, Boissevain, Man.

Other wells are mentioned by Dowling in the report already cited. Sandstone is of infrequent occurrence in wells and certainly appears only around the base of the mountain in isolated lenses. The hard shale of the well borers is probably the Odanah and the "soapstone" is the Millwood. It would appear that the Odanah fails and the Millwood comes to the surface both north and south of Deloraine.

More detailed accounts of the individual properties follows.

John Hawkins, Section 2, Township 3, Range 19 West.

One of the best exposures in the district is seen on the south side of this property close to the point where the road crosses a deep ravine. About 20 feet of sandstones are exposed in layers up to 3 feet thick, but with thinner material in places. The joints are irregular and the stone is much fractured on the surface but good building blocks could easily be obtained (Plate XXXIII). The stone is equal to if not better than the best obtained near Boissevain and it seems to have good weathering qualities judging from the condition of the material on the old dump. A large amount of stone could be obtained before the overburden would be excessive. Quarrying on a small scale was attempted here and the output was used for houses in Boissevain.

The stone: No. 1194—A hard, dark greenish-grey sandstone of fine grain with a calcareous cement: its structure is not essentially different from that of No. 1187 from near Boissevain but it is considerably harder and would be more difficult to work. This stone approaches the greenish Dakota sandstones from the foothills in colour and hardness.

James Shannon, West half Section 34, Township 2, Range 19 West.

On the southeast corner of this property a deep ravine crosses in a northwest direction. Forty feet below the general level is an exposure of soft shale with layers of greenish sand resembling that at Taylor's farm described further on. Farther down the ravine, *i.e.*, northwest, loose blocks of sandstone are found on the hillside at a higher level than the sandy layers referred to above. This stone is laminated and prone to part into thin material. As far as can be ascertained there is no promise of production on this section although it adjoins the very favourable location on Hawkins' property.

The stone: No. 1193.—This example is entirely oxidized to a red colour and gives little indication of the original character of the stone.

William Shannon, East half Section 34, Township 2, Range 19 West.

Stone similar to the above outcrops on the opposite side of the ravine on this property.

Peter Robinson, North half Section 7, Township 3, Range 19 West.

The stone exposed on this property occurs along a hillside facing the line of the Great Northern railway. The outcrops are isolated and unworked: they represent a continuation of the beds on Smith's property described below.

Archibald Smith, West half Section 18, Township 3, Range 19 West.

The outcrops on this property occur near the top of the hill south of the main road and facing the line of the Great Northern railway.

A small quarry has been worked here, which at the present time exposes a face of about 5 feet. The strata are irregular and somewhat crumpled with an average dip of about 4 degrees E.40°S. The average rock, at least in the upper part, is a soft, rather thin-bedded sandstone with pronounced lamination (1184). On the south face a layer of harder stone (1185) 4 inches thick is intercalated in the soft material and seems to be unconformable with it. On the opposite side, the upper layers are soft but the lower stone is harder (1186). These harder layers appear at the bottom on the south side. It is unfortunate that there is no available information of the conditions at greater depth as the stone is evidently improving in quality downwards. It is probable that prospecting along the face of the hill looking over the line of the railway would reveal other places at which the beds could be profitably exploited.

The stone: No. 1184.—A medium-grained, laminated, soft, friable sandstone in a seriously weathered condition. It is stained yellow, green and brown and can scarcely be broken to a hand specimen without parting on the planes of stratification.

No. 1185.—This rock is essentially a fine-grained limestone of crystalline structure with scattered grains of sand. The stone is rather hard and of a light greenish-grey colour.

No. 1186.—This is a better type of stone closely comparable with No. 1187 described in full on page 177. The present specimen is a little softer and more laminated in structure.

John Robinson, North half Section 12, Township 3, Range 19 West.

The openings on this property are on the opposite side of the ridge from those described above, at a distance of about quarter of a mile in a southwest direction. The first opening exposes soft sandstones similar to those on Smith's property. The stone is weathered to sand for a depth of 6 feet in places; in other parts it is more coherent. The beds capable of yielding building stone occur irregularly and seem to be merely more indurated parts of the general mass. The peculiar hard unconformable 4-inch band observed in Smith's quarry is present here also. The strata are practically horizontal but they are flexed and uneven. Some stone could doubtless be obtained here but the loss would be out of all proportion to the valuable stone.

A little farther north on the same hillside a much more promising quarry has been opened. The stripping does not exceed 3 feet and the underlying stone is more solid and better bedded. The layers are of variable thickness but stone to measure one foot could be obtained. Vertical joints are numerous. The general appearance of the face is that of a heavily bedded but friable sandstone much cut by vertical joints and with a tendency to split on the bedding planes. One is inclined to believe that better material is to be procured away from the zone of surface alteration. The stone here is better than in Smith's quarry and it is significant that the opening is at a lower level.

The stone: No. 1187.—This example has been selected for full description as typical of a good average Boissevain sandstone. It is a medium-grained, greenish-grey sandstone with considerable resemblance to some of the Dakota sandstones of the foothills (No. 2, Plate LV). Even in the hand specimen it shows a lack of uniformity of grain, as a distinct reediness with layers of different coarseness appears. The surface dresses smooth and shows glistening flakes of white mica and dark specks of black mica, also numerous small dark brown dots which are probably due to the oxidation of finely disseminated pyrite. Under the microscope the average diameter of the main constituent grains is about ·2 mm. These grains consist of quartz, orthoclase, plagioclase, mica, and indeterminable matter. The matrix is abundant and seems to be made up entirely of crystalline calcite.

Under the corrosion test the surface is slightly roughened and a distinct change of colour is observed: the peppery effect due to the black mica is increased but the general colour is distinctly more yellow than in the untreated stone. This same change was observed in the specimens subjected to wetting and drying in the porosity tests and also in the case of the frozen cube.

The physical properties are as follows:—

Specific gravity	2·71
Weight per cubic foot, lbs	158·633
Pore space, per cent	6·12
Ratio of absorption, per cent, one hour	2·043
" " " two hours	2·06
" " " slow immersion	2·26
" " " in vacuo	2·318
" " " under pressure	2·405
Coefficient of saturation, one hour	0·84
" " two hours	0·85
" " slow immersion	0·93
" " in vacuo	0·96

Crushing strength, lbs. per sq. in.,	dry	19,703·
" " "	wet	13,181.
" " "	wet after freezing	14,727·
Transverse strength, lbs. per sq. in		1,151·
Shearing strength, lbs. per sq. in		866·
Loss on corrosion, grams per sq. in		0·112
Drilling factor, mm		18·2
Chiselling factor, grams		11·97

The analysis confirms the microscopic examination as this stone contains the greatest amount of carbonic acid, and consequently the greatest amount of carbonates, of any of the sandstones tested. The amount of ferric oxide is not great, but 1·79% of ferrous oxide is high and indicates that colour changes will ensue on exposure.

The analysis by Turner follows:—

	Per cent
Insoluble residue	38·82
Soluble portion	61·18
Partial analysis of the soluble portion.	
Lime	29·82
Magnesia	1·20
Ferric oxide	1·22
Ferrous oxide	1·79
Carbonic acid	23·78
Total soluble constituents determined	57·81

John Shorey, South half Section 11, Township 3, Range 20 West.

The exposure here is quite comparable with that on the opposite side of the ravine described below.

E. B. Chambers, South half Section 10, Township 3, Range 20 West.

The exposures on this property and on that of John Shorey occur near the bottom of a ravine and consequently a prohibitive overburden would be encountered if quarrying operations were carried far. Dowling (*op. cit.*) describes these outcrops as follows: "The upper part of the exposures along the creek are of dark yellow sand with a few reddish streaks from ironstone. Below these sands at the quarry is a lighter coarse-grained sand in false beds and irregular layers, not apparently hard enough for building purposes, but below this is a dark grey sandstone, the cracks and crevices in which are stained dark with iron rust."

The face of the old workings is now badly decayed and fallen down and in consequence the strata are obscured. The following section was measured:—

2 ft.—Soft red sand.

10 in.—Thin-bedded friable sandstone.

3 ft.—Laminated sandstone, fairly coherent but with a tendency to split at any level (1188).

Joints cut the formation at about N.35°E. and numerous irregular cracks are present. Yellow skins occur on the joint faces. The lower stone is probably as good as any seen but the condition of the outcrop is such that no very definite remarks are warranted.

The stone: No. 1188.—This stone is of the same general type as No. 1187; it is softer, slightly coarser in grain, and more laminated. The specimen is badly weathered, with deep yellow staining on the surface and along certain of the planes of stratification. It must be remembered that this is surface stone.

Dugald Taylor, Northeast quarter Section 7, Township 3, Range 20 West.

The exposure here is of little interest from the present point of view but it is worthy of detailed study geologically. The section shows some greenish sand very similar to that of the other locations, but it is mixed with clay, crumpled in a peculiar manner, and appears to gradate upwards into an overlying layer of boulder clay. Lying at the same level as the soft sand is a large mass of very hard stone, and the sand also contains boulders of other stone but it could not be described as pebbly (1192). It is likely that we have here an interesting example of glacial action on the soft sandstone of the horizon being discussed.

Thomas Wilson, Section 5, Township 3, Range 21 West.

Stone has been reported as occurring on the sides of the ravine crossing this property. Although I had the advantage of Mr. Wilson's guidance we were unable to locate any actual outcrops of workable stone. There is no doubt, however, that fairly heavy beds occur under a slight covering at different points, for loose blocks of fair size and quality are not uncommon along the sides of the ravine. I am informed that stone was quarried here many years ago for the construction of a mill in old Deloraine (Section 30, 2, 22).

The stone: No. 1191.—A red oxidized type indicating an originally massive stone of the same structure as No. 1187.

William Steadman, Southeast quarter Section 32, Township 2, Range 23 West.

Soft, friable, greenish sandstone is exposed in a layer about 3 feet thick near the bottom of a ravine on this property. The overburden is probably 40 feet. I am informed by well borers that no sandstone is penetrated in wells north of this point.

The stone: No. 1189.—A very soft decomposed sandstone of laminated structure and dirty yellow colour. It is evidently the result of serious weathering of a harder, probably green type.

John Rutherford, Southeast quarter Section 15, Township 2, Range 23 West.

Stone was quarried on this property from a point where a small ravine from the west joins the main coulée. The overlying drift has fallen into the old workings and nothing is to be seen of the layers of solid sandstone. The present section exposes about 6 feet of soft sand only. Harder layers doubtless occur below and are represented by many fragments of which No. 1190 is a fair average. These lower beds are said to be 8 feet thick but I have no means of verifying this statement.

The stone: No. 1190.—This stone has the same grain as No. 1187 but it differs in colour being decidedly yellowish instead of green. It has the appearance of being derived by oxidation from a green type. It weathers still more yellow and is softer than No. 1187. The stone is massive and capable of being worked.

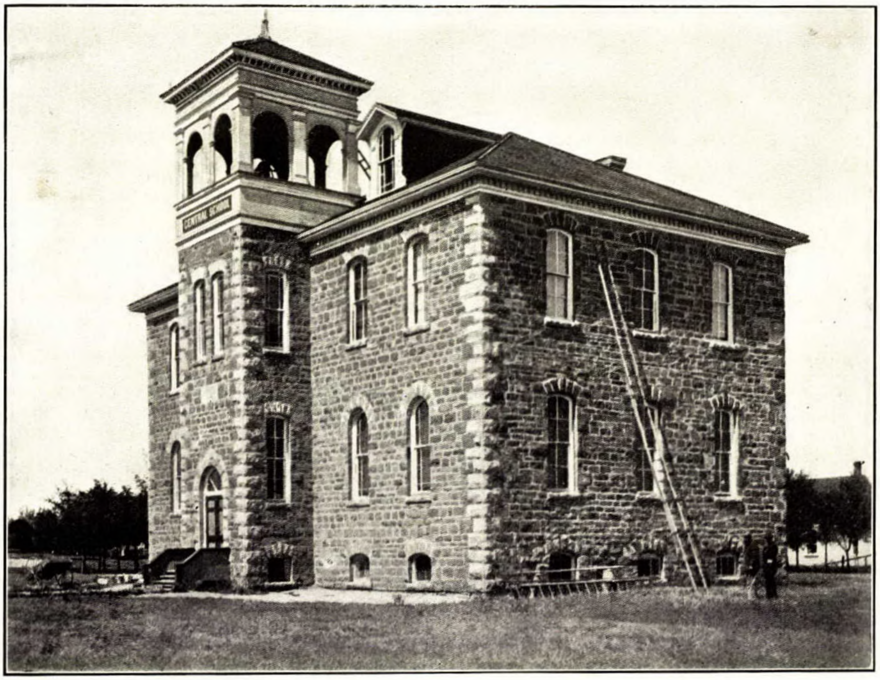
The sandstone layer must have a considerable extent in this vicinity as all wells penetrate it. The heavy overburden is of course prohibitive, but prospecting would probably reveal beds capable of being worked in many of the ravines. I am informed that the stone occurs in the big coulée about three miles east of Rutherford's but I was unable to ascertain the location of any definite outcrop.

Stone from this formation is best seen in buildings in Boissevain of which the more important are the school (Plate XXXIV), the Methodist church, the Queen's hotel, Dominion bank, and the residences of Dr. Rogers, Mr. B. Holiday and Mr. Sandy Cameron. These structures indicate that the general tendency of the stone is to darken and become more yellow. This yellow weathering is not always uniform but is frequently developed in streaks. The weathering is more pronounced near the natural joints; consequently, where the joint surface has been made to serve as rock face in the wall the result is far from pleasing. Lack of selection has likewise contributed towards an undesirable variation in colour. The general durability is greater than one would expect from a sandstone of this kind: very little deterioration was observed in any of the buildings. It is interesting to note that the laboratory tests are in every instance in accord with the observed facts of weathering.

EDMONTON FORMATION

The Edmonton formation is commonly regarded at the present time as the top of the Upper Cretaceous system in western Canada: it was formerly included in the Laramie, of which it constituted the lower member. Barnum Brown gives a good generalized account of the Edmonton as

PLATE XXXIV.



Boissevain sandstone. School at Boissevain, Man.

follows: "The Edmonton formation consists chiefly of siliceous clays interstratified with seams of lignite and thin strata of whitish sandstone. It is essentially a lignite formation.

"The strata are of marine and brackish-water origin and everywhere conformably overlie the marine beds below. The whole series shows an uninterrupted successive sedimentation from purely marine conditions at the base through brackish-water during most of the period, with a gradual freshening towards the top. The Edmonton is intermediate in position between the Judith river and the Lance."[1]

Dowling considers the Edmonton of northern Alberta equivalent to part of the St. Mary River beds of the south.

This formation occupies an enormous area in Alberta, stretching northward from the international boundary in a great belt of gradually increasing width: it is overlaid in its central part by the sandstones of the Paskapoo formation and consequently it forms the surface rock in a wide strip east of the Paskapoo sandstones and in a somewhat narrower strip west of them.

With the possible exception of the quarry near Monarch on the Crowsnest line of the Canadian Pacific railway, I know of no attempt to work the sandstones of this formation. According to the map of western Canada issued by the Geological Survey in 1911, the Monarch quarry is in Edmonton rock, but for economic reasons I have preferred to list it under the Paskapoo to which it possibly belongs. Making an exception of this quarry we are able to generalize the sandstones of the Edmonton formation as follows:—

1—Sandstones of the eastern belt. Soft or very hard, generally thin-bedded sandstones interstratified with shale. Apparently of little or no value for structural purposes.

2—Sandstones of the western belt. The sandstones here are somewhat better than those of the eastern belt and may be capable of yielding a soft type of building stone in places.

1—EASTERN BELT.

Sandstones of the formations are exposed throughout the belt in numerous river valleys and coulées from the international boundary to northern Alberta: they are also to be observed in the coal districts near Edmonton, Camrose, and Drumheller. Further remarks on distribution are not warranted by the importance of the subject from the present point of view.

RED DEER RIVER AREA.

The best known outcrops, which may be regarded as typical, occur along Rosebud creek and the valley of the Red Deer river. For miles along the Canadian Northern railway which follows the beds of these

[1] Bull., Geol. Soc. Am., Vol. 25, No. 3, p. 373, 1914.

streams, the shales and sandstones may be observed presenting a peculiar conical and hourglass-shaped type of weathering. Irregular hard layers are present in places but I know of no locality where they could be systematically quarried. Fallen masses of these harder layers could be obtained from the talus at many points and used for purposes of the roughest kind of building.

In order to obtain a few samples typical of the formation a section was examined on the Red Deer river near Munsey. The valley here is about 450 feet deep. The best exposures are on the west side near Tolman's ferry. At the highest point an upper layer of very yellowish sandstone occurs which is probably 50 feet thick. The surface of this stone is soft, even pulverulent, but on breaking some of the fallen blocks I was surprised to find that the unaltered stone is reasonably hard (1351). Lower down in the cliff, interstratified with the shales, are two other layers of sandstone each about 4 feet thick; these, like the previous examples, are very soft on the exterior, but when fresh broken, show a hard greyish type of stone (1350). I see no possibilities for the production of building stone but, of course, the hard layers could be used for rough construction; even for this purpose, I should fear the tendency to excessive weathering.

The following generalized section was measured by Mr. Barnum Brown near the mouth of Big Valley at a point which shows "the most rugged exposure of this formation along the river" (*op. cit.*).

10 ft.—Boulder clay.
40 ft.—Loosely cemented white sandstone and clay.
1 ft.—Impure lignite.
10 ft.—Light clay.
3 ft.—Lignite.
20 ft.—Dark grey clay.
1 ft.—Lignite.
25 ft.—Sandy clay, light grey above, darker below.
6 ft.—Impure lignite and carbonaceous clay.
20 ft.—White sandy clay.
40 ft.—Brown clay with ironstone.
15 ft.—Sandy white clay.
4 ft.—Hard laminated sandstone, generally persistent.
100 ft.—Light clay, occasional sandstones.
5 ft.—Laminated reddish sandstone, fossils numerous.
30 ft.—Clay and iron-encrusted pebbles, fossils numerous.
8 ft.—Sandstone.
70 ft.—Light blue grey clay.

This section gives little promise. Note the two hard sandstone layers. It is the sandy clays which are responsible for the peculiar cone-like weathering observed all along the valley.

The stone. No. 1350.—A very hard and compact, dark greenish-grey sandstone of fine grain, closely resembling the greenish type of Dakota sandstone. Considerable calcareous matter is present in the cement but the weathering properties are very poor.

No. 1351.—A muddy yellowish-grey sandstone with an abundant calcareo-argillaceous cement. The unaltered stone is not too hard to be used for building but the tendency to weather soft and yellow makes its application impossible.

II—WESTERN BELT.

This belt of Edmonton rocks extends from the international boundary at about longitude 113° 20′, in the form of a strip not more than 6 or 8 miles wide, to about the crossing of the Red Deer river: north of this point it gradually widens and at the crossing of the Grand Trunk Pacific railway it is nearly 40 miles wide. The eastern part of this belt shows soft sandstones interstratified with shales, but in places on the western border, where it has been caught in the zone of pressure attending the elevation of the Rocky mountains, the sandstones have been upturned and greatly hardened.

Edmonton sandstones are exposed in nearly every river valley and coulée crossing the belt; particularly may be mentioned St. Marys, Belly, Old Man, and Highwood rivers in the south, and Bow, Red Deer, Clearwater, Saskatchewan, Brazeau, Pembina, and Athabaska rivers in the north. Exposures may also be seen on all the lines of railway approaching the foothills; nevertheless, no attempt has been made to use the stone for structual purposes.

Coal Spur Area.

Edmonton rocks were observed at a few places in the vicinity of the line of railway between Bickerdike and Coal Spur.

Near mile 7 south of Bickerdike, Alberta.

I am informed than an exposure of Edmonton sandstone, located about a mile east of the track at this point, has been staked as a quarrying property. The locality was not visited.

Near mile 32 south of Bickerdike, Alberta.

East of the track at this point, in the valley of the Embarras river, are exposures of sandstone which have attracted some attention as possible quarrying properties. Locations have been staked by William Baillie of Coal Spur.

The more westerly exposure shows 50 or 60 feet of sandstones striking east and west and dipping north at a high angle. The stone is mostly soft, greenish in colour, and badly weathered, but it contains some harder streaks. The overburden is slight. A more typical exposure is seen on the opposite bank a little farther down stream (east). Here are 40 to 50 feet of stone covered by 20 to 30 feet of drift. The formation dips 45° to the north and is exposed for more than 100 yards along the river. The actual thickness of the sandstone layers is not revealed. The bulk of the rock is a soft, thin-bedded, greenish sandstone of extremely variable grain and composition (1229, 1230). Irregular lenticular masses of harder stone occur in less amount (1231). The soft stone is much too friable for our purposes, and the hard material would be suitable only for very rough construction. Economic extraction of the latter would be quite impossible.

The stone: No. 1229.—A soft, dirty greenish-yellow, rather coarse-grained sandstone. The constituent grains are of different minerals and the cement is calcareous.

No. 1230.—Finer in grain, more yellow and less speckled in appearance than No. 1229.

No. 1231.—A very hard, fine-grained sandstone of greyish colour and calcareous cement. The grey colour is not pleasing as it has a "dirty," yellowish cast.

Vicinity of Coal Spur, Alberta.

The following outcrops of Edmonton sandstone were observed along the line of railway in the vicinity of Coal Spur.

One mile north of Mine Head, bluish, soft sandstone with hard centres occur under coal seams in a cut. Useless.

Nearer Mine Head, south of the tunnel, nodular sandstones inter-stratified with shales occur under a heavy drift. Useless.

At mile 34½ are outcrops of coarse pebbly sandstone. Useless.

At mile 35⅛ occur outcrops of greyish-green shattered sandstones interlaminated with shales. The stone is pebbly in places and is beginning to show the hardening effect of earth movements. Useless.

At the river crossing north of Coal Spur are typical rusted greenish sandstones, deeply weathered from joint and bed planes, and presenting much hardhead. Useless.

North of Coal Spur station are ridges of greenish sandstone interstratified with hard shales. Some of these belts are 12 feet across and show layers of stone up to 2 feet thick. The beds dip at 70° and some of the thicker layers show hardhead centres. It would be possible to obtain rough building stone in quantity but there would be a large loss in thin material (1206).

South of the yard at Coal Spur is another exposure showing sandstones much interstratified with shales and coal seams. The sandstone layers are pebbly in places and much shattered but it would be possible to obtain some fairly thick stone resembling the blue variety from Entwistle. Regular quarrying could not be successfully carried on.

At mile 2½ south from Coal Spur is a cut in bluish sandstone showing fairly heavy beds in nearly horizontal position. The immediate overburden is not great, but it would rapidly increase if quarrying were attempted.

Near Beaver creek are exposures of a similar bluish sandstone, much fractured and interstratified with shale. Hardheads render this exposure impossible. From this point to mile 13, occasional outcrops of sandstone are seen. Excessive fracturing, thin-bedding, the presence of hardheads, and interbedding with shale seem to render all these exposures economically impossible for our purposes.

The stone: No. 1206.—A fine-grained, greyish-green sandstone with a tendency to weather more yellow. It is far softer than the Dakota sandstones and could be worked. The structure is fairly uniform but the stone splits easily parallel to the bedding. The cementing material is mostly clay but a little carbonate of lime is present.

Rocky Mountain House Area.

Canadian Northern Railway, Rocky Mountain House to Nordegg.

An excellent section of the Upper Cretaceous rocks is afforded by the valley of the Saskatchewan river along the northern side of which the above line of railway has been constructed. The sandstones doubtless belong chiefly to the Edmonton series but it is possible that some of the more westerly exposures are of Belly River age. The following brief notes will serve to indicate the possibilities of these rocks as producers of building stone.

At the crossing of the Saskatchewan river west of Rocky Mountain House are sandstones with much shale. Useless.

In a cut at mile 119 are sandstones under 50 feet of drift.[1]

The upper stone is thin-bedded and decomposed. The lower stone is more compact (1262) but with hard slaty streaks (1263). Not very promising.

At mile 131, high, vertical, scarped banks show on the river. Considerable sandstone is interbedded with the shales but it would be difficult to quarry.

East of mile 136, the railway passes through a rock cut about a half mile long showing 50 feet of sandstone and shale. Towards the east end the sandstones are thin, shattered and unpromising. Towards the west end the beds are heavier—in places as much as 3 or 4 feet thick (1264). Fifty feet of soft shaly sandstone and shale overlies the heavier beds making quarrying difficult or impossible. At mile 136 the cut is deeper into the heavy beds and shows them to be originally blue (1265). This stone is very soft and friable with pebbly streaks in places. The buff stone, No. 1264,

[1] Rocky Mountain House is at mile 118·8 from Warden. The miles are numbered westward.

is undoubtedly an alteration product of No. 1265: it is much harder than the original blue type of stone. The hand specimen shows a finer grain and could not have been derived from a stone of the same grain as the hand specimen, No. 1265.

At mile 139 are outcrops of thin-bedded stone. Useless.

At mile 142, a short distance east of Lamoral, a good section is seen extending several hundred feet down to the water level. The great preponderance of shales and the softness of the sandstone layers would not warrant any attempt at quarrying.

At mile 147, steep cut banks below the track show fairly heavy stone. On the opposite side of the river are exposures of heavy stone in horizontal beds under a moderate amount of drift. These beds are at a much lower level and present a face of about 10 or 12 feet in layers of 2 feet in thickness. The overburden is not more than 10 feet and would not greatly increase over a considerable area. I was unable to examine these beds at close range but from the railway they look more promising than most of the outcrops.

At mile 149 is a cut about a quarter mile in length showing the following section:—

20-25 ft.—Overburden of thin stone and drift.
2 ft.—Sandstone bed.
8 in.—Sandstone bed.
2 ft.—Sandstone bed.
2 ft.—Sandstone bed.
1 ft.— Shale.
2 ft.—Sandstone bed.
4 ft.—Shale.
2 ft.—Sandstone bed.
2 ft.—Sandstone bed, to rail.

The stone is fairly uniform and of a fine-grained type (1266). Although the formation is much shattered it would be possible to obtain building blocks but there would be a heavy waste.

At mile 151½, near Pollock, are exposures of thin stone in a greater amount of shale. Useless. Similar exposures occur at mile 152 where the strata are beginning to lose their horizontal position.

At mile 154, the lower stone is hard and siliceous (1067): it occurs in lenticular masses under a 4-foot bed of sandstone of a yellowish-green colour. This layer is much too soft to be of any use and it is covered by about 10 feet of soft, thin-bedded material.

At mile 156½, rather harder sandstone occurs in a heavy bed under an increasing amount of drift. The stone is irregularly bedded but almost horizontal in position. Although the rock is much shattered it would be possible to obtain some material for building purposes. This appears to be the most promising stone along the line of railway: it is described in detail below as No. 1268.

Edmonton sandstone. Cliffs on Canadian Northern railway between Rocky Mountain House and Nordegg, Alberta.

On the whole, it may reasonably be concluded that there is little hope for the production of building stone along this section. No place was observed where the quality of the stone and the structural features of the formation would justify the locating of a quarry. On the other hand, some reasonably heavy beds of sandstone occur: it is possible that prospecting might reveal localities at which quarrying could be done but it must be admitted that the outlook is not encouraging.

The stone: No. 1268.—A coarse, grey, somewhat friable sandstone, dark speckled by a profusion of black grains: it is only slightly reedy and resembles No. 1202 from Entwistle but is a much harder and more durable stone. The microscope shows quartz grains often more than ·5 mm. in diameter, opaque dirty feldspars of a like size, and numerous black opaque grains. The cement is abundant and does not react visibly for carbonate of lime.

The physical properties are as follows:—

Specific gravity	2·687
Weight per cubic foot, lbs	137·074
Pore space, per cent	18·4
Ratio of absorption, per cent, one hour	5·56
" " " two hours	6·11
" " " slow immersion	7·25
" " " in vacuo	8·25
" " " under pressure	8·39
Coefficient of saturation, per cent, one hour	0·66
" " " two hours	0·72
" " " slow immersion	0·86
" " " in vacuo	0·96
Crushing strength, lbs. per sq. in., dry	5,253·
" " " wet	2,943·
" " " wet after freezing	1,960·
Transverse strength, lbs. per sq. in	445·
Shearing strength, lbs. per sq. in	398·
Loss on corrosion, grams per sq. in	0·0194
Drilling factor, mm	23·2
Chiselling factor, grams	8·08 (II)

An analysis shows the total amount of cementing matter to be below the average of the Paskapoo sandstones. The carbonates are the lowest of any of the stones tested and the amount of carbonic acid is much below that required to convert the lime and magnesia into carbonates: it is probable, therefore, that the stone would harden on exposure. The cementing matter is essentially ferruginous and argillaceous as indicated by the relatively high percentage of ferric oxide and the considerable difference between the total soluble matter and the constituents determined.

The analysis by Turner follows:—

	Per cent
Insoluble residue	85·56
Soluble portion	14·44
Partial analysis of the soluble portion:	
Lime	1·14
Magnesia	0·68
Ferric oxide	3·28
Ferrous oxide	1·28
Carbonic acid	0·10
Total of soluble constituents determined	6·48

No. 1262.—A very fine-grained, soft, muddy, yellowish sandstone with a high clay content and a little lime. This type of stone is quite impossible for building.

No. 1263.—A hard, black, very fine-grained, fissile, slaty sandstone of no possible use.

No. 1264.—A light yellowish-grey, fine-grained sandstone with argillaceous cement. Black partings due to plant remains occur on the planes of stratification. As far as the hand specimen is concerned, this stone might be used for building. It is rather soft, however, but not more so than some of the Paskapoo sandstones actually used.

No. 1265.—A soft and coarse-grained bluish sandstone. A large number of the constituent particles are dark in colour giving the stone a speckled appearance. The cement is a whitish argillaceous material. The stone is probably too soft for structural purposes but it is not much softer than the blue stone from Monarch (No. 1360, page 196) which it resembles very closely except for the much coarser grain.

No. 1266.—This stone is fine in grain and yellowish-grey in colour. The structure is uniform.

No. 1267.—This is a hard indurated type of sandstone of a dirty yellowish-green colour; it resembles the greenish type of Dakota stone.

Highwood River Area.

Highwood river, Alberta.

Sandstones of the Edmonton formation cross the Highwood river on section 10, township 18, range 2 west of the fifth meridian. A rather prominent band striking due north and south, (mag.) has caused the river to follow the strike of the rocks for a distance of about a quarter mile. The sandstones of this belt dip 30-45° to the east: they are mostly thin-bedded, much decomposed, and interbanded with shale. The average stone is described as No. 1355. Harder layers occur in places: blocks of this type of stone might be gathered from the bed of the river and could be used in local foundations (1356).

The stone: No. 1355.—A yellowish-grey, fine-grained sandstone with calcareous cement. The colour is not pleasing but the stone is sufficiently coherent for structural purposes and not too hard to cut.

No. 1356.—This stone is a fine-grained bluish type very similar to the blue Monarch stone but a little harder and of better weathering properties: it is decidedly a good stone but the specimen was obtained from loose material in the river bed.

OTHER AREAS OF EDMONTON SANDSTONE.

Edmonton sandstones were examined in several other locations but nothing was observed of a more promising nature than in the localities already described. The following brief notes indicate the character of the formation in the two most important localities:—

Bow River valley.

Thin sandstones interstratified with shales occur in the valley of the Bow river from a little west of Cochrane almost to Kananaskis. The more easterly of these exposures are doubtless of Edmonton age while the more westerly belong to the Belly River series.

Old Man river.

Edmonton sandstones crop out along the Old Man river at many points to the east of Burmis. The layers are thin for the most part and much interstratified with shales. Some heavier bands occur which might furnish local stone, but the limited amount of heavy material would make serious quarrying practically impossible. The beds have a variable easterly dip with the upturned edges facing the mountains.

Sandstone of the Eocene System.

PASKAPOO FORMATION.

The Paskapoo formation, formerly regarded as the upper member of the "Laramie" occupies a wide belt in Alberta the extent of which has already been referred to in the chapter on general geology. With the exception of the mottled limestone from Tyndall, Manitoba, this formation yields the most important building stone of the three provinces. The product is a soft and easily worked sandstone which has been quarried at points on the Crowsnest line of the Canadian Pacific railway and at numerous places northward to the line of the Grand Trunk Pacific railway west of Edmonton. Many of the important buildings of Alberta have been constructed of this stone: a partial list of these structures is given on page 249.

Before proceeding to a general discussion of the stone it is advisable to indicate the location of the more important quarries. Following the practice adopted throughout these reports, the quarrying regions may be arranged, from south to north, in the following, more or less defined, geographical "areas," which are indicated on the accompanying map (Fig. 6.).

The areas are as follows:—

Monarch area on the Old Man river west of Monarch station on the Crowsnest line of the Canadian Pacific railway.

Macleod-Brocket area embracing quarries in the Porcupine hills west of Macleod, at Brocket on the Crowsnest line to the westward, and on Pincher creek still farther west.

High River area including abandoned quarries on Highwood river west of the town and a few scattered quarries to the east.

Sandstone area comprising a few unimportant quarries near the village of Sandstone on the Calgary-Macleod line of the Canadian Pacific railway.

Calgary area embracing the immediate vicinity of Calgary and the country northward to Beddington.

Glenbow-Cochrane area including quarries at Keith, Glenbow, and Cochrane on the main line of the Canadian Pacific railway west of Calgary.

Red Deer area with small and unimportant quarries at Red Deer, Didsbury, and Innisfail.

Entwistle area on the main line of the Grand Trunk Pacific railway west of Edmonton.

The marketable stone from the different quarries varies in grain and colour and in the degree to which reediness or a marked laminated structure is developed. On the basis of colour we may classify the product of the principal areas as follows:—

Blue Stone.

Monarch, Entwistle, Sandstone.

Very yellow stone.

Entwistle.

Yellow stone.

Calgary.

Buff stone.

Monarch.

Greyish yellow stone.

Glenbow-Cochrane, Red Deer, High River, Sandstone.

Grey stone with a slightly brown cast.

Macleod-Brocket.

In grain the stone varies so much in a single area or even in a single quarry that no general observations can be made. The coarsest type is the grey variety at Entwistle and the finest the stone from the Maclean and

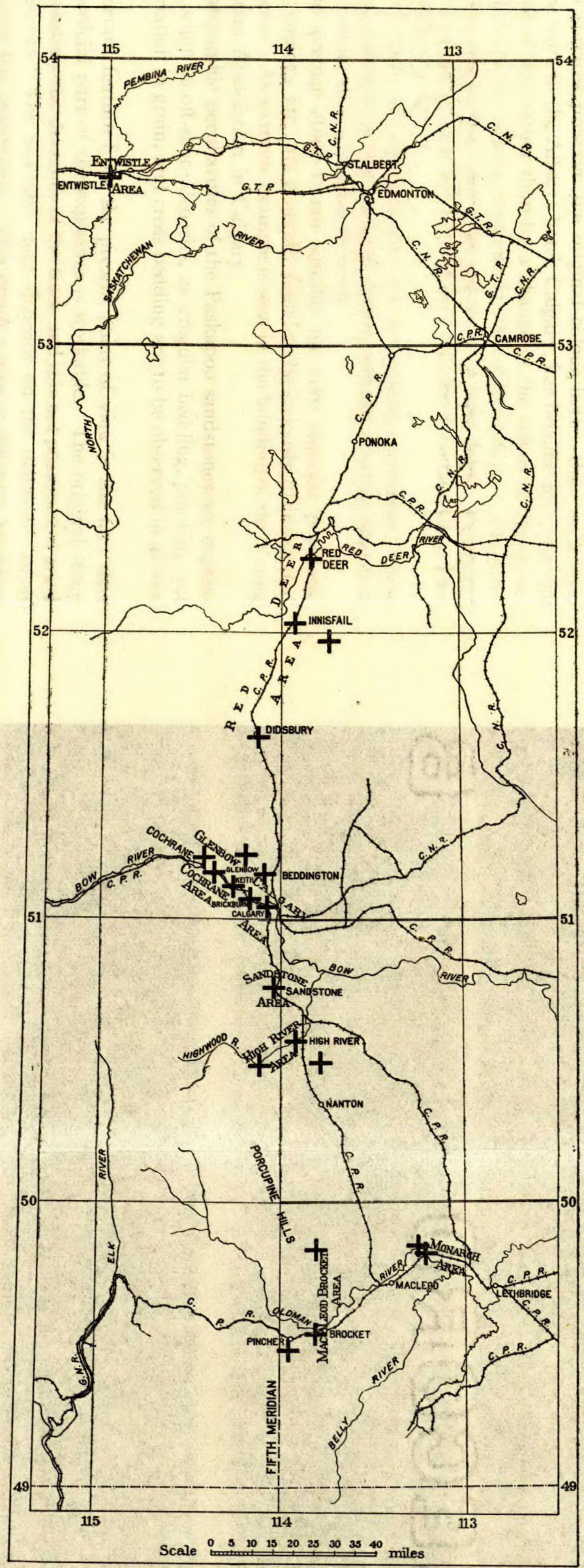


Fig. 6. Sketch map of part of Alberta, showing the quarry areas and the chief quarries in the Paskapoo sandstone.

Arnold quarries in the Monarch area. Observations on buildings bring out the following points of a general character:—

(1)—The stone should not be used for the lower courses of buildings where the injury from wetting and freezing is excessive. Striking instances of the deterioration the stone suffers under such conditions may be observed in the City Hall, the Cathedral of the Redeemer, and the building of the Young Men's Christian Association in Calgary.

(2)—The stone should never be laid up on edge as it is prone to exfoliation. A striking example may be observed in the Natural Resources building of the Canadian Pacific railway in Calgary.

(3)—The stone is bibulous and rapidly absorbs dirt. On this account, sand rubbed surfaces preserve the original colour better than rock face. The rock face work in the Alberta hotel, Calgary, has become grey through the imbibition of dirt rather than by a change in the colour of the stone. The McDougall block, Calgary, was built in 1905 of local stone. The lower courses became so grey that they were cleaned at a later date. The upper courses, however, and particularly the rubbed work, have retained the yellow colour to a better degree.

(4)—Mud spots or clay inclusions are of frequent occurrence: these are not conspicuous in rock face work but they constitute a serious objection to the use of certain stones for smooth finish.

(5)—The average stone is not suitable for very exposed positions. Small pillars, copings, etc., are generally found to be seriously disintegrated after a few years. An extreme example is seen in the building of the Young Men's Christian Association in Calgary.

The stratigraphic peculiarities of the Paskapoo sandstones are expressive of their origin as off-shore deposits, as irregular bedding, pinching out of layers, variation in grain, and cross bedding are to be observed in all the quarries.

An important feature from the present point of view is the fact that only the superficial part of the exposures is workable. The original stone is too hard to satisfy the demands of the trade and it is not possessed of good wearing properties. The workable zone depends on the depth to which surface oxidation has penetrated. This depth varies in different localities but it is never very great, and in consequence, neither deep or extended quarries can be expected. This failure of the quarries to supply unlimited material is an important factor bearing on the success of the industry. An exception to the above principle is seen in the case of the blue stone at Monarch which, although primary, is even softer than the buff stone which is the result of oxidation.

Speaking generally, the original Paskapoo sandstone consists, as to mineral grains, of about one-third quartz, one-third semi-decomposed feldspar, and one-third dark coloured indeterminable grains of a ferro-magnesian character. These components vary somewhat, and in consequence, there is a more or less defined "pepper and salt" effect according to the amount and clearness of definition of the darker grains. The original stone has a high content of lime carbonate in the cement: it is to this substance that the stone owes its hardness and it is to its solution and removal that the altered stone owes its softness and greater porosity.

Besides the normal unaltered stone and the softened secondary derivative, many quarries present a still harder type which occurs in limited layers or in the centres of natural blocks of the altered stone. This material is known as "hardhead" but the term is also applied to the normal unaltered stone, particularly in those quarries where "hardhead" proper is not conspicuous. I am of the opinion that this very hard material is the result of secondary concentration of carbonate of lime.

As already stated, the quarry at Monarch differs from all the others in that the original stone is softer than the secondary oxidized type. The quarries at Entwistle also differ from the majority in that the original stone is very soft although harder than the altered yellow variety.

It may be said, therefore, that we have three different types of alteration to consider:—

(1)—A soft blue stone altering to a harder buff stone—Monarch.

(2)—A soft blue stone altering to a still softer yellow stone—Entwistle.

(3)—A hard bluish to grey stone altering to a soft stone of grey, brownish-grey or yellow colour—all the remaining quarry areas of the Paskapoo sandstone.

A preliminary examination has been made in order to determine the process of alteration in these different cases. As a more detailed description is given under the various stones it will suffice to state here the general conclusions in each instance as follows:—

(1) Monarch.—The amount of cement increases with a consequent reduction of pore space. The original content of carbonate of lime is only slightly reduced and the loss is more than made up by the addition of argillaceous matter derived from the decay of the original mineral grains of the blue stone. It is quite to be expected that the altered stone would be harder than the original. (See page 197).

(2) Entwistle.—The alteration in this instance consists of a large removal of carbonate of lime by solution, a decomposition of some of the original mineral grains and a further removal of some of the results of this decomposition in the form of carbonates. There is little or no addition of argillaceous matter to the cement but there is a pronounced oxidizing effect with a consequent bright yellow colour owing to the presence of a considerable percentage of iron. This type of alteration is evidently one of excessive leaching and oxidation. (See page 246).

(3) Calgary, as indicative of the general type.—In this case there has been a partial removal of carbonate of lime in solution, also a conversion into carbonate of certain constituents of the original grains. Oxidizing effects are not pronounced. This type of alteration is evidently due to car-

bonation; it is to be expected that the Entwistle type would ensue were the flow of water through the stone more abundant. (See page 218).

A review of the general physical characteristics of the Paskapoo sandstones is best presented by a comparative table in which the averages of the different types of stone are placed side by side. In compiling the following statement of averages, only the better known stones of recognized commercial importance have been included as representative of the different types. In some cases the average is not very expressive as the variation is too great, *e.g.*, the two Cochrane stones in respect to hardness.

The types recognized and the stones used are as follows:—

I. The blue Monarch stone.
II. The buff Monarch stone.
III. The Calgary type, represented by the best stone from Oliver's quarry and the stone from Beddington.
IV. The Glenbow stone.
V. The Cochrane stone, represented by two examples from the Shelley Quarry Company.
VI. The Macleod-Brocket type represented by stone from the Porcupine hills and from the quarry of the Crowsnest Stone Company near Brocket.

An average of these nine best known commercial stones is given in column VII.

	I	II	III	IV	V	VI	VII
Specific gravity..	2·691	2·688	2·687	2·665	2·672	2·677	2·679
Weight per cubic foot, lbs.......	138·64	140·02	131·48	134·19	136·24	144·66	137·54
Pore space per cent..........	17·47	16·56	21·72	19·34	18·26	12·83	17·66
Coefficient of saturation.....	·71	·79	·69	·68	·72	·76	·72
Dry crushing strength, lbs. per sq. in......	7,092	6,796	5,985	7,631	9,617	11,119	8,306
Wet crushing strength, lbs. per sq. in......	3,963	4,708	3,874	5,640	7,007	7,224	5,613
Frozen crushing strength, lbs. per sq. in......	2,976	3,679	2,782	3,896	4,212	6,524	4,065
Transverse strength, lbs. per sq. in......	308	556	398	554	658	582	521
Shearing strength, lbs. per sq. in......	459	512	431	497	642	586	531
Loss on corrosion grams per sq. in.	·0223	·0255	·06746	·04301	·05031	·04194	·04558
Drilling factor, mm...........	21·4	....	25·2	21·0	26·6	17·8	22·7
Chiselling factor, grams.........	27·40 II	8·55 II	9·44 II	6·87 II	14·66 II	4·72 II	11·16 II

The general averages in column VII may be taken without comment as expressing the physical characteristics of the commercial Paskapoo sandstones.

The other columns indicate that the Glenbow, Cochrane, and Calgary stones are the most porous, that the Cochrane and Macleod-Brocket stones are the strongest, and that the blue Monarch stone is the most easily chiselled. The Macleod-Brocket stone suffers the least and the blue Monarch stone the most under the freezing test.

At the time of my examination of the Paskapoo sandstones, in the summer of 1915, no quarries were in actual operation: in consequence, most of the specimens were obtained from old dumps or from the exposed face. There can be no doubt that some departures from the figures herein given would be obtained by conducting the experiments on uniformly seasoned stone. Nearly all the Paskapoo sandstones harden somewhat on exposure, due to the conversion into carbonates of the lime and magnesia of the cement; this factor alone renders necessary the procuring of equally seasoned samples if closely comparative results are to be obtained.

The present state of inactivity in the industry is to be ascribed to various causes among which the more important are:—

1—The failure of the quarries with depth.

2—The variable nature of the stone and the presence of hardhead and mud holes.

3—The lack of confidence on the part of contractors in the ability of the operators to supply stone to order.

4—The competition of other stone, particularly Tyndall and Indiana limestone.

5—The high cost of quarrying due to the large amount of waste for which there is no market either as rubble or for use in macadam. The only stone a quarryman can dispose of is his best quality of soft building blocks.

6—The high wages demanded by stonecutters ($6 per day). Stone can be dressed in the big mills of Indiana at a cost which makes this figure almost prohibitive.

7—The refusal of contractors to accept any but the softest stone. This attitude is doubtless due to the high cost of stone-cutting. It is to be remembered that few commercially successful sandstones in other centres are as soft as the average Paskapoo stone.

8—The average stone, however optimistic we may desire to be, is not really a first class sandstone for monumental structures.

Monarch Area.

Macleod Quarrying and Contracting Co.; M. Freeman, president, 1266 Fourth Ave. S., Lethbridge, Alberta.

The quarries of this company are situated on the north bank of the Old Man river a short distance above the crossing of the Canadian Pacific railway about 5 miles west of Monarch station. The property consists of 86 acres, being part of section 17, township 10, range 24 west of the fourth meridian.

The quarry extends about 200 feet along the face of the escarpment facing the river and has been worked in to about the same distance, thereby exposing stone farther from the original face than is to be seen in most of the sandstone quarries of Alberta. The section is as follows:—

6-8 ft.—Soil and thin stone.

8-10 ft.—Thin-bedded stone (1359).

15 ft.—Shale and thin stone.

15 ft.—Building beds, 1 to 3 feet in thickness.

The major joints strike N.40°W., and are well defined at intervals of about 10 feet: they have been utilized for successive faces as the quarry has been advanced. Cross joints are infrequent, permitting the extraction of stone of any practicable size.

Three distinct types of stone are presented by this quarry and these types correspond in a general way with similar stones in other quarries of the formation. The first type (1360) is a soft bluish stone which constitutes the bulk of the lower building beds as now exposed. The second type is a soft buff-coloured stone (1361) which is evidently derived from the alteration of the blue stone as it occurs in the form of a zone, 5 or 6 inches in thickness, around the blocks of blue stone. In the earlier stages of operation this buff stone was more abundant, and it formed the bulk of the product when the quarry was first opened. As this variety is the result of the oxidation of the blue stone, it is apparent that it will diminish in amount as the quarry is extended farther from the zone of surface weathering. At the present time the amount of buff stone is too small to be utilized and it really is a drawback to the quarry as it must be sawn off the surface of the blue stone before the latter can be marketed. The third type of stone is the so-called hardhead which occurs in layers and lenticular masses to about 10 per cent of the lower building beds. This stone (1362) is very hard and compact and appears to be of secondary origin: it is of no use for building purposes. The soft nature of the unaltered blue stone is not in accord with the condition presented in most of the Paskapoo quarries where the unaltered stone is the harder.

The stone of the upper beds (1359) shows scarcely any of the soft blue type but the hardhead is of frequent occurrence, particularly towards the bottom. The general stone of these layers resembles the buff type of the lower beds but it is thin and fractured and is not commonly employed for building purposes.

The closing of this quarry, while in part due to the general falling off in demand, was occasioned chiefly by the heavy overburden of 30 feet or more. Experiments have proven that the overlying shales are suitable for the manufacture of a certain type of ornamental brick and in consequence a project is on foot to reorganize the company as the Rocky Coulée Stone and Brick Co., Limited, and to carry on operations for both shale and stone. It is to be hoped that this project meets with success as we have here the only sandstone quarry in Alberta which has been extended to any considerable distance from the natural face without encountering unmarketable material (Plate XXXVI).

The stone: No. 1360.—A medium or fine-grained sandstone with a distinctly blue colour (No. 5, Plate LV); it is much the bluest of all the Paskapoo sandstones tested and is approached only by the blue stone from Entwistle (No. 1203, page 245). Little reediness is seen in the specimen and the stone is almost devoid of a speckled appearance. The mineral grains are of quartz, feldspar, and an indeterminable, dark coloured, ferro-magnesian substance. Black mica is present sparingly and also glistening flakes of a silvery mica which is probably of secondary origin and is associated with the cement, which is abundant and amounts to about 24 per cent of the rock. The corrosion test rapidly destroys the blue colour and replaces it by a yellow tone. The freezing test results in considerable exfoliation and surface disintegration. Wetting causes a loss of half the crushing strength. The high chiselling factor is indicative of the softness of the stone but the figure recorded below is relatively too great as it includes the weight of very large side chips thrown out along the track of the chisel: the stone actually *cut* out is probably about 15 grams in weight.

The physical properties are as follows:—

Specific gravity	2·691
Weight per cubic foot, lbs	138·64
Pore space, per cent	17·47
Ratio of absorption, per cent, one hour	3·13
" " " " " two hours	3·53
" " " " " slow immersion	5·59
" " " " " in vacuo	7·86
" " " " " under pressure	7·86
Coefficient of saturation, per cent, one hour	0·39
" " " " " two hours	0·44
" " " " " slow immersion	0·71
" " " " " in vacuo	1·0
Crushing strength, lbs. per sq. in., dry	7,092·
" " " " " wet	3,963·
" " " " " wet after freezing	2,976·
Transverse strength, lbs. per sq. in	308·
Shearing strength, lbs. per sq. in	0·459
Loss on corrosion, grams per sq. in	0·0223
Drilling factor, mm	21·4
Chiselling factor, grams	27·40 II

Paskapoo sandstone. Lifting a block in the quarry of the Macleod Quarrying and Contracting Company, Monarch, Alberta.

As this blue stone undoubtedly represents the original material from which the buff stone, No. 1361, was derived, a comparison of the analyses of the two varieties is important. Before making such a comparison, it is well to have the two analyses before us, as follows:—

	No. 1360 Per cent	No. 1361 Per cent
Insoluble residue	76·42	70·38
Soluble portion	23·58	29·62
Partial analysis of soluble portion:		
Lime	6·24	9·48
Magnesia	3·07	4·05
Ferric oxide	1·28	1·50
Ferrous oxide	2·04	1·21
Carbonic acid	6·33	5·08
Total soluble constituents determined:	18·96	21·32

In the first place it must be remembered that stone is too variable a substance to justify the conclusion that these two examples were originally exactly the same, *i.e.*, that they contained the same relative amounts of grains and cement. Assuming, however, that this was the case we observe that the altered stone, No. 1361, contains a greater amount of cement than the unaltered stone, No. 1360; this is not in accord with the observations in any other instance with the Paskapoo sandstones. It is to be noted also that the difference between the combined determined constituents and the total soluble portion is greater in the altered stone—8·30% as compared with 4·62% in the unaltered stone. The increase in the cement is due, therefore, largely to the addition of lime, magnesia and clayey matter. Before instituting a comparison between the determined constituents of the two cements, they must be expressed as percentages of the total amount of cement present in each instance, as follows:—

	No. 1360 Per cent	No. 1361 Per cent
Lime	26·4	32·0
Magnesia	13·0	13·6
Ferric oxide	5·5	5·0
Ferrous oxide	8·6	4·1
Carbonic acid	26·8	17·1
Alumina water, etc., etc	19·6	28·0
	99·9	99·8

The changes in the actual chemical composition of the cement are indicated in this table and may be summarized thus:—

1—A slight decrease of ferric oxide.

2—A marked decrease of ferrous oxide.

3—A pronounced decrease of carbonic acid.

4—A heavy increase of aluminous material, indicating an increase of clayey matter.

5—A slight increase of magnesia.

6—A heavy increase of lime despite the decrease of carbonic acid.

A third and more satisfactory means of comparison, which is particularly useful in tracing the changes which the cement undergoes, is to express the determined constituents as pounds per cubic foot of the stone. This gives a direct means of comparing the cement in a fixed volume of stone, obviates any error due to pore space, and is not dependent on a knowledge of the total amount of cement. The table follows:—

	Lbs. per cubic foot.	
	No. 1360	No. 1361
Lime	8·63	13·27
Magnesia	4·25	5·67
Ferric oxide	1·77	2·1
Ferrous oxide	2·82	1·69
Carbonic acid	8·77	7·11
Alumina, etc.	6·404	11·62

This table illustrates in the clearest manner the addition of a large amount of lime, magnesia and aluminous matter to the cement of the original stone, the slight solution of carbonates, and the oxidation of part of the ferrous oxide.

The striking features of the alteration of No. 1360 into No. 1361 are:—

(1)—An actual increase in cement with a reduction of pore space.

(2)—A slight solution of the original carbonates.

(3)—A partial oxidation of the ferrous oxide.

(4)—A considerable decay in the ferro-magnesian constituents of the original grains whereby much lime and aluminous matter, and a less amount of magnesia and iron are added to the cement.

A comparison of the course of alteration in this instance with the changes that occur in the Calgary and the Entwistle stones indicates that essential differences are presented by the three examples. (See pages 218 and 246).

No. 1361.—A fine to medium grained sandstone of a buff colour (No. 6, Plate LV); it is not as yellow as the typical Calgary stone (No. 1285, page 217) but presents rather a greyish-yellow tint. The colour is uniform with little reediness apparent but with glistening spots due to the presence of flakes of white mica. The quartz grains which constitute about a third of the rock do not commonly exceed ·3 mm. in diameter. Other grains, feldspar and the usual dark decomposed mineral, occur in abundance and fade imperceptibly into the cement; glistening white mica also occurs in appreciable amount. In places the mineral grains seem to be closely apposed and are stained reddish on their margins. In other places, the decomposition of the feldspar seems further advanced so that more cement is apparent. The stone closely resembles No. 1285 from Calgary: it is a slightly "cleaner" stone, however, and may be distinguished by the reddish stains not observed in the Calgary stone. This stone is less porous and much stronger and harder than the blue variety.

The physical properties are as follows:—

Specific gravity	2·688
Weight per cubic foot, lbs	140·02
Pore space, per cent	16·56
Ratio of absorption, per cent, one hour	3·72
" " " two hours	4·14
" " " slow immersion	5·87
" " " in vacuo	7·26
" " " under pressure	7·36
Coefficient of saturation, per cent, one hour	0·5
" " " two hours	0·56
" " " slow immersion	0·79
" " " in vacuo	0·98
Crushing strength, lbs. per sq. in., dry	6,796·
" " " wet	3,993·
" " " wet after freezing	3,679·
Transverse strength, lbs. per sq. in	556·
Shearing strength, lbs. per sq. in	512·
Loss on corrosion, grams per sq. in	0·0255
Drilling factor, mm	......
Chiselling factor, grams	8·55 II

For analysis and discussion of chemical properties, see under the blue Monarch stone, No. 1360, page 197.

No. 1359.—This stone is very like No. 1361 but it is slightly more grey and less yellow and a little softer.

No. 1362.—In colour and grain this stone is very like No. 1360 but it is much harder and has much more lime in the cementing material.

The equipment of the quarry is as follows—

2 15-ton derricks with steam hoists and separate boilers.
2 hand loading derricks.
1 60 h.p. engine and boiler.
2 single pitman gang saws (Patch).
1 planer (Patch).
Pump, track, cars and accessories.

The gang saws are said to have an efficiency of 8 inches per hour working with 7 or 8 blades on blocks 10 feet long.

A mill, 45 by 60 feet, and several other buildings are on the property, which is connected by a siding with the Canadian Pacific railway.

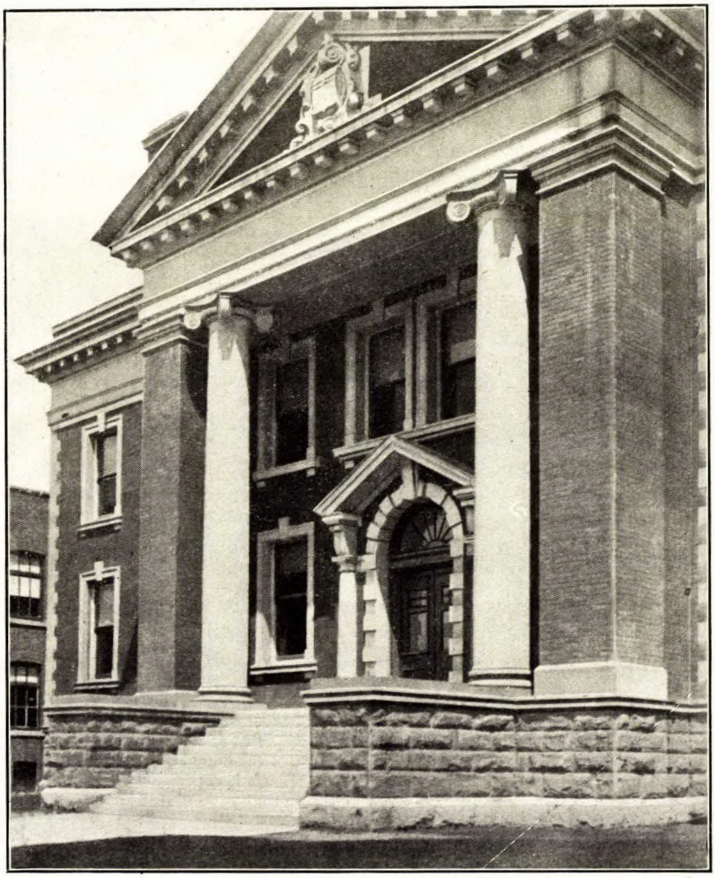
The buff stone is no longer available in quantity and the blue variety is off the market unless the reorganization referred to above is effected, nevertheless, the following prices are quoted, all f.o.b. quarry siding:—

Mill blocks, guaranteed all soft stone—65 cents per cubic foot.
Mill blocks less perfect—special lower prices.
Coursing, rock face, bedded and jointed, 6 to 8 in. on bed—75 cents per lineal foot.
Sills, 2 brick, sawn top and bottom—$1 per lineal foot.
Dimension stone, rough—75 cents per cubic foot.
The total production from this quarry is given below:—
1911—18,000 cu. ft. buff and blue stone.
1912—30,000 cu. ft. cut blue; 3,000 cu. ft. cut buff; 16,000 cu. ft. blue and buff coursing.
1913—2,500 cu. ft. blue stone.

In 1911 and 1912, 60 men were employed on an average with a pay roll of $4,000 per month for eight months in the year.

The most important structure built of the blue stone from this quarry is the building of the Department of Natural Resources of the Canadian Pacific Railway Company in Calgary. The basement is laid up in rock face coursing which has retained the bluish-grey colour very well, a slight tendency to yellow weathering being observed in much exposed places only. The stone is harder than when fresh quarried and can scarcely be abraded by the thumb nail. The rest of the building is of sand rubbed finish which, as usual with the Alberta sandstones, is less satisfactory than the rock face. Some variation in the colour of different blocks is to be observed and this type of finish emphasizes the cross bedding of others. Small cavities which have been filled with cement are quite numerous and detract much from the appearance of the building. I am unable to state with certainty to what extent these blemishes represent original mud holes and to what extent they may be due to abrasions occasioned in handling the dressed stone. Unfortunately a number of blocks have been laid up on edge resulting in an inevitable exfoliation. The darker colour of this building as compared with the other stone structures in Calgary is striking.

The blue stone may also be seen in the Molson bank and Wesley Methodist church in Lethbridge and in the Canadian Pacific Railway station at Claresholm. The stone in the bank is sand finished and shows reediness, some mud holes, and spots of buff stone which had not been completely sawn off. The church presents a more uniform appearance but some of the stone in exposed positions is turning slightly yellow. The Claresholm station can not be regarded as a good example: I am informed that it was built partly of blue Monarch stone, partly of Cochrane stone, and partly



Paskapoo sandstone, Macleod Quarrying and Contracting Company's quarry. Court house, Lethbridge, Alberta.

of the stone taken from the old station at Calgary which I believe was quarried at the Elbow.

The buff stone may be seen in the base and trimmings of the public school at High River (the door is of blue Monarch), in the trimmings of the Lethbridge brewery, in the Bank of Montreal, Lethbridge, and in the Court House, Lethbridge. This last building is of brick with the basement and trimmings of buff Monarch, and the pillars at the door of blue Monarch. The rock face basement is a good uniform buff colour and the cut work of buff stone shows little signs of deterioration. The pillars are less satisfactory as they show both buff and blue colours and some mud holes (Plate XXXVII).

Stone from this quarry was used in Assiniboia hall, University of Alberta, Edmonton, and also in some business blocks in that city. Several buildings in Macleod, *e.g.*, Leather, Anderton, Struthers, and Bryan blocks are said to have been constructed of stone from this locality. These buildings show several types of buff, blue, and greyish stone, with an unfortunate amount of admixture. Hard blue cores are seen in some instances: the yellow weathering of these has not added to the appearance of the buildings.

Mrs. Arnold, Staunton, Alberta.

Stone is exposed in both banks of the Old Man river for at least two miles above the quarries of the Macleod Quarrying and Contracting Company, but the outcrops are mostly thin and interbedded with so much shale that little prospect of successful quarrying is presented to the eastward of the present property—the northwest quarter of section 30, township 10, range 24 west of the fourth meridian.

At this point a coulée enters the river valley and stone is exposed on the river front and on both sides of the coulée. At the mouth of the ravine the sandstone is about 10 feet thick under a slight stripping; ascending the coulée the layers increase to at least 30 feet in thickness but with a corresponding increase in overburden. The stone, for the most part, is heavy bedded and is cut by rectangular joints at reasonable intervals. A large amount of accessible material is doubtless available. All the stone is soft and friable with a muddy appearance; also there are many clay holes and stained vertical streaks. The quality of the stone, rather than formational difficulties, is the chief point to be considered in any attempt to work this property. The long haul to the railway is at present a deterrent factor and no quarrying has been done beyond the winning of a few blocks for local use. With the completion of the new line of the Canadian Northern railway, a siding will be located within 6 miles. The stone is described in detail below as No. 1363: this description will apply equally well to the stone from across the river on the property of Duncan Maclean.

The stone: No. 1363.—This stone is the finest in grain and the lightest in colour of any of the Paskapoo sandstones tested: it has a light greyish-buff tint and a muddy appearance. It is difficult to obtain pieces free from mud holes and flaws but only surface material is available. The microscope shows quartz grains of about ·1 mm. in diameter making up a fourth of the rock. The rest seems to be composed of other mineral fragments of a similar size and grains of still smaller dimensions. Uncrystallized cementing material is not so evident as in many of these sandstones. The high coefficient of saturation indicates a danger of injury by frost. The corrosion test produces little change but the angles of the test cube crumbled under the freezing test. While the stone is very soft, the chiselling factor is possibly too high as side chipping has greatly increased it. The modified chiselling test (II) is still too severe to give very satisfactory results with extremely soft stones.

The physical properties are as follows:—

Specific gravity	2·713	
Weight per cubic foot, lbs	142·213	
Pore space, per cent	16·03	
Ratio of absorption, per cent, one hour	4·95	
" " " two hours	5·0	
" " " slow immersion	6·107	
" " " in vacuo	6·97	
" " " under pressure	7·0	
Coefficient of saturation, per cent, one hour	0·7	
" " " two hours	0·71	
" " " slow immersion	0·87	
" " " in vacuo	0·99	
Crushing strength, lbs. per sq. in., dry	7,470·	
" " " wet	5,427·	
" " " wet after freezing	4,912·	
Transverse strength, lbs. per sq. in	468·	
Shearing strength, lbs. per sq. in	334·	
Loss on corrosion, grams per sq. in	0·03928	
Drilling factor, mm	27·	
Chiselling factor, grams	19·26	II

The analysis of this stone shows that it is remarkably similar to the buff stone from the quarries of the Macleod Quarrying and Contracting Co. In the amount and character of the cement there is scarcely any difference except a higher content of carbonates and a lower content of clayey matter. The general appearance of the stone would not lead to this conclusion as the very fine grain suggests a more muddy base.

The analysis by Turner follows:—

	Per cent
Insoluble residue	70·42
Soluble portion	29·58
Partial analysis of the soluble portion:	
Lime	9·90
Magnesia	4·50
Ferric oxide	1·07
Ferrous oxide	1·34
Carbonic acid	10·79
Total of constituents determined	27·60

Duncan Maclean, Staunton, Alberta.

This property, the southwest quarter of section 30, township 10, range 24 west of the fourth meridian, lies on the opposite side of the river from that of Mrs. Arnold.

The cliff is about 30 feet high at the southeast end, and 16 feet high at the northwest end of the exposure; it is covered by soil to a depth of 10 feet, and, 100 yards in from the brink, it shows a second exposure of stone about 4 feet thick. All the upper stone appears to be thin but the lower layers along the shore are heavily bedded and have been quarried to a small extent. The stone is essentially the same as No. 1363 described on page 202.

Mr. Maclean quotes the following prices:—

Quarry blocks, rough—60 cents per cu. ft. at quarry; 70 cents per cu. ft., f.o.b. Pearce.

Coursing, rock face, bedded and jointed, 6 in. on base—90 cents per lineal ft.

Sills, 2 brick, rock face, bedded—$1 per lineal ft.

Stone from this quarry was used in the power house and in the new part of Macdonell's block in Macleod. The latter building, erected in 1912, shows a much lighter and more yellowish colour than most of the stone buildings in Macleod. The rock face work is of fair appearance but the surface is rather soft. The cut work shows many mud holes and lines and streaks of varying colour. The mullions in the Hudson Bay Company's building in Macleod are of this stone.

MACLEOD-BROCKET AREA.

This area includes quarries in the Porcupine hills near Macleod, a quarry on Pincher creek near Brocket, and others farther west on the creek and in neighbouring buttes. The sandstones occur near the base of the Eocene system and were formerly ascribed to the St. Mary River series but they are now generally regarded as belonging to the Paskapoo. Outcrops occur along the base of the Porcupine hills, in the valley of the Old Man river, and in a number of lateral ravines, particularly that of Pincher creek, also at higher levels in the sides of a number of little buttes.

Stone was formerly quarried from the Porcupine hills for the erection of buildings in Macleod, and also in the vicinity of Pincher creek about $2\frac{1}{2}$ miles south of Pincher station. Small buttes in the vicinity of Pincher yielded a certain amount of stone and more recently the quarry of the Crowsnest Stone Company has been opened on Pincher creek about a mile west of Brocket.

The stone from this area is rather characteristic in its slightly brownish colour wherein it differs from the blue, buff, and yellow types of the other areas of Paskapoo sandstone. The weathering properties of the stone are excellent and it ranks among the best of the Alberta sandstones.

Porcupine hills, near Macleod, Alberta.

Sandstones are exposed for a distance of at least two miles along the southeast aspect of the Porcupine hills to the westward of Macleod. The face of the foothill runs nearly north and south presenting numerous exposures at which stone might be obtained under a very slight amount of drift.

Quarrying has been done at one point only with the production of a very limited amount of stone. The face of the most northerly excavation shows an upper 10 feet of thin stone and a lower 10 feet of heavier material. in beds up to 4 feet in thickness. The main joints are wavy and irregular in a north and south direction, *i.e.*, parallel to the face. Cross joints of a formational character are infrequent but individual beds are cut by irregular partings at more frequent intervals. The stone of the external weathered zone presents a uniform greyish colour (1357), but, although the excavation is extremely shallow, blue cores are already showing in the lower layers (1358).

A second opening, immediately south of the above, shows 12 feet of sandstone in one solid bed with some thinner material above. The jointing is the same as in the first opening but it would be possible to obtain very large stone here—up to 20 feet in length. The weathered stone is of the greyish type, but although the amount removed is insignificant, blue centres are already appearing in the lower stone. Local mud holes were observed at certain levels at this point.

Still farther south are exposures of 30 feet or more of stone presenting different detailed sections at different points.

There is no doubt that this locality presents heavy beds of stone in large amount and in accessible position. It is also certain that the grey type of stone is a very desirable building material. On the other hand, the zone of oxidation seems to be very shallow, and in consequence, the outcrops could be exploited profitably only by a series of small quarries along the hillside. The haul to the rail is about 7 miles.

The stone: No. 1357.—This specimen represents a fair average of the more desirable stone. The colour is distinctly grey with a slight brownish cast and is shown in No. 2, Plate LVI. The permanence of colour is remarkable as no perceptible difference was noted between the fresh sample and the stone which has been exposed for 12 years in the walls of the Queens hotel in Macleod. This stone strongly resembles and is to be classified with the Brocket stone described as No. 1388 on page 208.

Under the microscope about one-third of the stone is seen to be made up of quartz fragments of 0·3 mm. or less in diameter. The abundant cement is very "dirty" and clouded and shows a large amount of secondary iron oxide, and evidence of recrystallization. No effect is produced by the corrosion test and but little disintegration resulted under the freezing test.

This stone is softer and more easily abraded than No. 1388 and has a greater pore space: its drilling factor is proportionally higher but the low chiselling factor requires verification.

The physical properties are as follows:—

Specific gravity	2·672
Weight per cubic foot, lbs.	143·76
Pore space, per cent	13·81
Ratio of absorption, per cent, one hour	3·96
" " " " " two hours	4·05
" " " " " slow immersion	4·68
" " " " " in vacuo	5·98
" " " " " under pressure	6·00
Coefficient of saturation, per cent, one hour	0·66
" " " " " two hours	0·67
" " " " " slow immersion	0·78
" " " " " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	9,841·
" " " " wet	5,803·
" " " " wet after freezing	4,985·
Transverse strength, lbs. per sq. in.	501·
Shearing strength, lbs. per sq. in.	491·
Loss on corrosion, grams per sq. in.	0·03565
Drilling factor, mm.	20·
Chiselling factor, grams	2·0 II(?)

The analysis of this stone shows that it is comparable with the stone from Brocket which it resembles in general appearance and in physical properties. The present example, however, has considerably less cementing material, particularly the carbonates, but it is much higher in ferric oxide.

The analysis by Turner follows:—

	Per cent
Insoluble residue	74·72
Soluble portion	25·28
Partial analysis of the soluble portion:	
Lime	9·52
Magnesia	2·22
Ferric oxide	3·00
Ferrous oxide	0·51
Carbonic acid	8·30
Total of constituents determined	23·55

No. 1358.—This specimen represents the great bulk of the stone of the locality. At all points observed it occurs wherever a very moderate amount of the superficial grey altered stone has been removed. The tendency of this stone to weather to the grey type is not strong as the surfaces exposed by quarrying operations have scarcely lost the characteristic blue colour as the consequence of 10 years exposure to the weather. This fact will tend to explain the limited depth to which oxidation has extended in the natural exposures. The stone is considerably harder and more bluish than No. 1357: it effervesces more freely with acids indicating a greater content of carbonate of lime. Under the miscroscope about one-third of the stone is made up of quartz fragments averaging about 0·3 mm. in diameter. Other fragments of about the same size are numerous but so excessively altered that they are not to be clearly differentiated from the cementing matter which shows secondary calcite and considerable iron oxide. The section is much "cleaner" than that of No. 1357.

The Queens hotel in Macleod was built of the grey stone in 1903. The walls are laid up in good uniform 14-inch rock face coursing which has preserved its original colour remarkably well. In very exposed positions only has a slight yellow colouration appeared. Some mud holes are apparent but they are small and confined to a few blocks. Cut work standing in vertical position is still sharp but in horizontal position it shows a superficial disintegration. The surface of the stone can scarcely be abraded by the thumb nail even on sharp points of the rock face and in no place was any evidence of powdering observed. The general appearance of the building is very satisfactory as it lacks the variation in colour of different blocks which is a feature not uncommon in many buildings constructed of Paskapoo sandstone.

The Pioneer furniture store is another example of this stone which illustrates its remarkable durability of colour and its susceptibility to fine carving. Sills over 8 feet in length were observed.

Paskapoo sandstone, Crowsnest Stone Company's quarry. Royal Bank, Medicine Hat, Alberta.

Rock cut on railway west of Brocket, Alberta.

The general character of the higher parts of the formation as exposed in the various buttes is well indicated by a rock cut west of Brocket station. Here a face of 20 feet is presented with thin stone showing in the upper half, and heavier material—up to 3 feet in places—in the lower half. The strata are very irregular and false bedding is much in evidence. In the valley of Pincher creek just beyond, this section is extended downwards 30 feet or more. A sample of the heavy beds is described below as No. 1387. In the natural exposure this stone weathers grey with a cast of yellow.

The stone: No. 1387.—This stone is very like No. 1388 (page 208) but it is slightly more blue in colour and somewhat harder: it resembles the upper beds in the quarry of the Crowsnest Stone Co.

Pincher, Alberta.

The locality south of Pincher was not visited but the stone may be examined in the Hudson Bay Company's building in Macleod and in the Reach block in the same place. The former building resembles the Queen's hotel, which is of Porcupine Hill stone: it is, however, of a rather darker colour. The building shows heavy coursing and large base stones of good uniform grey colour. The cut work is well preserved and the surface of the stone is reasonably hard. The stone in the Reach block which was erected in 1907 shows a brownish tint not seen in other buildings in Macleod: it resembles the stone in the Hudson Bay Company's building, but it is softer, browner, and rather more reedy.

Crowsnest Stone Co., Limited; Dr. De Veber, president; Wm. Oliver, manager, 606 Fifth Ave. S., Lethbridge, Alberta.

The property of this company is situated west of Brocket and consists of 43 acres in the southeast quarter of section 12, township 7, range 29 west of the fourth meridian. The scarped bank of Pincher creek presents a section of more than 100 feet in all: of this the upper 60 feet is drift or thin stone beneath which occur about 22 feet of sandstone in heavy beds. The lower 50 feet is more or less covered by talus but probably consists of fairly heavy sandstones. Above the heavy sandstone layers the bank is sloping and in consequence the 60 feet of overlying material is not to be regarded as an immediate overburden: in fact, a very large amount of stone could be quarried before the stripping would become heavy.

The quarry proper which is opened on the face of the cliff in the heavy beds shows the following section:—

17 ft.—Shale and sandstone, the latter sometimes fairly thick. Not quarried (included in the upper 60 feet).
2 ft.—Hard bed of sandstone. Not used.
20 ft.—Practically one solid bed of sandstone (1388).

All the stone quarried has been obtained from the lower bed which has been opened for a distance of about 200 feet. Taken as a whole, this bed seems to be a single layer but locally it is divided by horizontal partings or even by the development of narrow thin-bedded bands. Few mud holes were observed but the reediness is developed to a varying degree. Blue hardhead is associated with some of the thin bands and occurs also in a decidedly secondary manner in other parts of the face. As the quarry is yet very shallow it is well to bear in mind that the amount of this objectionable material is liable to increase. At the northeast end of the opening where most work has been done the main joints strike N.15°E. nearly vertical. As these joints are wide spaced and as cross joints are practically absent it is possible to quarry blocks of great size. At the southwest end of the quarry some joints were observed striking N.40°E. and dipping 75° to the southeast.

The stone: No. 1388.—The stone exposed in the face of the heavy bed and in the blocks lying in the quarry is remarkably uniform in colour (No 1, Plate LVI) and shows variation only in the degree to which reedy structure is developed and in the occasional occurrence of vegetable matter on the planes of stratification. The sample is a good general average of the product of the quarry; it is fine to medium in grain and grey in colour with a slight brownish cast and with a clean "peppery" appearance. This stone closely resembles that from the Porcupine hills described as No. 1357. The microscopic sections of these two stones are very much alike but the present example is a little finer, as the quartz grains are about ·25 mm. in diameter. The other mineral grains, probably feldspar, are fresher than in No. 1357 and can be differentiated from the brown cloudy cement with greater ease. The stone seems to be harder than No. 1357 but the chiselling factor is higher. Corrosion causes a slight darkening of the colour and the freezing test has but little effect.

The physical properties are as follows:—

Specific gravity	2·682
Weight per cubic foot, lbs	147·57
Pore space, per cent	11·86
Ratio of absorption, per cent, one hour	3·02
" " " " " two hours	3·25
" " " " " slow immersion	3·72
" " " " " in vacuo	5·00
" " " " " under pressure	5·02
Coefficient of saturation, one hour	0·6
" " " two hours	0·64
" " " slow immersion	0·74
" " " in vacuo	0·99

Crushing strength, lbs. per sq. in., dry	12,397·
" " " " " wet	8,646·
" " " " " wet after freezing	8,064·
Transverse strength, lbs. per sq. in.	663·
Shearing strength, lbs. per sq. in.	682·
Loss on corrosion, grams per sq. in.	0·0482
Drilling factor, mm.	9·6
Chiselling factor, grams	7·45 II

The analysis shows that the amount of cement is fairly high in this stone and that the cementing matter is very largely carbonate of lime. The analysis follows:—

	Per cent
Insoluble residue	64·38
Soluble portion	35·62
Partial analysis of the soluble portion:	
Lime	14·74
Magnesia	3·13
Ferric oxide	1·07
Ferrous oxide	0·96
Carbonic acid	13·57
Total constituents determined	33·47

The property is connected with the Crowsnest line of the Canadian Pacific railway by a spur about a half mile long. A mill building, 60 by 45 feet, a cutting shed, 60 by 25 feet, and several small buildings have been erected.

The equipment is as follows:—

Mill.

1 45 h.p. engine by the Struthers Wells Co., Warren, Pa.
1 engine (New Ball).
2 single pitman gang saws with an efficiency of 3 to 3½ inches per hour with 5 or 6 blades on stone 6 feet long.
1 Frenier sand pump.

Quarry.

1 derrick of 10 tons capacity with steam hoist.
1 loading derrick of 10 tons capacity operated by a friction hoist in the mill.
1 Ingersoll-Rand drill.
1 rigid head channeller.
Inclined track and cars. The cars are hauled up the incline by a steam hoist in the mill.

The large derrick is erected on the hillside at about the level of the 2-foot hard bed. The track extends along the face of the hill providing an easy means of transferring the blocks to the gang cars.

About 9,000 cu. ft. of stone have been shipped and 4,000 cu. ft. of marketable quarry blocks are on the ground. The quarry is now idle but 30 men were at one time employed. Mr. Oliver has kindly furnished the following quotations:—

Rubble—$3.50 a cord, f.o.b. quarry siding.

Coursing, rock face, 12 in., bedded and jointed, 6 to 8 in. on bed—90 cents per lineal ft., f.o.b. quarry siding.

Quarry blocks, rough—40-50 cents per cubic ft., f.o.b. quarry siding.

Dimension stone, sawn two sides—65 cents per cu. ft., f.o.b.

Dimension stone, sawn four sides—90 cents per cu. ft., f.o.b.

Sills, 2 brick, rock face, sawn top and bottom—$1.25 per lineal ft., f.o.b. quarry siding.

Freight to Calgary—15½ cents per cu. ft.

Practically all the output of this quarry was used in the construction of the buildings of the Royal bank in Lacombe and in Medicine Hat. The latter building is of brick with a granite base, the trimmings only being of Brocket stone. All the sandstone is rubbed or cut and it presents a remarkably uniform pleasing grey colour with the slightest cast of green. I was particularly impressed with the "liveliness" of the colour which is in favourable contrast with most of the grey sandstones of Alberta. The cut work has retained its sharp edges and the surface of the stone can scarcely be abraded with the thumb nail. Evidence of reediness and cross bedding in some few blocks is the only unfavourable criticism I would offer. No mud holes were observed nor any deterioration in colour except a very slight tendency to yellow which has developed on exposed horizontal surfaces. On the whole, I consider this building as proof that the Brocket stone ranks very high among the sandstones of Alberta (Plate XXXVIII).

High River Area.

Wm. Brazier, High River, Alberta.

On both sides of the Highwood river about a mile below the main forks are banks of sandstone extending to a height of about 50 feet and covered with a variable amount of drift. The exposures extend for a half mile or more, and, in a general way, show both thick and thin-bedded stone. There is no doubt that at several points reasonably heavy stone could be quarried in quantity. Freshly scarped exposures show a bluish type of stone (1352) which probably represents the original rock. Weathered surfaces and blocks are of grey colour (1353): this altered stone is more desirable but it would appear that the zone of oxidation is not deep.

A small amount of quarrying was done at a point on the south side of the river about a mile below the forks. Here a cliff of 50 feet shows fairly heavy stone in lenticular beds with pronounced cross bedding. The grain is rather finer than the average and no blue material is seen on the face but it is impossible to state how soon it might be encountered if serious quarrying were attempted (1354). Above this point the banks are lower and shale is the predominating rock to the forks.

There is little doubt that a considerable quantity of desirable stone could be procured in this locality: the long haul to the railway and the probability that the zone of oxidation is not deep are considerations to be carefully kept in mind by a prospective operator.

The stone: No. 1354.—A medium-grained, uniform, greyish sandstone with a slightly yellowish-green cast and with little evidence of reediness: it is very similar in colour but slightly finer in grain than the buff stone from the quarries at Monarch (No. 1361, page 198). Under the microscope the quartz grains average about ·2 mm. in diameter. Cloudy grains of altered feldspar can be made out and there are less opaque black grains than in many of these stones. The usual brownish and muddy cementing matter is present and it reacts strongly for carbonate of lime. Corrosion changes the slightly greenish tone to a more pronounced yellowish-grey. Freezing produces considerable disintegration.

The physical properties are as follows:—

Specific gravity	2·683
Weight per cubic foot, lbs	139·0
Pore space, per cent	17·01
Ratio of absorption, per cent, one hour	5·02
" " " two hours	5·09
" " " slow immersion	5·97
" " " in vacuo	7·60
" " " under pressure	7·64
Coefficient of saturation, one hour	0·65
" " two hours	0·66
" " slow immersion	0·78
" " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	7,964·
" " " wet	5,324·
" " " wet after freezing	3,337·
Transverse strength, lbs. per sq. in	478·
Shearing strength, lbs. per sq. in	295·
Loss on corrosion, grams per sq. in	0·06892
Drilling factor, mm	14·
Chiselling factor, grams	4·95 II

No. 1352.—A bluish sandstone of coarser grain than No. 1354: it resembles the blue stone from Monarch (No. 1360, page 196), but it is considerably coarser in grain and somewhat harder. It effervesces freely with acids indicating a high content of lime in the cementing material.

No. 1353.—A yellowish sandstone with a grain comparable with that of No. 1352: it is considerably coarser than No. 1354, but otherwise resembles it closely.

Stone from this locality was used in the construction of the Union bank in High River. This building presents rather a dead grey (concrete) colour with a slight tendency to yellow weathering on exposed parts. The grain of the stone is rather coarse and lighter coloured streaks are to be observed in certain blocks, but clay holes are almost absent. The coursing stone is all of good thickness and some lintels a foot thick and 5 feet long have been used. The stone seems to be of a high order of resistance for Paskapoo sandstone, as the surface of the rock face can scarcely be abraded by the thumb nail and treads show much less abrasion than usual. On the whole the building presents a creditable appearance, the rather dead grey colour being the chief objection.

R. Brothers, High River, Alberta.

A small amount of stone was quarried on the banks of the Little Bow river about six miles from High River and was used in the construction of the building of the High River Trading Co. The stone is essentially the same as that from Brazier's quarry but is, perhaps, slightly more yellow in colour.

High River, Alberta.

A small quarry was opened on the Highwood river about 2 miles above High River. The inconsiderable output was used for foundations.

Sandstone Area.

This area comprises a few quarry locations near the village of Sandstone on the Calgary-Macleod line of the Canadian Pacific railway. The district is better known for its shale deposits and brick-making plants than for its production of building stone; nevertheless, two quarries were definitely opened in pursuit of structural stone but the actual output was negligible. At the present time the only stone produced is incidental to the quarrying of shale for brick-making.

The stone is variable and inclined to strong reediness. The general colour is a yellowish-grey but it is much less yellow than the typical Calgary stone.

Canada Cement Co. Brick Plant No. 11, Sandstone, Alberta.

The quarry of this company is situated on the northeast quarter of section 11, township 21, range 1 west of the fifth meridian: it is about 150 yards long and has been worked into the hillside in a semicircular form. An excellent section of sandstone and shales is exposed in this excavation as follows:—

15 ft.—Soil.
6-12 ft.—Variable sandstones. In places quite heavy, in other parts thin with much shale (1341).
20 ft.—Shale with a little sandstone.
3 ft.—Sandstone (1342).
8 ft.—Shale.
8 ft.—Sandy shale and hardhead.
20 ft.—Shale and thin sandstone.
——— Floor of upper quarry.
4 ft.—Sandstone and shale.
60 ft.—Mostly shale with thin bands of both hard and very soft sandstone.

The upper sandstone layer is rather badly shattered and shows a considerable amount of hardhead. The beds increase in thickness and evenness towards the north and extend beyond the quarry. The stone is of a greyish colour and frequently shows hard centres of a blue tint: these centres are not as hard as the typical hardhead. The second bed produces a similar stone and frequently shows the same moderately hard bluish centres. Neither bed could be worked economically for the production of building stone, but a certain amount of fair material could be obtained incidentally in operating the quarry for shale. Some stone was shipped from here for the construction of a school in Okotoks and a small quantity was sent to Calgary.

On the property of the company, at a point about 200 yards north and west of the large quarry, is situated the old opening made by John Watson for the production of building stone.

The section here is as follows:—
4-6 ft.—Drift.
10 ft.—Thin stone, with thicker beds in places.
12 ft.—Heavy stone in two or more beds.

The stone of the lower beds is not of good colour and is rather hard and reedy with considerable variation but it could be quarried in large blocks without difficulty. An average sample is described as No. 1343.

The stone: No. 1341.—This is a fine-grained sandstone of light greyish colour with a cast of yellow: it is very like No. 1354 but slightly darker and more reedy. The cementing material is largely carbonate of lime.

No. 1342.—This stone is very similar to No. 1341 but it is of coarser grain and less reedy structure.

No. 1343.—This stone is darker in colour and considerably harder than either of the above: it has a large content of carbonate of lime in the cement. Compared with the Paskapoo sandstones that are usually worked, this stone is too hard to meet the approval of contractors.

Sandstone Brick and Sewer Pipe Co., Calgary: Quarry at Sandstone, Alberta.

The quarry is a half mile south of that of the Canada Cement Company; it shows a section of 50 feet or more of sandstone and shale. The chief sandstone layers are two in number—one of about 4 feet towards the top and another of 10 feet or more towards the bottom of the section.

The sandstone has been much shattered by explosives but blocks of considerable size are lying in the quarry. The stone varies greatly in texture and in the degree of coherence: some of it is fairly hard while some is so soft as to be pulverulent. Blue hardhead cores are much in evidence (1345). An average sample is described as No. 1344 but it is questionable if stone of this quality could be quarried in economic quantity. The variability in grain and coherence and the presence of hardhead would render difficult the employment of this stone even as a by-product in quarrying for shale.

The stone: No. 1344.—This stone is very like No. 1342 from the Canada Cement Company's quarry: it is slightly harder and darker.

No. 1345.—A very hard bluish sandstone with a high content of carbonate of lime. This stone is almost flinty and quite unworkable: it is the typical "hardhead" and is quite comparable with similar material in many of the quarries.

Burnvale Brick Co., Calgary : Quarry at Sandstone, Alberta.

This quarry is situated about a mile north of Sandstone on the east side of the line of the Canadian Pacific railway: it is opened at a considerable elevation in the east bank of the same ravine on the west side of which the quarries already described are located.

The quarry is very small and has not been carried beyond the prospecting stage. The section is as follows:—

————Slight stripping which would rapidly increase.
10 ft.—Thin-bedded stone.
20 ft.—Fairly heavy stone in irregular lenticular beds.

The general run of the stone of the lower beds is a greyish type weathering yellow and presenting a wavy reediness (1346). Mingled irregularly with the grey stone is a blue harder variety which probably represents the original unoxidized stone (1347). Although blocks of fair size can easily be quarried the quality of the stone and the large amount of blue material are unfavourable features.

A dismantled derrick is on the property.

The stone: No. 1346.—This stone is dark yellowish-grey and distinctly reedy: it is harder than the average good Paskapoo stones and yet slightly softer than No. 1343 which it resembles except for a more defined reediness and slightly coarser grain.

No. 1347.—A bluish sandstone resembling No. 1360 from Monarch but somewhat harder. This stone does not approach the true hardhead, like No. 1345, in hardness but is a workable stone although considerably harder than the average stone used.

Calgary Area.

This area is made to include the quarries in the immediate vicinity of Calgary, locations recently in operation at Brickburn to the west, and properties which have not been worked in many years in the vicinity of Beddington to the north of the city.

Stone is exposed at points on the Bow river within the city of Calgary and was formerly worked near the point where the railway enters the city from the north. Near the mouth of the Elbow river a quantity of stone was obtained from quarries in the cut bank. At the present time the only quarry in operation is that of Wm. Oliver and Company, situated at Sunalta. Sandstones are exposed in almost every coulée and along the sides of many minor ridges throughout the district between Didsbury and Beddington and even south of the latter place in the direction of Calgary. In this district there must be many locations from which stone of a more or less satisfactory nature might be obtained but it would appear that few of these outcrops are sufficiently promising to have attracted the attention of stone operators. I have been able to learn of only two places at which quarrying has been attempted on a commercial scale.

The typical stone of the area is yellowish-buff in colour, but greyish-yellow tones are seen in some of the outcrops farthest from the centre. The stone at Hay's quarry north of Beddington more closely resembles the greyish-yellow stone from Glenbow than it does the typical Calgary variety. Were the "areas" established on the nature of the stone and not on geographical grounds, this location would be included in the same list with Glenbow.

Wm. Oliver and Co., 1823 16th. Street West, Calgary, Alberta.

The quarry is located in the city of Calgary at the corner of 17th. avenue and 21st. street west. At this point a small lateral gulley cuts through the rim of the high land which forms the outer bank of the Bow river above Calgary. The quarry was originally opened 14 years ago along the sides of this small ravine and was extended south of 17th. avenue. The construction of a roadway on this street necessitated the filling in of the excavation with the result that the portion north of the avenue has been abandoned. The present quarry has a width of about 600 feet along 17th. avenue and a length of 600 feet in a north and south direction, *i.e.*, in the direction of the small ravine. Mr. Oliver's property consists of 6 acres, and although much stone must be accessible in an east and west direction along the ridge, I understand that quarrying operations are prohibited by the conditions under which this land was sold for building lots. At the southern end, the quarry is practically the width of the property but towards the north the width is restricted with a consequent considerable reserve of available stone (Plate XXXIX).

The formation is practically horizontal, but as the beds are lenticular, a detailed section will not hold for all parts of the face. An average section is as follows:—

10 ft.—Drift.

8 ft.—Shale and thin sandstone.

6 ft.—Sandstone in 2 variable beds. The colour is not good and the stone is not used for fine cut work but it could be used for rubble, etc.

28 ft.—Sandstone in beds up to 4 ft. thick. Averages about 20 feet of good buff stone. The balance is hard stone either buff or blue in colour.

10 ft.—Solid sandstone bed. About the middle this bed shows a variable band of hard blue stone, bounded on both sides by zones of hard grey. In places the blue is absent and the central band is hard grey. Some of the buff stone also is much harder than the average soft material. Best soft buff, No. 1285; hard buff, No. 1286; hard grey No. 1288; hard blue, No. 1287.

The hard blue and grey stones are not suitable for cutting and according to Mr. Oliver constitute about 30 per cent of the output. Contractors object to the hard buff on account of the additional cost of cutting; but this is not really a hard stone when compared with sandstones which are successfully used in other parts of Canada.

The general observation already made, that the Paskapoo sandstones become harder and practically unworkable at any considerable distance in from the exposed surface, is borne out by this quarry, as there is a great increase in the amount of hard material as the excavation is advanced. Mr. Oliver considers that the greatest percentage of desirable soft buff stone lies between the superficial shattered zone and a distance from the natural exposed face of about 100 feet. There can be no doubt that the soft buff stone represents the extreme phase of oxidation and alteration due to percolating waters. The hard buff stone is a somewhat less altered phase, while the very hard blue material (hardhead, 1287) is, in all prob-

PLATE XXXIX.

Paskapoo sandstone. Quarry of Wm. Oliver and Co., Calgary, Alberta.

ability, the result of secondary hardening due to the impounding of mineral laden waters towards the inner parts of the heavier beds. The grey stone may represent a slightly oxidized phase of the original material or, perhaps, a phase of the blue type in which the secondary hardening has not been carried so far.

The jointing in the upper 34 feet of sandstone is very irregular with two indistinct sets, east and west, and north and south, the former being more closely set. The lower 10-foot bed is differently jointed with a major set striking S. 30°E. at wide intervals. Cross joints are infrequent. It would be possible in places to quarry stone 20 feet square on the bed. It is worthy of note that the major joints are open permitting the free escape of water: without this formation feature it is unlikely that this lower bed would furnish the large amount of soft buff stone that it does.

The stone: No. 1285.—This specimen was selected by Mr. Oliver himself as representing a good general average of the best stone: it may be regarded as typical of the Calgary area. It is a medium-grained yellow to buff sandstone of uniform structure and clean peppery appearance (No. 3, Plate LVI). The microscope shows about one-fourth of the stone to be of quartz grains which are apparently somewhat smaller than in the hardhead described as No. 1287. The rest of the rock is practically indeterminable, for although certain centres occur, which doubtless represent original fragments, probably of feldspar, they fade so imperceptibly into the cementing matter that no definite boundaries can be seen. The cement is stained and clouded throughout by oxide of iron. The stone is soft and may be drilled or chiselled with facility. The chiselling factor is not remarkably high as the stone is not flaky and only very small side chips were thrown out along the track of the chisel. Corrosion produced no colour change but considerable deterioration resulted from the freezing test.

The physical properties are as follows:—

Specific gravity	2·683
Weight per cubic foot, lbs.	130·51
Pore space, per cent	22·08
Ratio of absorption, per cent, one hour	6·62
" " " " " two hours	6·62
" " " " " slow immersion	7·21
" " " " " in vacuo	10·45
" " " " " under pressure	10·56
Coefficient of saturation, one hour	0·62
" " " two hours	0·62
" " " slow immersion	0·68
" " " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	5,647·
" " " " wet	4,144·
" " " " wet after freezing	2,677·

Transverse strength, lbs. per sq. in.	467·
Shearing strength, lbs. per sq. in.	408·
Loss on corrosion, grams per sq. in.	0·06938
Drilling factor, mm.	23·
Chiselling factor, grams	10·4 II

An analysis of this stone was kindly furnished me by Mr. F. C. Field, city analyst, Calgary, as follows:—

	Per cent
Silica	52·27
Ferric oxide	1·84
Alumina	4·64
Lime	22·78
Magnesia	3·94
Soda and potash	0·858
Loss on ignition	10·96
Total	97·288

A total analysis of this kind, while of a certain interest, furnishes very little information from our point of view, as no separation is made between the cementing material and the constituent mineral grains. In order to obtain information as to the character of the alterations which are going on in these Paskapoo sandstones, four samples of stone were selected from this quarry and submitted to a similar chemical examination. These samples are as follows:—

No. 1285—Good average soft buff stone. The most altered phase.

No. 1286—Hard buff stone. A less altered phase.

No. 1288—Hard grey stone. Still less altered.

No. 1287—Blue hardhead. The least altered phase, or possibly secondary.

For comparative purposes the analyses of these stones are given side by side below:—

	No. 1285	No. 1286	No. 1288	No. 1287
Insoluble residue	70·50	62·84	55·00	54·34
Soluble portion	29·50	37·16	45·00	45·66
Partial analysis of the soluble portion:				
Lime	10·98	16·92	21·00	21·96
Magnesia	2·83	2·00	2·16	2·28
Ferric oxide	1·71	1·78	2·43	0·47
Ferrous oxide	1·15	0·32	0·38	1·28
Carbonic acid	11·19	14·43	17·60	17·30
Total constituents determined	27·86	35·45	43·57	43·29
Difference between determined constituents and the total soluble portion—representing alumina, etc.	1·64	1·71	1·43	2·37

This table shows clearly that the progress of alteration is marked by a decreasing percentage of cement and this observation is confirmed by an increasing pore space, the softening of the stone is due, therefore, in some part at least, to an increase in the pore space with a consequent loss of cohesion. The second point of interest in the table is the great similarity between Nos. 1288 and 1287, the only alteration being a conversion of the ferrous oxide of No. 1287 into ferric oxide in No. 1288. It is to be observed also that the content of magnesia remains practically the same in all four stones, indicating that the magnesia is not removed by solution whereas the actual content of lime is much reduced.

The percentages given above do not permit us to make a direct comparison of the chemical nature of the cement in the different cases: this can be better done by compiling the figures as percentages of the total amount of cement present in each instance as below:—

	No. 1285	No. 1286	No. 1288	No. 1287
Lime......................	37·00	45·5	46·6	48·1
Magnesia..................	9·25	5·4	4·8	5·0
Ferric oxide................	5·8	4·8	4·8	1·0
Ferrous oxide..............	3·8	0·86	0·84	2·8
Carbonic acid..............	37·9	38·8	39·1	37·9
Alumina, etc...............	5·5	4·6	3·2	5·2

This table shows us that there is very little difference in the chemical character of the cement in Nos. 1286, 1288 and 1287, except in the increase of ferric oxide and the decrease of ferrous oxide in the former two.

No. 1285 shows that the percentage of carbonates in the cement has not altered essentially as the content of carbonic acid is nearly the same as in the other three cements. On the other hand the lime has diminished and the magnesia increased. If the lime magnesia and ferrous oxide were present in the form of carbonates, they would together require 41·44% of carbonic acid whereas only 37·9% is available. The same is true in No. 1287, for the 48% of lime would require 44% of carbonic acid with only 37·9% available. It follows that some of the magnesia, lime or ferrous oxide is present in the form of compounds other than carbonates. The much lower percentage of lime in No. 1285 as compared with the other stones can not be interpreted otherwise than as indicating a solution and removal of carbonate of lime. The fact that the total amount of carbonates remains the same must mean that other bases have been derived from the decay of mineral grains and have been converted into carbonates: these substances were doubtless magnesia and iron as indicated by the greatly increased percentages of these substances. The large amount of ferrous iron can only be explained thus: its presence does not stand for colour durability in the stone. It would appear, therefore, that the original cement is composed of a large amount of carbonates with a less amount of uncertain argillaceous material. The first effect of alteration is the conversion of the ferrous oxide into ferric oxide; then follows a diminution in amount without any striking change otherwise. The third stage of alteration—the conversion of No. 1286 into No. 1285—is much more marked and consists in a considerable solution and removal of carbonate of lime accompanied by an addition of carbonate of magnesia and iron. There is no marked increase in the amount of argillaceous matter.

A third means of comparison, whereby the necessity of knowing the total amount of cement is avoided, and allowance is made for difference in pore space, is to express the determined constituents of the cement as pounds per cubic foot of the stone. As this compilation of the figures indicates a comparison by *volume* it is much to be preferred in drawing conclusions as to the alterations which have taken place. As the exact weight per cubic foot has been determined only for Nos. 1285 and 1286 the other stones are omitted from the table below:—

	Lbs. per cubic foot of stone.	
	No. 1285	No. 1286
Lime	14·3	27·32
Magnesia	3·793	3·11
Ferric oxide	2·231	2·769
Ferrous oxide	1·5	0·497
Carbonic acid	14·6	22·45
Alumina, etc.	2·14	2·235

This table indicates that no aluminous matter has been added to the cement in the process of alteration although, as shown by the second table, it constitutes a greater percentage of the cement in the altered stone.

The magnesia has actually increased and therefore it must have been added to by the decomposition of some constituent of the mineral grains. The iron oxides of No. 1286 indicate 2·324 lbs. of metallic iron per cubic foot, while the similar oxides of No. 1285 indicate 2·726 lbs. of metallic iron, showing that a small amount of this element has been added to the cement. The carbonic acid of No. 1286 is only slightly more than enough to combine with the lime present and it is not sufficient to form carbonates of the magnesia and ferrous oxide. In No. 1285 the carbonic acid would convert all the lime into carbonates and a large part of the magnesia and ferrous oxide.

The alteration appears to have proceeded thus:—

1st. A considerable solution and removal of carbonates.

2nd. A conversion into carbonates of some of the lime and magnesia contained in the less altered stone in other forms.

3rd. A decomposition of ferro-magnesian grains of the constituent minerals resulting in a slight addition of magnesia and iron.

4th. A conversion of the added constituents into carbonates.

5th. A slight reduction of the ferric oxide.

No. 1286.—This stone is the typical "hard buff" Calgary stone. The colour is a greyish-buff not greatly different from that of the soft stone No. 1285: it dresses to a smooth even finish with sharp edges and angles not at all friable. The stone is undoubtedly much harder than the soft variety and in consequence is rejected by contractors as too hard to work, but it is not really a hard stone compared with sandstones worked elsewhere. Its superior hardness and wearing properties should recommend it for certain purposes. The microscope shows this stone to be much finer in grain than Nos. 1285 and 1287 as the quartz grains do not average more than ·1 mm. in diameter. These grains probably make up $\frac{1}{5}$ to $\frac{1}{4}$ of the whole rock. Other mineral grains or rock fragments of about the same dimensions occur in abundance but it is impossible to clearly separate them from the cementing material. Iron oxides are developed in the cement in the same manner as in No. 1285: in fact, except for the finer grain, this stone is identical with No. 1285 as far as microscopic features are concerned. It is to be noted that the coefficient of saturation is high indicating a danger of injury by frost.

The physical properties are as follows:—

Specific gravity	2·694
Weight per cubic foot, lbs.	155·61
Pore space, per cent.	7·47
Ratio of absorption, per cent, one hour	2·11
" " " " " two hours	2·11
" " " " " slow immersion	2·69
" " " " " in vacuo	2·927
" " " " " under pressure	3·0
Coefficient of saturation, one hour	0·7
" " " two hours	0·7
" " " slow immersion	0·89
" " " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	14,089·
" " " " wet	11,246·
" " " " wet after freezing	10,574·
Transverse strength, lbs. per sq. in.	1,158·
Shearing strength, lbs. per sq. in.	892·
Loss on corrosion, grams per sq. in.	0·062
Drilling factor, mm.	13·8
Chiselling factor, grams	1·0 II

For chemical analysis of the stone and remarks on alteration see pages 218-220.

No. 1287.—This bluish stone belongs to the type of true hardhead. Although similar in grain to the average of the quarry, its much greater hardness renders it useless for cut stone work. It might be employed with advantage for footings. Like all this type of stone it has a high content of carbonate of lime.

A microscopic examination shows about one-fourth of the stone to be quartz grains seldom exceeding ·3 mm. in diameter. The second fourth is of mineral grains, often of larger dimensions and evidently of different kinds, but not determinable on account of alteration. Half of the stone is matrix of light colour containing a large amount of crystalline calcite. This matrix is not all cementing matter but is made up of cement passing imperceptibly into decomposed rock fragments. Doubtless the original amount of rock fragments was more than half the stone.

For analysis, see page 218.

No. 1288.—This stone is known as the "hard grey" type: it is much less yellow than either No. 1285 or 1286 and it is slightly harder than the "hard buff," No. 1286, but is softer than the blue stone, No. 1287. The cementing material is largely carbonate of lime which is more abundant than in No. 1285. In grain this stone resembles No. 1287 but it is much "dirtier," and does not show the same clear crystalline cement.

For analysis see page 218.

Quarrying is effected chiefly by the use of crow bars and wedges on the bedding and joint planes. Powder is occasionally used in $1\frac{1}{2}$ in. rimmed holes in small charges with an air chamber: fairly straight breaks 10 feet long are thus produced. Owing to the presence of hardheads and the consequent lack of uniformity, plug and feather methods are not satisfactory.

The equipment is as follows:—

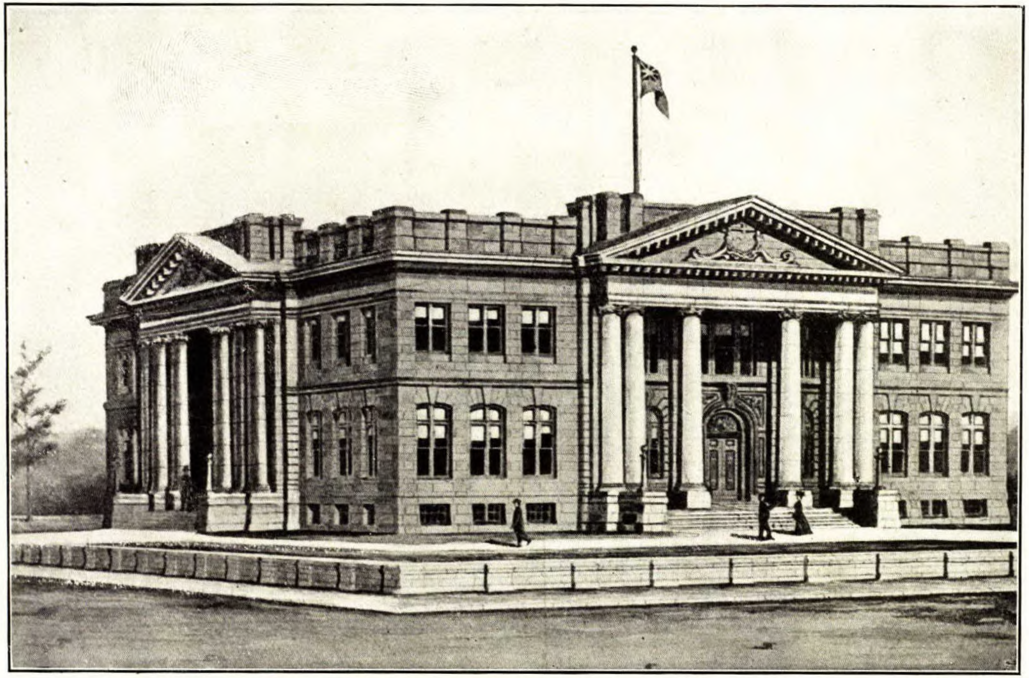
2 boilers and 2 derricks with steam hoists.
2 horse derricks.
3 steam drills.
1 orange-peel stripper.
1 gang saw operated by electric power.
Minor appliances.

At the time of my visit operations had been suspended but as many as 40 men have been employed at different times. Mr. Oliver has kindly furnished the following scale of wages:—

Steam drillers—45 cents per hour.
Quarrymen—40 cents per hour.
Labourers—$32\frac{1}{2}$ to 35 cents per hour.
Stonecutters—65 cents per hour.

The haul to a siding of the Canadian Pacific railway is about a half mile. The following prices are quoted, all delivered in Calgary:—

Rough dimension blocks—Up to 70 cubic ft., 70 cents per cu. ft.; larger sizes, special prices.
Rubble—$7 per cord.
Coursing, rough, 12 in., 8 in. on bed—25 cents lineal foot.



Paskapoo sandstone, Calgary quarries. Court house, Edmonton, Alberta.

Paskapoo sandstone, Calgary quarries. Knox church, Calgary, Alberta.

PLATE XLII.

Paskapoo sandstone, Calgary quarries. Land Titles building, Calgary, Alberta.

PLATE XLIII.

Paskapoo sandstone, Calgary quarries. City hall, Calgary, Alberta.

Coursing, 12 in., ready to lay—Add 20 cents per sq. ft. for bedding and jointing.
Coursing, rough, 11 in.—23 cents per lineal ft.
Coursing, rough, 10 in.—21 cents per lineal ft.
Coursing, rough, 6 in.—10 cents per lineal ft.
Coursing, sawn or sand rubbed, ready to lay—Add to 70 cents per cubic foot, 25 cents per superficial foot.
Sills, 6 in. by 6 in., rough—30 cents per lineal foot.
Sills, 2 brick, rock face, bedded, sawn or sand rubbed top—70 cents per lineal ft.
Lintels, 12 in. high, 6 in. on bed.—70 cents per lineal foot.

In connexion with the above prices, Mr. Oliver attributes the declining stone industry in Alberta and the successful competition of Indiana limestone to two chief factors—the high cost of labour, and the lack of a market for rubble or for any product of the quarry except the best quality of soft buff freestone.

The characteristic yellowish-buff stone may be regarded as typical of the immediate vicinity of Calgary. It has been largely used in a great many local buildings but it is not always possible to ascertain the quarry from which a particular building has been constructed. This is partly due to lack of information but chiefly owing to the fact that contractors have used stone from different localities in the same structure. The recent additions to the post-office in Medicine Hat and the post-office in Bassano are entirely constructed of Oliver's stone. The Carnegie library in Calgary (Plate XLVI) is almost entirely of this stone as well as the greater part of the City Hall (Plate XLIII). In this building some blocks of stone 15 feet long were used and columns five feet high cut from stone on the bed were used in the Land Titles building. The City Hall is distinctly yellow in colour with some variation in different blocks. Some stone is seriously marred by mud holes, and efflorescences accompanied by local disintegration occur in places. The rock face work seems more satisfactory than the cut stone. The old part of the post-office in Medicine Hat was constructed in 1906 of a buff stone, probably from Calgary, which has weathered well and presents a uniform and reasonably hard surface. The new part was build in 1914 of Oliver's stone: the grain is slightly coarser and the colour a little more yellow. Assuming that both stones are of the same origin, the result of 8 years longer weathering of the old portion has resulted only in the assumption of a slightly greyish cast owing to the imbibition of dirt. For remarks on the general weathering of Calgary stone see page 191.

Elbow river, Calgary, Alberta.

The Elbow river enters the Bow south of Calgary through an erosion valley about 100 feet deep. This valley is concave on the east side towards its mouth and exposes sandstone in the consequent scarped bank for a distance of nearly half a mile. The covering of drift is heavy, in places reaching a thickness of 50 feet. Beneath this overburden the sandstones appear for a depth of 25 to 40 feet and may possibly extend lower but the bottom of the slope is covered with talus. The bedding is very irregular but stone of a foot in thickness is easily obtained, and in places, blocks could be quarried in limited amount up to three feet in thickness. False bedding is much in evidence and the jointing is severe and irregular. Quarrying has been done at the southwest end of this exposure where the sandstone beds are less interrupted by layers of shales. The general average of the desirable stone is a greyish type (1289) which is mixed in greater amount with a harder variety (1290). An unfortunate amount of blue hardhead occurs throughout the whole exposed face and is perceptibly more abundant towards the bottom of the exposure. The weathered surfaces of the stone exposed by the old workings show a superficial skin of buff, but in most instances, the hard grey type is revealed immediately beneath the surface. It would appear that the properly weathered stone formed but a narrow external zone which has been removed by the insignificant amount of quarrying already done. In view of the heavy overburden and the small percentage of good stone in the present face, it is not likely that operations will be resumed at this point.

A little farther up stream, the concavity of the valley and in consequence the scarped bank occurs on the opposite side. The section here is as follows:—

10 ft.—Drift.
8 ft.—Thin rough sandstone.
20 ft.—Sandstone interstratified with much shale.
20 ft.—Sandstone to water level.

This lower stone is of the same general type as on the other side and presents the same formational features. A little quarrying has been done but extended operations would soon encounter an impossible overburden.

The beds dip slightly north and west and in consequence only the overlying shales are exposed farther up the Elbow river.

The stone: No. 1289.—A rather soft type of stone of about the same grain as No. 1285 from Oliver's quarry but decidedly more grey and less yellow in colour. The colour is almost identical with that of the grey type from Oliver's quarry but the present example is much softer.

No. 1290.—This stone is greyish-yellow and intermediate between the buff and grey types from Oliver's quarry. It is harder than No. 1289 or No. 1285 but is not as hard as No. 1288. This is a very good type of stone, with good colour and reasonable hardness: it works very nicely under the hammer. Under the microscope the quartz grains which are numerous and closely set have an average diameter of ·2 or ·25 mm. Semi-decomposed feldspar crystals are present in less amount. Mica is present and a few dark indeterminable grains. The cement reacts strongly for carbonate of lime.

Stone from this quarry was used in the construction of the old Calgary station which was torn down and re-erected at High River. This building shows a diversity in colour and grain which may indicate an admixture of other stones. I am informed that Elbow stone was used in the old Hudson Bay Company's building, now the Royal bank in Calgary.

Bone and Leblanc, Calgary, Alberta.

This firm operates a quarry at Brickburn on the main line of the Canadian Pacific railway about 5 miles west of Calgary. The excavation has been made in the face of the high bank of the Bow river some distance above the level of the railway. The cutting is about 200 feet long and at its maximum height the face shows the following section:—

2-6 ft.—Drift which would rapidly increase.
12-15 ft.—Shale with broken layers of sandstone.
25 ft.—Heavy bedded sandstone.
——— Blue shale.

The 25 feet of sandstone lies in very heavy beds of pronounced lenticular character and with irregular jointing. Towards the top, the stone is distinctly fine-grained and buff in colour (1292). Passing downwards the stone becomes coarser, greyer and more reedy (1293). Blue hardheads are encountered at all levels. It is significant that at the east end, where the quarry is still in the superficial stone, there is scarcely any hardhead, while at the west end, where the excavation is about 100 feet in from the original face, the hardhead is so abundant that the further extension of the quarry would be ill advised. Recognizing this peculiarity, Mr. Leblanc proposes to open new quarries at other points along the face of the escarpment where doubtless a large amount of desirable stone is to be obtained within the zone of oxidation (Plate XLIV).

The stone: No. 1291.—This is an average sample of the marketable stone. It is a good, even-grained, greyish to buff type very similar to No. 1361 from the quarries at Monarch but slightly more yellow; it is far less yellow than No. 1285 from Oliver's quarry in Calgary.

No. 1292.—This is a nice, even-grained, easily worked stone of much finer grain and slightly more yellow colour than No. 1291: it is scarcely as yellow as No. 1285 from Oliver's quarry.

No. 1293.—Resembles No. 1291 but is somewhat coarser in grain: it is remarkably like the buff stone from Monarch.

This quarry was opened about six years ago and continued in operation until 1914. The only equipment is one hand derrick. The stone may be seen in the recent addition to the high school, in the Balmoral school (all except the base), in the Riverside school, and in the addition to the Victoria school. Knox church, Calgary, is partly of this stone, and it is said to have been used in the Central Methodist church and in the Alberta hotel in

Calgary. The upper, fine-grained, yellow stone may be seen in the Fire Hall near the corner of 18th avenue east and 2nd street.

J. A. Lewis, Rocky View, Alberta. Northwest Quarter Section 21, Township 25, Range 1 west of the Fifth Meridian.

A prominent ridge crosses this property in a direction E.20°S. and presents a steep escarpment on the southerly side towards Knowles creek. The workings have been extended along the upper face of this escarpment for a distance of 300 feet with a maximum width of possibly 100 feet (Plate XLV). The face of the quarry, having been cut into a dome-shaped hill, is much higher in the middle than at the ends: a section at the point of greatest height is as follows:—

20 ft.—Soil, thin stone and shale.
10 ft.—Buff sandstone (1279).
4 ft.—Hard blue sandstone (1280).
———Buff sandstone, opened in test pits only.

The hill gradually runs up to a considerably greater elevation and in consequence the overburden of thin and shaly material would increase if the workings were extended farther into the ridge. It is possible, however, that higher layers of desirable stone would be found above the shale. The 10 feet of buff stone is disposed in variable but fairly heavy beds, in places as great as 3 feet in thickness. This buff stone fades imperceptibly into the 4 feet of hard blue which does not form a strictly continuous band throughout the length of the quarry. Below the blue band, buff stone again occurs but it has not been sufficiently opened to reveal its formational features. Wavy and variable but pronounced joints cut the formation a little south of east: they are not too closely spaced to permit the extraction of large blocks. More troublesome are the rather numerous cross joints particularly at the eastern end of the opening. On the whole the formation is rather seriously broken and although some large stone can be obtained the waste is necessarily great. Another unfortunate feature is the great variation in the character of the stone both horizontally and vertically. Differences in grain, in reediness, and in the amount of carbonaceous matter is to be observed throughout the exposure. The hard blue layer is also to be reckoned with and we must face the probability that this type of stone would increase in amount if the quarry were extended farther into the hill. A good average example of the buff stone is described below as No. 1279. Nos. 1281 and 1282 are examples of variation and No. 1280 is the blue hardhead.

To the westward of this opening, after a short talus-covered interval, a second quarry has been opened at a higher level exposing the shales which lie above the quarry described above. Resting on these shales are 25 feet of sandstones in very irregular layers with much false bedding, shaly partings, and both hard and soft streaks. Very irregular joints cut the sand-

Paskapoo sandstone, Calgary area. Quarry of Bone and Le Blanc, Brickburn, Alberta.

Paskapoo sandstone, Calgary area. Lewis' quarry at Beddington, Alberta.

stones in a direction a little south of east as in the other quarry. This location does not look promising, as the quarrying of large blocks, while not impossible, would occasion an excessive amount of waste (1283).

The stone: No. 1279.—A medium to fine-grained, distinctly yellow sandstone closely resembling No. 1285 from Oliver's quarry in Calgary. It is rather finer in grain than the Calgary stone and somewhat less clean and "peppery" in appearance. The quartz grains seldom exceed ·2 mm. in diameter and are associated with other grains of equal size, some of which may definitely be determined as feldspar. The more decomposed grains of this mineral pass imperceptibly into cement. The usual dark opaque fragments are present in considerable amount and some crystals of calcite appear in the cementing material. The corrosion test increases the yellow tone and the freezing test causes some exfoliation on the plane of stratification.

The physical properties are as follows:—

Specific gravity	2·692	
Weight per cubic foot, lbs	132·45	
Pore space, per cent	21·37	
Ratio of absorption, per cent, one hour	6·53	
" " " two hours	6·59	
" " " slow immersion	7·21	
" " " in vacuo	9·94	
" " " under pressure	10·09	
Coefficient of saturation, one hour	0·64	
" " two hours	0·65	
" " slow immersion	0·71	
" " in vacuo	0·98	
Crushing strength, lbs. per sq. in., dry	6,224·	
" " " wet	3,604·	
" " " wet after freezing	2,887·	
Transverse strength, lbs. per sq. in	329·	
Shearing strength, lbs. per sq. in	455·	
Loss on corrosion, grams per sq. in	0·06554	
Drilling factor, mm	27·4	
Chiselling factor, grams	8·9	II

No. 1280.—This stone is of light bluish colour and would be classed as true hardhead with stones like No. 1345 from Sandstone and No. 1287 from Oliver's quarry in Calgary.

No. 1281.—Finer grained, softer, and rather more yellow than No. 1279.

No. 1282.—Differs from No. 1279 only in a slightly green cast in the yellow.

No. 1283.—This stone is coarser than No. 1279 and of a darker yellow colour: it seems to be rather soft.

These quarries have not been worked in the past 6 or 7 years. There is no equipment on the ground. The City Hall in Calgary is in part built of the product of these quarries and it is said to have been used in the new part of the Imperial bank.

Stone is exposed at intervals along this ridge for at least five miles in a north and west direction but no attempt has been made to quarry it, with the possible exception of a few rough blocks for local foundations. Farther north and west a small amount of stone was quarried as described below:—

James Hay, Simons Valley, Alberta. Northwest Quarter, Section 15, Township 26, Range 2 West of Fifth Meridian.

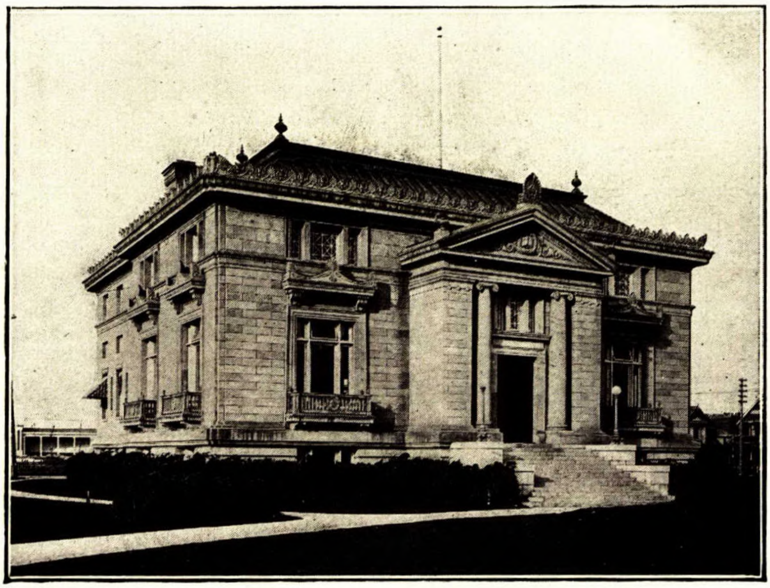
On this property an extensive exposure is seen along the top of the bluff on the north side of Beddington creek. Quarrying has not been attempted in the face of the bluff but openings have been made in the surface stone towards the west side of the property. Here the formation is practically free from drift and presents a good uniform type of greyish stone in fairly heavy layers. Thinner material and hard streaks are not altogether absent but the possibility of quarrying good large blocks of uniform stone is attested by the pieces now lying on the dump. Joints cross due east and west and also a series a little east of north. The general average of the stone is grey in colour and shows but little tendency to turn yellow even after a considerable exposure: it resembles the product of the quarries of the Glenbow-Cochrane area rather than that of the other quarries of the Calgary area. Doubtless this location lies on a belt of greyish stone extending from Cochrane towards Red Deer. I understand that only one load was ever taken out from the property (1284).

Glenbow-Cochrane Area.

This area is situated on the main line of the Canadian Pacific railway about 20 miles west of Calgary. It includes quarries at Keith, Glenbow, and Cochrane. The stone at the latter locality is of a distinctly greyish colour while that at Glenbow and Keith is yellowish-grey and may be regarded as intermediate between the greyish Cochrane type and the typical yellowish-buff stone of Calgary. Large amounts of stone were raised at Glenbow and later at Cochrane but at the time of my visit no quarrying operations were being carried on.

C. de Lavergne, Glenbow, owner; Quinlan Carter Co., operators, Calgary.

Glenbow station is on the main line of the Canadian Pacific railway about 20 miles west of Calgary. The railway follows the valley of the Bow river on the north side at an elevation of 75 to 100 feet above the water.



Paskapoo sandstone, Calgary quarries.
Carnegie Public Library, Calgary, Alberta.

The bank of the river extends several hundred feet above the railway. Below the track thin sandstones and shales are to be seen: the same formation outcrops at intervals up the hillside and is topped with heavy layers of sandstone in which the old Glenbow quarries were opened. The excavation was made on a projecting point between two lateral ravines: it has a length of several hundred feet and presents the following section:—

25 ft.—Drift, thin stone and shale.
10 ft.—Sandstone, partly in heavy beds but mostly thin and useless: it is much broken towards the ends of the face where the covering is less.
2-5 ft.—Shale.
20 ft.—Sandstone, mostly in heavy beds.

These lower beds appear to dip slightly to the west: they are much cut by joints but I was unable, in the present condition of the quarry, to make out any regular system. The stone is essentially of the buff type but it shows considerable variation in grain, in colour, and in the development of reedy structure and false bedding. The deeper parts of the excavation show the presence of the usual blue hardhead: I have little doubt that the increase in the amount of the hard blue type together with the considerable overburden necessitated the cessation of operations.

Extensive quarrying was at one time carried on here with a force of 60 to 75 men, but no stone has been raised since 1909. An inclined tramway to the railway, dismantled derricks, foundations for engines and gang saws, cutting sheds and houses for the workmen indicate a scene of former activity. Average stone from this quarry is described below as No. 1298 and a weathered example from the lowest bed as No. 1297.

About a quarter mile west of the above quarry a small opening was made on the next prominent point to the west, and, at a distance of a half mile, a third opening was made on a similarly projecting point. This quarry is situated at a lower level than the old Glenbow quarry and is extended in a direction E.25°S. for about 200 feet. The excavation has been partly filled with debris following the advance of the quarry into the hill. The present face shows the following section:—

1-2 ft.—Soil.
6-8 ft.—Shale and thin sandstone.
14 ft.—Sandstone in three roughly defined beds.

Of these heavy beds the upper is rather fine in grain and of a distinctly yellowish-buff colour. The middle bed shows a wide band of blue hardhead at about its centre and a lower layer strongly cross bedded and of coarser grain (1295). On the whole there is considerable variation in the quality of the stone. No. 1294 may be regarded as a fair average while No. 1296 is a yellowish reedy type.

The jointing is disposed in a general north and south direction but the joint planes are very irregular and in places strongly curved. Judging from the present condition of the face I see no reason why fairly desirable stone in large blocks could not be procured especially as the overburden would not materially increase. The inevitable increase in the amount of hard blue stone, however, must be remembered. A dismantled derrick is the only equipment on the property.

The stone: No. 1294.—This is a rather coarse-grained, greyish sandstone with a distinct "pepper and salt" appearance (No. 4, Plate LVI). It shows some evidence of cross bedding and reediness and is somewhat friable. The microscope shows quartz grains up to ·5 mm. in diameter but the average is considerably less. Feldspar grains are present and a considerable percentage of the black grains so common in these stones.

The cement reacts freely for carbonate of lime.

Corrosion increases the yellow colour and some exfoliation results under the freezing test.

The physical properties are given below:—

Specific gravity	2·665	
Weight per cubic foot, lbs	134·19	
Pore space, per cent	19·34	
Ratio of absorption, per cent, one hour	4·09	
" " " two hours	4·51	
" " " slow immersion	6·14	
" " " in vacuo	8·92	
" " " under pressure	8·98	
Coefficient of saturation, one hour	0·45	
" " two hours	0·5	
" " slow immersion	0·68	
" " in vacuo	0·99	
Crushing strength, lbs. per sq. in., dry	7,631·	
" " " wet	5,640·	
" " " wet after freezing	3,896·	
Transverse strength, lbs. per sq. in	554·	
Shearing strength, lbs. per sq. in	497·	
Loss on corrosion, grams per sq. in	0·04301	
Drilling factor, mm	21·	
Chiselling factor, grams	6·87	II

The analysis of this stone shows that it is very similar in the cementing matter to the Cochrane stone (No. 1299, page 233); the total amount of cement is not essentially different and the carbonates are only slightly lower. The present example is lower in ferrous oxide and considerably higher in ferric oxide; this will account for the more yellow colour and gives promise of a slightly better colour durability. Compared with the typical Calgary stone (No. 1285, page 217) we find a lower percentage of total cement and yet a higher percentage of ferric oxide. The less amount of ferrous oxide should indicate a better colour durability.

The analysis by Turner is given below:—

	Per cent
Insoluble residue	77·72
Soluble portion	22·28
Partial analysis of the soluble portion:	
Lime	8·22
Magnesia	2·28
Ferric oxide	3·07
Ferrous oxide	0·32
Carbonic acid	7·76
Total of constituents determined	21·65

No. 1295.—Similar to No. 1294 but somewhat coarser and more cross bedded and reedy.

No. 1296.—Finer in grain, softer and more yellow than the other samples from this quarry. This stone is very like No. 1285 from Oliver's quarry in Calgary but it is more grey although a decidedly yellow stone with a reedy structure. The cement is of a calcareous nature and the stone is markedly bibulous.

No. 1297.—Slightly less reedy but otherwise very like No. 1296.

No. 1298.—A fine-grained, even, yellowish-grey type, with an abundant calcareous cement. It is a much finer grained stone than No. 1294 and resembles rather closely the best type of stone from the Elbow quarries in Calgary—No. 1290, page 224. This type shows fragmentary plant remains on fractures parallel to the bedding.

The Glenbow quarries must be included among the really important producers of Paskapoo sandstone and yet they are now commonly regarded as "worked out." I very much doubt if this conclusion is to be accepted. The old quarry has certainly been extended beyond the depth at which profitable extraction is possible and the newer opening is possibly approaching the same condition. On the other hand, we have in this locality a prominent hillside with stone proved for a distance of more than a half mile. Until the brow of this ridge has been more fully prospected it is too soon to regard the region as presenting no further possibilities. Stone has been quarried in small amount at Keith a few miles farther east: the intervening area is worthy of close examination.

The buildings of the Legislative Assembly in Edmonton (Plate XLVIII) are built very largely of Glenbow stone, with some yellowish Paskapoo sandstone from other quarries and a little Ohio sandstone and Indiana limestone. The basement is of British Columbia granite. The general appearance of the building is distinctly yellowish and some diversity of colour is to be observed in different blocks. Blue cores are seen in certain stones and their presence induces a tendency to horizontal cracking. In a few places the dressed stone shows small cavities due to clay inclusions. The Ohio stone is finer in grain and slightly more yellow than the Glenbow, but, on the whole, the two stones match very well.

Glenbow stone may also be seen in Athabaska hall, University of Alberta, Edmonton.

Shelley Quarry Co., Calgary: Quarries at Cochrane, Alberta.

Sandstones are exposed at many points along the west side of the valley of Big Hill creek near Cochrane, but a short distance west of that town the strata begin to assume highly inclined positions and present little possibility of successful quarrying. Numerous little quarries have been opened at various points along Big Hill creek and also in other coulées immediately to the west exposing stone similar to that described below. The present company has 3 quarries about one and a half miles up the stream from Cochrane. These quarries are opened in the face of a more or less continuous exposure on the west side of the valley at a considerable elevation above the stream: they are described as No. 1, No. 2, and No. 3 in order from the northeast to the southwest.

No. 1.—This, the most northerly opening, is about 125 feet long in the side of the hill but not at the brow of the escarpment; in consequence, the overburden as given below would greatly increase if the excavation were extended farther into the hill. So little stone has been removed that the present face represents the condition of the formation at a very limited distance from the natural exposure. The section is as follows:—

10 ft.—Soil, shale and thin sandstone.
6 ft.—Sandstone, mostly thin but with some good stone towards the bottom.
21 ft. 6 in.—Sandstone in practically 3 heavy beds with irregular partings. Minor horizontal partings divide the formation locally but heavy stone is obtainable in quantity.

Jointing is better defined than in most of the Paskapoo exposures as there is one very distinct set parallel to the face (N.30°E.) with a dip of 70° to the southeast: these divisions are 8 to 10 feet apart. Joints in the opposite direction occur, but they are far enough apart to permit the quarrying of stone of any practical length. The upper of the three heavy beds is the softest and most uniform but it is not devoid of the unfortunate hardhead (1299). The middle bed contains still more hardhead and presents much false bedding and irregular, twisted and inclined lamination. The lower bed contains much hardhead with a pronounced and continuous layer at the bottom. Along joint planes and bedding planes soft stone surrounds

PLATE XLVII.

Paskapoo sandstone. Quarry of the Shelley Quarry Company, Cochrane, Alberta.

Paskapoo sandstone. Parliament buildings, Edmonton, Alberta.

the hardhead to a depth of about 9 inches. False bedding and a decided reediness are more or less present throughout the formation and are more pronounced towards the bottom and at the northeast end of the excavation.

The stone already removed probably contained much less hardhead than is shown by the present face in which the amount of this undesirable material is so great that a further extension of the quarry, at least in the lower layers, does not seem to be warranted (Plate XLVII).

The quarry is now idle but the following equipment is on the ground:—

1 derrick with boiler and steam hoist.
1 steam drill.
1 auxiliary horse hoist replacing the steam hoist.

No. 2.—This opening is about 200 yards southwest from that described above. The section shows 8 to 10 feet of thin stone overlying 12 feet of heavy beds. Joints are developed as in No. 1. Differences in colour and in the development of reedy structure are to be observed and also some bands of bluish stone which are not as hard as the typical hardhead. Very large stone can be quarried in quantity but most of the blocks shows the unfortunate hard centres. No. 1300 is a selected example of the best stone.

No. 3.—This opening shows 20 feet of stone under a very moderate stripping. The sandstone is practically one single bed but it is locally divided by curving horizontal partings. Hardheads occur throughout the face but not in sufficient amount to prevent the obtaining of much good stone. The lower beds show bluish stone of moderate hardness: each block is altered into the typical grey material to a depth of about 9 inches. No. 1301 is a selected example and shows less reediness and false bedding than the average of the product.

The conditions in these quarries prove that the desirable stone is only to be procured in the superficial zone, as the hard stone is encountered in every instance at a very moderate depth. There can be little doubt that the desirable grey stone is obtainable only where a free circulation of waters has been able to effect a complete alteration of the natural blocks lying between bedding and joint planes. Where this circulation is partially checked, mineral solutions have concentrated cementing material in the centres forming hardhead. It is likely that the softer blue stone observed in some of the lower layers represents the original stone which has been superficially altered into the grey material. Future development in this area undoubtedly lies in the opening of shallow quarries along the escarpment which presents numerous favourable sites.

The stone: No. 1299.—A fine-grained greyish sandstone showing distinct cross bedding and reediness. It is finer in both grain and reediness than No. 1294 from the old Glenbow quarries. It must be remembered, however, that this remark applies to the specimen and not necessarily to the whole output of the quarry. It is about the same in grain as No. 1298 but it is decidedly more grey and less yellow. This stone is illustrated in No. 5, Plate LVI.

The microscope reveals the fine grain of the stone as the quartz fragments average about ·15 mm. in diameter. Muddy feldspar grains are present and the usual black indeterminable specks.

The corrosion test produced little effect but the frozen cube showed serious disintegration. This stone is finer in grain and lower in strength than No. 1301 from the same quarries; its pore space is higher and it is much softer. The very high chiselling factor is due to the laminated structure which favours the throwing out of large chips along the track of the chisel. The considerable differences between this stone and No. 1301 well illustrate the variability of the Paskapoo sandstones even at short intervals.

The physical properties are given below:—

Specific gravity	2·675
Weight per cubic foot, lbs	134·16
Pore space, per cent	19·54
Ratio of absorption, per cent, one hour	5·61
" " " " " two hours	5·61
" " " " " slow immersion	6·66
" " " " " in vacuo	9·07
" " " " " under pressure	9·08
Coefficient of saturation, one hour	0·61
" " " two hours	0·61
" " " slow immersion	0·73
" " " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	8,807·
" " " " wet	6,231·
" " " " wet after freezing	3,490·
Transverse strength, lbs. per sq. in	657·
Shearing strength, lbs. per sq. in	707·
Loss on corrosion, grams per sq. in	0·05271
Drilling factor, mm	32·3
Chiselling factor, grams	23·24 II

Compared with the typical Calgary stone this example shows about 5 per cent less cement of a similar character except for a considerably lower content of ferrous oxide.

The analysis is as follows:—	Per cent
Insoluble residue	76·00
Soluble portion	24·00

Partial analysis of soluble portion:	Per cent
Lime	9·12
Magnesia	2·64
Ferric oxide	1·50
Ferrous oxide	0·45
Carbonic acid	8·36
Total of constituents determined	22·07

No. 1301.—A medium to fine-grained, grey sandstone with a slightly brownish cast and "peppery" effect: it somewhat resembles the stone from Brocket described as No. 1388 on page 208 but it is slightly darker. The specimen is almost free from reediness (No. 6, Plate LVI). The constituent grains are variable in size but seldom exceed ·25 mm. in diameter. The grains are mostly rounded and consist of quartz, cloudy decomposed feldspar, and opaque indeterminable fragments in about equal amounts. When very thin, these dark grains are brownish and show crystalline characteristics but their mineral nature is not determinable. In the hand specimen they appear as black specks giving the stone a "peppery" appearance. Although referred to more definitely here, these black grains are not uncommon in many of the Paskapoo sandstones.

This is a much harder and better grained stone than No. 1299: the corrosion test produced no effect and the frozen cube suffered very little apparent injury.

The physical properties are given below:—

Specific gravity	2·669
Weight per cubic foot, lbs	138·32
Pore space, per cent	16·98
Ratio of absorption, per cent, one hour	4·55
" " " " " two hours	4·65
" " " " " slow immersion	5·47
" " " " " in vacuo	7·62
" " " " " under pressure	7·64
Coefficient of saturation, one hour	0·59
" " " two hours	0·60
" " " slow immersion	0·71
" " " in vacuo	0·99
Crushing strength, lbs. per sq. in., dry	10,427·
" " " " wet	7,783·
" " " " wet after freezing	4,934·
Transverse strength, lbs. per sq. in	660·
Shearing strength, lbs. per sq. in	587·
Loss on corrosion, grams per sq. in	0·0479
Drilling factor, mm	21·
Chiselling factor, grams	6·08 II

No. 1300.—Very like 1301 but coarse and with numerous plant remains: it is rather soft and serves to illustrate the great variation in the stones of this locality. These quarries are out of commission at present. The stone may be seen in the west wing of the Canadian Pacific Railway station at Calgary.

Red Deer Area.

The Paskapoo sandstones are covered by only a slight amount of soil along the line of the Edmonton-Calgary branch of the Canadian Pacific railway between Beddington and Red Deer; in consequence, outcrops of rock are seen in many coulées and river banks and on the weathered side of small knolls. Quarrying on a very small scale has been attempted at a few localities, the more important of which are described below.

The stone is essentially a grey type, in places showing a yellowish cast and approaching the variety from Glenbow. While some stone for local use can undoubtedly be obtained at a number of points, I have observed no location in this area which gives promise of producing desirable stone on a commercial scale.

Peter P. Dick, Didsbury, Alberta.

The quarry is situated on the southwest quarter of section 7, township 31, range 1 west of the fifth meridian. The exposures occur in the side of a ravine which extends to a depth of 30 feet below the floor of the quarry. The face of the cutting is about 100 feet long in a north and south direction and presents the following section:—

4-5 ft.—Drift.
10 ft.—Thin-bedded stone.
4 ft.—Heavy-bedded stone.
——Rough fossiliferous layers.

The lower, heavy-bedded stone is divided by curved parting planes into lenticular beds. These thicker beds do not seem to be sharply divided from the upper thin-bedded material but appear to result from the cessation of secondary thin parting: it is probable, therefore, that a greater thickness of heavy stone would be found by more extended development. Main joints traverse the formation N.20°W. and dip 80° southwestwardly: they are about 5 feet apart. Joints roughly at right angles to the above are developed irregularly at considerable intervals. The stone (1277) seems to become lighter in colour on exposure and to assume a cast of yellow, although after five years, it is not really yellow.

The occurrence of a fossiliferous layer below the sandstone and the fact that coal is found at a depth of 20 feet in Didsbury indicate a low position in the Paskapoo formation for this exposure.

The stone: No. 1277.—A medium to fine-grained type of sandstone of grey, rather than yellow colour: it resembles No. 1294 from Glenbow and is almost identical with certain types from Brocket.

The product of this quarry was used in the grist mill and in a number of foundations in Didsbury. The mill was built in 1910 and shows much variation in the colour of different blocks: some are still of true grey colour while others have weathered to dark yellow. The surface of most of the stones can easily be abraded with the thumb nail, and certain of the blocks, particularly those showing false bedding, are rather badly disintegrated.

Christopher Lorine, Didsbury, Alberta.

This quarry lies across the ravine and a short distance northeast of Mr. Dick's property. About 15 feet of sandstone is exposed under a slight overburden. All the stone is essentially thin-bedded but somewhat thicker lenticular beds occur towards the bottom. Cross bedding is prominent and much carbonaceous matter is present in the stone. Wavy irregular joints cross in both northeast and northwest directions. The excavation extends about 100 feet along the bank but neither the quality of the stone nor the structural features of the formation look promising.

The stone: No. 1279a.—Practically the same as No. 1277 from Dick's quarry but slightly coarser. The weathered stone is decidedly yellow.

Wm. Gunston, P.O. Box 466, Innisfail, Alberta.

A small amount of stone has been obtained from two different properties belonging to Mr. Gunston. The first of these is situated on the northwest quarter of section 1, township 35, range 27 west of the fourth meridian and the second is on the southwest quarter of section 27, township 35, range 28 west of the fourth meridian. These locations are described below as the eastern and the western quarries respectively.

Eastern quarry.—The quarry extends for 100 feet along the northwestern bank of a coulée which has a general direction of N.60°E. About 10 feet of stone are exposed with scarcely any immediate overburden; the bank, however, extends fully 20 feet higher, but whether this 20 feet is drift, or stone covered with talus, has not been ascertained. The stone exposed shows thin beds for the upper 4 or 5 feet while the lower part is fairly heavy-bedded but with irregular planes of parting. In places stone of 18 inches in thickness could be procured. False bedding is distinctly developed and is to be observed over the greater part of the exposed face. No regular systems of joints could be made out but the jointing, while irregular, is not excessive. There is little doubt that a considerable quantity of stone could be quarried here without undue loss. The stone is all of a uniform bluish-grey colour and seems to retain its original tint remarkably well, as the material used in Mr. Gunston's barn has altered very little after two years' exposure. It was observed also that the stone in this building has become very much harder than that exposed on the face of the quarry (1274).

Western quarry.—The exposures at this point occur on both the north and the south sides of a ravine which strikes nearly due east and west.

On the south side, the actual exposure is about 100 feet long, but, undoubtedly, stone would be found for a much greater distance under a slight talus. The actual overburden at the quarry is about 5 feet but this would probably increase to 15 or 20 feet if the excavation were extended. The upper 6 feet or more of stone is thin-bedded and much shattered: the lower stone is in variable beds with lenticular planes of parting. Material 2 ft. 6 in. thick could be obtained from some of the heavier beds. All the fresh stone is of a grey colour but in exposed positions it shows a distinct tendency to weather yellow (1275).

On the south side of the ravine, heavy bedded stone occurs in a face of about 6 feet under 15 to 20 feet of drift. The beds are in places 2 to 3 feet thick but they are lenticular in shape and seem to be rather badly jointed. The exposed surface has weathered distinctly yellow.

The stone: No. 1274.—Practically identical with No. 1277 from Didsbury. The stone is rather soft—insufficient coherence seems to distinguish these stones from the apparently similar material from Cochrane and Brocket.

No. 1275.—A fine-grained greyish sandstone with distinctly reedy structure: it is darker and slightly more yellow than the average of the stone from the Glenbow-Cochrane area but it is less yellow than the Calgary type of stone: it is more yellow than No. 1274. The stone is very susceptible to the action of frost as it crumbled to powder under the freezing test. On the other hand, it suffered no appreciable change in colour under the corrosion test. The stone is so soft that no reliable figure could be obtained for either test. Some of the drilling tests were as high as 112 mm. The chiselling factor is also rather uncertain but undoubtedly very high: it was found to vary greatly on account of excessive flaky side chipping.

The physical properties are given below:—

Specific gravity	2·687
Weight per cubic foot, lbs	127·17
Pore space, per cent	25·38
Ratio of absorption, per cent, one hour	8·35
" " " " " two hours	8·57
" " " " " slow immersion	9·13
" " " " " in vacuo	12·51
" " " " " under pressure	12·66

Coefficient of saturation, one hour	0·66
„ „ „ two hours	0·68
„ „ „ slow immersion	0·72
„ „ „ in vacuo	0·98
Crushing strength, lbs. per sq. in., dry	4,905·
„ „ „ „ wet	3,283·
„ „ „ „ wet after freezing	0,000·
Transverse strength, lbs. per sq. in	366·
Shearing strength, lbs. per sq. in	305·
Loss on corrosion, grams per sq. in	0·08572
Drilling factor, mm	high
Chiselling factor, grams	21·37 II

Stone from the western quarry was used in the Simpson block and in the basement of the school in Innisfail. The general tendency to yellow weathering is to be observed in these structures but certain blocks seem to have resisted much better than the average as the greyish colour has scarcely altered.

As usual, the practice of using joint planes for rock face has not added to the appearance of the buildings. There is little evidence of deterioration except in regard to colour and the stone in the buildings is perceptibly harder than the freshly quarried material. The masonry has certainly resisted the weather better than would be expected from the nature of the stone.

It is stated that hammer broken stone was delivered in Innisfail at $10 per cord.

Frank F. Malcolm, Innisfail, Alberta.

In the valley of the Red Deer river east of Innisfail, on the northeast quarter of section 6, township 28, range 36 west of the fourth meridian are cut banks exposing about 10 feet of soft decomposed sandstones with some harder bands (1276). At low water, masses of this harder stone have been gathered from the bed of the river and have been used for structural purposes, *e.g.*, in the basement of the Bank of Commerce in Innisfail. There are no possibilities of serious production at this point.

The stone: No. 1276.—A very hard, dirty greyish-green sandstone. This stone resembles some of the greenish Dakota or hard Edmonton stones and possibly belongs to the latter series. It is too hard and of too poor colour and weathering properties to be of any use except for the roughest purposes.

In connexion with the Innisfail district may be mentioned small quarries near Grainiston about 6 miles southeast of Innisfail, and at a point about 13 miles west of Olds.

Red Deer, Alberta.

Stone is exposed in the banks of the Red Deer river above the town where it has been quarried at one or two points. Close to the town the sandstone occurs in thin beds associated with shales and presents no economic possibilities: this stone is described below as No. 1259. A short distance farther up stream are situated the only quarries in this immediate vicinity.

The stone: No. 1259.—A very fine-grained sandstone of a true light grey colour but with a strong tendency to weather yellow. The stone is rather hard and is of a "dead" appearance: the cement seems to be largely lime.

John T. Moore Estate, Red Deer, Alberta: John T. Moore, Toronto, Ont.

A small quarry was formerly worked on the southwest quarter of section 17, township 38, range 27 west of the fourth meridian, at a point on the south bank of the Red Deer river about a half mile above the town of Red Deer. The quarry extends a distance of nearly 100 yards along the bank, but excepting at the western end, the face is hidden by an accumulation of debris. At this point the stone is covered by about 15 feet of drift beneath which the sandstone is exposed to a depth of 8 feet. The stone lies in horizontal beds but the bedding planes are not regular. The average thickness is about 10 inches but heavier stone may be obtained in places. The lenticular character of the bedding would occasion some loss in quarrying. Systematic jointing is not to be observed on the small extent of face available. The weathered stone presents a uniform grey colour with some evidence of reediness and false bedding. The stone on the exposed face is rather soft but blocks lying in the quarry are considerably harder and show vegetable matter in places.

Further exploitation of this quarry would be difficult on account of an increasing overburden. Upstream, this overburden would soon become prohibitive.

Similar stone was quarried in very small amount on the adjoining property of E. P. Cronqvist.

The stone: No. 1261.—A fine-grained, soft, true grey sandstone like No. 1259 but softer and with numerous remains of plants. Softness is probably the worst feature of this stone.

Stone from this quarry was used in the construction of the Green block in Red Deer (Plate XLIX). For the most part this building presents a clean greyish colour, but yellow stains are to be observed in places as well as yellow skins where a joint plane has been used for the rock face. Chisel marks have been retained for the 12 years that the building has stood but the surface of the stone may be abraded by the thumb nail indicating a superficial decay. The coursing averages a foot in thickness with heavier stone in places. On the whole, the stone seems to stand the weather reasonably

Paskapoo sandstone, Red Deer area. Green's block, Red Deer, Alberta.

well but as usual the rejection of a small number of blocks would have added greatly to the appearance of the structure. It would appear that a tendency to yellow weathering exists as the more exposed parts of the building show a yellow tinge not observed in more protected positions.

Sills in the Arlington hotel in Red Deer have broken and are badly disintegrated: they appear to be of this stone but I have no certain information as to their origin.

In connexion with this area may be mentioned the occurrence of sandstones along the line of the Canadian Pacific railway to Rocky Mountain House: they were observed at the following points:—

Cut west of Sylvan lake.

In creek and on railway east of Kootube.

About a mile east of Loch Earne.

These occurrences are sufficient to suggest possible economic outcrops in this district.

Entwistle Area.

Paskapoo sandstones are exposed at the point where the Grand Trunk Pacific railway crosses the Pembina river about 34 miles west of Edmonton. The beds are thick and accessible but their economic importance is doubtful on account of the soft and friable nature of the stone. In many important respects, the sandstones of this area differ from those of the areas previously described. On this account a full description is given of the three typical varieties on which tests have been conducted in full. Although none of these stones reach a high standard as building stone, some interesting results bearing on questions of alteration and weathering have been secured.

Pembina Quarries, Limited; John Kenwood, president, Edmonton; L. W. Hall, lessee and manager, 10608, 123rd. St., Edmonton, Alberta.

The company controls quarry lands on both sides of the river and both above and below the Grand Trunk Pacific railway bridge as follows:—

South of the track.

Part of southwest quarter, section 20, township 53, range 7 west of fourth meridian.

North of the track.

12½ acres adjoining Entwistle townsite on the north. Part of section 29, township 53, range 7 west of the fourth meridian, including 100 acres south of the river and 40 acres on the north side.

The river valley is 200 to 250 feet deep and presents the following general section:—

20 ft.—Drift.

50 ft.—Paskapoo sandstones.

130-180 ft.—Edmonton sandstones, shales, and coals, mostly covered with debris.

On the southern property (section 20), stone is exposed along the whole of the frontage on the river. At the point where quarrying has been carried on the section is as follows:—

20 ft.—Drift.
28 ft.—Blue and buff sandstone in fairly heavy but irregular beds with some hard, flinty bands. The whole passes insensibly down into
28-30 ft.—Grey sandstones in beds ranging from 10 inches to 3 feet thick.
To water.—Thin sandstones and shales.

The actual quarry face is 320 feet long in a direction a little south of west. The jointing is irregular but the main series runs about north-east: a second series at right angles is less distinctly developed, and minor fracturing has further broken the formation particularly in the upper stone. These upper layers (Plate L) originally were of the blue variety (1203) which has been altered along the planes of jointing and bedding into the buff stone (1204). In some cases the whole block between divisional planes has been uniformly altered; in other cases a blue core remains. About 75 per cent of the exposed surface is buff. The beds average 5 to 18 inches in thickness and probably one-third of the stone would make blocks of sufficient size for coursing. Hardhead bands (1205) occur in limited amount. Some variation in grain and in the cementing material is to be observed in both the blue and the buff varieties, neither of which occurs in distinct beds. Blocks of reasonable size can be procured in either variety from selected parts of the face. There can be no doubt that the buff stone is derived from the oxidation of the blue variety and it is highly probable that the hardhead layers are also the result of secondary action with the infiltration of a large amount of carbonate of lime. In presenting soft blue and buff or yellow stone together with hardhead, these beds are in exact accord with the quarries at Monarch but they differ from the other Paskapoo sandstones in the soft character of the original blue stone. The blue and the buff stones are very soft and of little strength; they are prone to rapid decay under the influence of the weather, particularly the yellow variety, as attested by the serious disintegration observed in blocks which have been lying in the quarry for 2 years.

The lower grey beds (1202) are thicker, more uniform and less shattered than the upper stone: they differ considerably in grain and show a different structure under the microscope; nevertheless, they fade imperceptibly upwards into the overlying beds and contain patches of yellow stone near the top. This stone hardens considerably on exposure and has a remarkable property of retaining water: two-inch cubes wetted and exposed to the

Paskapoo sandstone. Upper beds in quarries of Pembina Quarries, Limited, Entwistle, Alberta.

ordinary temperature of the laboratory were still distinctly wet after 36 hours. This grey stone could certainly be quarried in large blocks but it is very friable, low in strength, and subject to rapid disintegration under the weather.

The northern property (section 29) shows stone along the entire river front under practically the same conditions as on the other property. The upper 25 to 40 feet shows buff stone under 20 feet of drift. Hard flinty bands and cores occur but no blue stone is exposed as only the naturally weathered surface is exposed. These layers pass imperceptibly into the lower grey stone which contains lignitic bands and some shales towards the bottom. The natural surface is very soft and in places is little more than incoherent sand.

It is stated that the company installed $16,000 worth of machinery at the time the quarry was operated 2 years ago. Of this equipment there now remains only two one-ton steel derricks, one two-ton wooden derrick, and one steam pump. Fifty-two men were employed at the time the quarry was worked. Six men were at work getting out a carload of stone at the time of my visit. Mr. Hall proposes to introduce the stone in Edmonton where he is prepared to dispose of it at 10 cents per cubic foot, f.o.b. cars. This carload was shipped on May 18th; it contains blocks 5 ft. by 2 ft. by 1 ft. The blue stone in 2 years time has acquired a yellowish-grey tint and is rapidly passing into the buff variety.

The stone: No. 1202.—A coarse-grained, grey stone with a pepper and salt effect. The colour is uniform and little reediness is apparent in the specimen. The surface dresses rough owing to the extreme friability of the material. In appearance it resembles No. 1268 from the Edmonton formation of the Rocky Mountain House area and also No. 1294 from Cochrane. The mineral grains are rounded for the most part and occasionally reach a diameter of one mm. although the general average is less. These grains are about one-half quartz; and the other half is composed of cloudy to opaque grains representing indeterminable rock fragments, among which the black opaque type common to all these stones is abundant. The cement seems to be deficient but it reacts strongly for carbonate of lime. This stone is very different in structure from No. 1203 and from any other sandstone tested for this report.

The pore space is remarkably high and the cement deficient; the stone, therefore, is very friable, particularly when wet. Under the freezing test the cube crumbled to powder. The corrosion test produced a general darkening of colour and a peculiar blotched appearance. The stone is so soft that it could not be examined for hardness under the conditions of our tests.

The physical properties are given below:—

Specific gravity				2·703
Weight per cubic foot, lbs				115·466
Pore space, per cent				31·57
Ratio of absorption, per cent, one hour				11·45
"	"	"	two hours	11·45
"	"	"	slow immersion	12·76
"	"	"	in vacuo	16·76
"	"	"	under pressure	17·072
Coefficient of saturation, one hour				0·67
"	"		two hours	0·67
"	"		slow immersion	0·74
"	"		in vacuo	0·98
Crushing strength, lbs. per sq. in., dry				1,253·
"	"	"	wet	636·
"	"	"	wet after freezing	000·
Transverse strength, lbs. per sq. in				147·
Shearing strength, lbs. per sq. in				105·
Loss on corrosion, grams per sq. in				0·3028
Drilling factor, mm				....
Chiselling factor, grams				....

As this stone and the buff variety (No. 1204) from these quarries have almost the same pore space, approximately 31 per cent, and also a nearly equal amount of cement, a comparison of the analyses of the two stones is interesting. Such a comparison shows that the present stone is considerably higher in carbonates and consequently lower in argillaceous matter than No. 1204. If these two stones were derived from the same source, it follows that there must have been an addition of argillaceous matter to the cement of No. 1204. I am inclined to believe, however, that this grey stone is of distinct origin and represents a different condition of sedimentation.

As already noted, the present stone is remarkably bibulous and retains the absorbed water with great persistency. I am inclined to ascribe this peculiarity to the presence of hydrated silica. The method of analysis adopted has removed this material from the cement and added it to the insoluble residue, thus introducing an error of considerable moment. Further investigations are desirable along this line.

The analysis follows:—

	Per cent
Insoluble residue	30·89
Soluble portion	19·11

Partial analysis of the soluble portion:	Per cent.
Lime	5·34
Magnesia	2·12
Ferric oxide	2·14
Ferrous oxide	1·72
Carbonic acid	5·27
Total constituents determined	16·59

For further remarks on the chemical character of the cement in this stone see page 246.

No. 1203.—A distinctly bluish, medium grained sandstone; it is of lighter blue colour and distinctly coarser grain than the blue stone from Monarch. It is much harder and more resistant than No. 1204 and it seems to have a coarser grain but this can be due only to surface appearances as the yellow stone, No. 1204, is derived from the oxidation of the present type. The microscope shows quartz grains of ·3 to ·5 mm. in diameter which occur sparingly. Other grains of equal size present varying degrees of opacity with cloudy margins. The matrix is abundant and of a fine-grained crystalline structure which can be distinctly made out except where invaded by the cloudy margins of decomposing feldspar crystals. This crystalline matrix which is doubtless calcite has not been found in so apparent amount in any other soft Paskapoo sandstone. The cloudy grains are probably feldspar but the dark and truly opaque grains show no optical properties: they appear as black grains in the hand specimen and are common in many of the sandstones.

The corrosion test resulted in the entire loss of the blue colour and an alteration to a distinct yellow. The frozen cube was about half reduced to powder. While the strength and hardness tests are satisfactory, the unfortunate results of the corrosion and freezing tests, together with the high coefficient of saturation, indicate very poor weathering properties.

The physical properties are as follows:——

Specific gravity	2·704
Weight per cubic foot, lbs	146·4
Pore space, per cent	13·27
Ratio of absorption, per cent, one hour	2·41
" " " two hours	2·63
" " " slow immersion	5·34
" " " in vacuo	5·48
" " " under pressure	5·66
Coefficient of saturation, one hour	0·42
" " two hours	0·46
" " slow immersion	0·94
" " in vacuo	0·96

Crushing strength, lbs. per sq. in.,	dry	5,893·
„ „ „	wet	3,264·
„ „ „	wet after freezing	000·
Transverse strength, lbs. per sq. in		625·
Shearing strength, lbs. per sq. in		430·
Loss on corrosion, grams per sq. in		0·1675
Drilling factor, mm		12·6
Chiselling factor, grams		7·42 II

There can be no doubt that No. 1204 is derived by alteration from No. 1203, and No. 1205 is probably a form of the same original material either primary or secondary. For comparative purposes the analyses of these three stones are given side by side with No. 1202:—

TABLE A.

	No. 1202	No. 1203	No. 1204	No. 1205
Insoluble residue	80·89	37·41	81·29	48·38
Soluble portion	19·11	62·59	18·71	51·62
Partial analysis of the soluble portion:				
Lime	5·34	30·70	2·51	26·24
Magnesia	2·12	1·06	1·86	0·98
Ferric oxide	2·14	0·64	3·78	0·64
Ferrous oxide	1·72	2·17	1·66	1·72
Carbonic acid	5·27	22·47	1·90	19·94
Total constituents determined	16·59	57·04	11·71	49·52
Undetermined constituents	2·52	5·55	7·0	2·10

The above analyses give the percentage by weight of the different substances but as the amount of cement varies in the different stones it is advisable to rearrange the table so that the different substances will appear as percentages of the total cement present. The following table is therefore more useful in comparing the four cements as to their *chemical nature.* The figures of this table can not be regarded as very accurate for they are based on the assumption that "soluble matter" and "cement" are synonomous. It is probable that the cement contains insoluble material which, by our method of analysis, has been added to the insoluble residue as well as the silica which is in combination with the other elements in the cement. The table is therefore to be regarded as expressing the composition of the soluble portion of the cement entirely disregarding the soluble silica.

TABLE B.

	No. 1202	No. 1203	No. 1204	No. 1205
Lime	27·2	49·	13·4	50·8
Magnesia	11·	1·7	10·	1·9
Ferric oxide	11·2	1·	20·2	1·2
Ferrous oxide	9·	3·4	9·	3·3
Carbonic acid	27·5	35·9	10·	38·6
Other constituents, alumina, etc	13·1	8·8	37·4	4·

While the above table is as good as can be prepared from the figures available, in order to institute comparisons as to the actual chemical nature of the different cements, it is independent of the amount and also makes no allowance for the fact that the cement does not fill all the space between the mineral grains. The table can not be applied in drawing deductions as to the changes that have occurred in the alteration of one cement into another because it makes no allowance for materials abstracted from a primary cement and represented in the altered stone by vacuities only.

A satisfactory compilation for the purpose of tracing the changes that occur in the cement must be based on volume and not on weight. If we can ascertain the actual amount of the different substances in the cement of a cubic foot of stone, unaltered and altered, we can make direct comparisons as to the nature of the alteration. Now we have ascertained the actual weight per cubic foot of the stones in question we can readily construct a table to show the amount of the different substances in a cubic foot of each stone: a table of this kind is not only better for comparative purposes but it is much more accurate as it is quite independent of both total cement and pore space.

In the following table the figures given for No. 1205 are based on a weight of 160 lbs. per cubic foot, which is an approximation only.

TABLE C.

	Lbs. per cubic foot.			
	No. 1202	No. 1203	No. 1204	No. 1205
Lime	6·167	44·94	2·9	41·98
Magnesia	2·44	1·55	2·53	1·56
Ferric oxide	2·47	·94	4·37	1·02
Ferrous oxide	1·98	3·17	1·82	2·75
Carbonic acid	6·08	32·89	2·20	31·9
Alumina, etc	2·9	8·125	8·1	3·36

Returning to a consideration of Nos. 1203 and 1204, we see from Table A that there is a much more abundant cement in No. 1203 with an excess of carbonates. Table "B" emphasizes the highly ferruginous and aluminous character of the cement of No. 1204 as compared with the strongly calcareous cement of No. 1203.

The changes that have occurred in the alteration of No. 1203 into No. 1204 are best shown by Table C. The two columns show that the amount of magnesia in the altered stone is increased by more than a pound per cubic foot, and that the aluminous matter has remained practically the same. The comparison of the other constituents requires a little calculation. First as to the iron:—the total content of metallic iron in the soluble cement of a cubic foot of No. 1203 is 3·123 lbs. and of No. 1204 it is 4·374 lbs. It is apparent therefore that there has been an actual addition of iron to the cement in the process of alteration. Second as to the carbonates:—32·89 lbs. of carbonic acid in No. 1203 requires 41·86 lbs. of lime to neutralize it, leaving 3·08 lbs. of lime in some other form than carbonate. In No. 1203 a similar computation shows that the lime present is just sufficient to combine with the carbonic acid and that 3·08 lbs. of excess lime has disappeared. This may be explained in part by a replacement of lime by magnesia but the fact remains that a certain amount of lime, not in the form of carbonate, has been removed from the stone in the process of alteration. These various observations justify us in the following conclusions as to the course of alteraton:—

(1). A large abstraction of carbonates by solution.

(2). An oxidation of ferrous oxide into ferric oxide.

(3). A decomposition of the ferro-magnesian constituents of the mineral grains resulting in an addition to the cement of iron, magnesia, and possibly lime.

(4). A conversion of lime into carbonates and its removal by solution.

(5). Little or no addition of aluminous matter to the cement.

No. 1204.—A medium-grained yellow sandstone—the most yellow of the Paskapoo sandstones tested. It is derived from the oxidation of the blue stone, No. 1203, but it appears to have a finer grain and it has lost the speckled appearance of No. 1203. It is very soft and difficult to handle without abrasion. A description of the chemical characteristics of the cement is given under No. 1203 on page 246.

The corrosion test did not produce much change in colour but it increased the muddy aspect of the stone. The frozen cube disintegrated entirely. The high porosity and coefficient of saturation are in accord with the behaviour of the stone. The drilling test was too severe as the test slab broke to pieces under the first few blows of the drill and the chiselling test was little more satisfactory.

The physical properties are as follows:—

Specific gravity	2·72
Weight per cubic foot, lbs.	115·784
Pore space, per cent.	31·81
Ratio of absorption, per cent, one hour	12·38
" " " " " two hours	12·77
" " " " " slow immersion	14·42
" " " " " in vacuo	16·69
" " " " " under pressure	17·157
Coefficient of saturation, one hour	0·73
" " " two hours	0·84
" " " slow immersion	0·83
" " " in vacuo	0·97
Crushing strength, lbs. per sq. in., dry	1,793·
" " " " wet	600·
" " " " wet after freezing	000·
Transverse strength, lbs. per sq. in.	261·
Shearing strength, lbs. per sq. in.	201·
Loss on corrosion, grams per sq. in.	0·39348
Drilling factor, mm.	high
Chiselling factor, grams	38·00 II

No. 1205.—Typical blue hardhead with a high content of lime: it differs only by a shade of colour from No. 1358 from the Porcupine hills, No. 1345 from Sandstone and No. 1287 from Calgary. The stone weathers a dirty brown colour: the chemical properties are discussed on page 246.

Summary—Paskapoo Sandstone.

The Paskapoo sandstone is the most important building stone of Alberta: it has been quarried in the vicinity of Calgary, at points on the Crowsnest line of the Canadian Pacific railway, and at other less important centres. The stone is a soft and easily carved variety, varying greatly in grain and colour; blue, yellow and grey types are the more common. An account of the distribution of the formation and a general discussion of the quality of the stone may be found on pages 189 to 194.

The stone has been used in the construction of many of the important buildings in Alberta and to its use is due the characteristic appearance of the cities of Calgary and Edmonton.

A partial list of important buildings of Paskapoo sandstone follows:—

Edmonton, Alberta.

Bank of Nova Scotia (base).
Merchants Bank.
Bank of Montreal.

Imperial Bank (base of Tyndall stone).
Bank of Commerce (base).
Court house (Plate XL).
Parliament buildings (some Ohio sandstone and some Indiana limestone).
Government house (cut stone is partly Ohio sandstone).
Athabaska hall, University of Saskatchewan (trimmings).

Calgary, Alberta.

City hall (Plate XLIII).
Carnegie Public Library (Plate XLVI).
Land Titles building (Plate XLII).
Canadian Pacific Railway station.
Imperial Bank building.
Bank of Commerce.
Royal Bank building.
Calgary Grain Exchange.
Bank of British North America building.
Central Methodist church.
Alberta hotel.
Dominion Trust Company's building.
Royal Bank.
Normal school.
Knox church (Plate XLI).
Custom house.
Young Men's Christian Association building.
Cathedral of the Redeemer.
McDougall block.
Numerous churches, schools, and business blocks.

Lethbridge, Alberta.

Molson Bank.
Wesley Methodist church.
Bank of Montreal.
Court house (Plate XXXVIII).

Macleod, Alberta.

Hudson Bay Company's building.
Queen's hotel.
Numerous business blocks.

Medicine Hat, Alberta.

Royal Bank (Plate XXXVIII).
Post-office.

Literature:—Geol. Sur. Can., Ann. Rep. 1879-80, p. 134B.
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FORT UNION FORMATION.

Souris River Area.

The valley of the Souris river near Pinto and Roche Percée in southern Saskatchewan has been referred to since the earliest days of exploration as a locality in which sandstone exposures constitute a striking topographic feature. An extensive account of the region together with reference to previous reports may be found in Mr. Dowling's report on "The Coal Field of the Souris River" being Part F of the Fifteenth Volume of the Annual Report of the Geological Survey of Canada. These rocks have been considered to be of Laramie age but as that term is losing its significance in the light of recent investigations, we may consider these beds as occupying a position at the base of the Tertiary system. According to Dowling they belong to the Fort Union group which is more or less comparable with the Paskapoo of Alberta.

Briefly, these sandstones present an upper hard, and a lower soft layer, neither of which gives any promise as a source of building stone. The soft material, in every instance, is much too friable to be of any use and the hard upper stone could be employed only for purposes of rough local construction.

On the south side of the valley about a mile above Pinto the upper hard stone crops out in a cliff of limited height but the soft stone is largely hidden under a talus. Scattered in this vicinity are numerous blocks of the hard stone which might be utilized for rough purposes. Some of these blocks are almost flinty in hardness and they all seem to weather a dirty yellow colour (1396). Descending the valley to a point directly opposite Pinto station, vertical cliffs are seen which expose the formation more clearly. The upper hard stone is from one to four feet thick and in places is strongly laminated

(1394). Beneath this are 2 or 3 feet of very soft sandstone followed downward by 20 feet or more of slightly harder but still very soft stone (1395). Numerous exposures, quite similar in character, occur between this point and Roche Percée: a sample taken about halfway down shows the laminated type of upper rock (1397). The cliffs of the south side of the valley near Roche Percée show no appreciable difference and the exposures on the opposite side of the river east of Roche Percée station are practically the same. Here it was observed that some of the soft stone which had fallen from the face of the cliff is slightly harder (1398) but the face itself is quite as soft as at the other localities.

Exposures occur down the valley below Roche Percée and also in the valleys of tributary streams but there is no reason to believe that any difference would be found in the quality of the stone.

The stone: No. 1394.—This is a fine-grained, yellowish-grey, quartzitic sandstone with calcareous cement: it is fairly massive and without distinct reediness. The stone is rather harder than the average Paskapoo type that is actually worked but it is by no means as hard as the Dakota sandstones of the foothills. Formational features are more detrimental to the use of this stone than the quality of the material as shown by a small specimen.

No. 1395.—This is a soft, friable, fine-grained sandstone of a green-yellow-grey colour. It is so soft that the specimen has broken to small pieces despite careful packing.

No. 1396.—A hard laminated stone of dirty yellow-grey colour: it consists of a very fine-grained crystalline limestone base with scattered sand grains and mica on the parting planes. Useless.

No. 1397.—A strongly laminated, greenish-yellow sandstone with a marked tendency to split on the planes of stratification which are accentuated by the alteration of the stone to a more yellow colour. The material is softer than No. 1394 and might be employed for rough work.

No. 1398.—Coarser than 1395 and considerably more coherent but I doubt if it is sufficiently hard to have any value as a building material.

CHAPTER V.

GRANITES AND GNEISSES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Rocks of this type do not occur in the three provinces save in the region to the eastward of Lake Winnipeg in Manitoba. This Pre-Cambrian district is mainly composed of gneisses and presents areas of granite at different points. Gneiss, although a strong and durable stone, is usually too hard for chiselling, and its laminated structure does not recommend it for monumental work; in consequence, it is commonly employed for rough rock face work only. Some stone of this type is quarried for building purposes incidentally to operations for crushed stone.

The granites of Lake Winnipeg have not actually been quarried but several locations have been staked as quarry lands. The stone is variable in grain and colour and is described in detail on page 254.

LAKE WINNIPEG AREA.

Rabbit Point, Lake Winnipeg, Manitoba.

Several areas of granite are mentioned by Tyrrell and Dowling in their description of the east shore of Lake Winnipeg, but these granitic masses have attracted little attention on the part of prospective quarry operators.[1]

The only locality that seems to have been prospected is Rabbit point where a few shots have been put in and mineral claims located by Mr. Donald Sutherland and others. Rabbit point presents a bold coast line rising 40 or 50 feet above the water: this coast is broken near the extremity of the point by a fairly deep bay which affords a good harbour. On the north shore of the inner harbour Mr. Sutherland has put in a few shots to test the quality of the granite. The formation at this point is much fractured in places, in others it is more solid but is never free from rather numerous joints in a southwesterly direction with many irregular cross joints. The formation is cut by veinlets but these are not present in great numbers. The sheeting is visible only in the upper layer which is about 20 inches thick. The stone is coarse in grain and variable in colour with a rather dull red type predominating. A livelier red colour is presented by part of the mass as well as tones of reddish-grey and grey (1037). Fair sized stone can be obtained here but there would be a large amount of waste.

On the south side of the inner harbour, the formation is rather shattered but presents distinct sheeting with the parting planes 4 to 6 feet apart and dipping 20° to the southward. The stone is mixed red and grey types (1035, 1036).

[1] Geol. Sur. Can., Ann. Rep., Vol. XI, Part G.

The granite is also well exposed on the north side of the outer harbour where the great mass is of dark colour (1033) which, however, is mixed with the fine-grained reddish stone (1034).

On the south side of the point, the stone is well exposed over considerable areas and rises to a height of 40 or 50 feet above the water. The main joints are vertical and vary in strike from S.10°W. to S.10°E. Cross joints are infrequent but areas occur in which the fracturing is excessive. With care a quarry could be located in fairly solid stone. An average sample is No. 1032 but some of the stone is coarser and some is finer in grain.

The Rabbit Point granite is of medium to coarse grain and is rather dull in colour: it is not uniform either in colour or in grain and therefore does not present great possibilities as a high grade building stone. In places the fracturing is excessive but in others the formation would permit the extraction of fair sized blocks. In my opinion the stone is suitable for foundations and for the lower storeys of large buildings, but not for ornamental purposes or for buildings of the monumental type.

On the islands opposite Dog head are exposures of porphyritic types of granite and gneiss (1038).

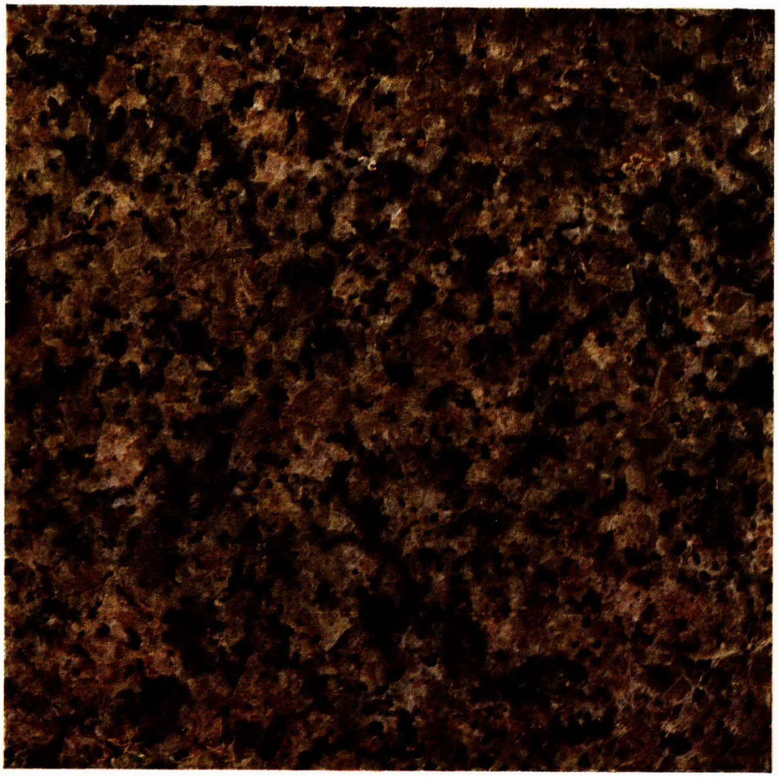
The stone: No. 1033.—A distinctly coarse-grained reddish granite with the black ferro-magnesian minerals in large crystals giving the stone a distinctly speckled appearance. While it is a good average granite for building purposes its colour has none of the distinctiveness demanded in a granite for decorative purposes.

A microscopic examination shows the rock to be a grano-diorite rather than a true granite as crystals of plagioclase are numerous. The orthoclase is partially represented by the variety known as microcline. Both varieties of feldspar show incipient but not serious decomposition. Quartz is fairly abundant and the dark ferro-magnesian mineral is practically all biotite (black mica). The stone is illustrated in Plate LI.

The physical properties are as follows:—

Specific gravity	2·712
Weight per cubic foot, lbs	168·07
Pore space, per cent	0·606
Ratio of absorption, per cent, one hour	0·136
" " " " " two hours	0·141
" " " " " slow immersion	0·155
" " " " " in vacuo	0·187
" " " " " under pressure	0·225
Coefficient of saturation, one hour	0·60
" " " two hours	0·64
" " " slow immersion	0·69
" " " in vacuo	0·83

PLATE LI.



Granite, Granite point, Lake Winnipeg, Man.

Crushing strength, lbs. per sq. in., dry	29,526·
" " " " wet	23,519·
" " " " wet after freezing	23,199·
Transverse strength, lbs. per sq. in.	1,700·
Shearing strength, lbs. per sq. in.	1,765·
Loss on corrosion, grams per sq. in.	0·00368
Drilling factor, mm.	6·
Chiselling factor, grams	0·00

No. 1034.—Very like No. 1033 but it is slightly lighter with less black mica and with a slightly laminated or gneissoid structure.

No. 1035.—This granite is of about the same grain as No. 1033 but it is grey rather than red in colour as the feldspar crystals are white or occasionallly slightly pink. It consists of clear glassy quartz, opaque white or pinkish orthoclase, and black mica with a less amount of black hornblende.

No. 1036.—This type is coarser in grain than No. 1033 and with considerably less black mica. Some of the feldspar crystals are a half inch in diameter. These crystals are either pink or white in colour giving the stone as a whole a prevailing pinkish tint:

No. 1037.—Like No. 1033 but of a duller and more "dirty" appearance. This is in part due to alteration but in part to a distinctly yellow cast in the quartz crystals.

No. 1032.—This is a distinctly red type and differs from No. 1033 in a deeper red in the feldspar crystals and in the presence of a smaller percentage of black mica. The rock shows considerable evidence of alteration.

No. 1038.—This is a distinctly porphyritic type with crystals of pink orthoclase as much as an inch in length: these are imbedded in a dark coloured matrix of quartz, orthoclase, and black mica with a somewhat schistose structure. The stone would make good building material but it is too hard to work with facility. The dark matrix is not sufficiently "clean" to render the stone adaptable for monumental purposes. Many variations of this type of rock are seen in the vicinity—some are darker and some lighter with a wide range in the size and colour of the porphyritic crystals.

Lake Winnipeg Shipping Co., 201 Tribune Building, Winnipeg; Hugh Sutherland, president; F. W. Smith, manager; C. Sifton, superintendent; C. Hamlin, quarry superintendent.

At a point on the east shore of Lake Winnipeg opposite Bull head a small natural harbour affords a favourable site for the operation of a quarry in the grey laminated gneiss which forms the shore along this part of the lake.

The formation strikes W.30°N. and dips at a high angle to the north-east. The quarry, which is as yet quite small, is opened at the south end of a well defined ridge rising about 65 feet above the water and extending in the direction of strike about quarter of a mile with a width of approximately 100 yards. The main joints run irregularly across the strike and divide the formation at intervals of 2, 4 and 6 feet approximately. The stone is a grey gneiss for the most part but it is interlaminated in places with reddish bands. A typical example is described below as No. 1040 and a somewhat redder and less frequent type as No. 1041.

The stone: No. 1040.—This stone is a hard, compact, indistinctly laminated, fine-grained gneiss of a general dark greyish-red colour. In a broad way the banding shows red and grey components. Under the microscope a very fine mosaic of quartz and orthoclase is presented with the individual crystals averaging about ·25 mm. in diameter. Scattered through this general ground mass are much larger crystals of both minerals, sometimes reaching a diameter of 1·5 mm. A very small amount of greenish-brown mica is present. The feldspars are quite fresh but the mica shows evidence of decomposition. The gneissoid character of the rock is shown in its banded structure and in the irregular and broken outline of the constituent minerals.

The physical properties are as follows:—

Specific gravity	2·666
Weight per cubic foot, lbs.	166·106
Pore space, per cent	0·193
Ratio of absorption, per cent, one hour	0·0205
" " " " " " two hours	0·0291
" " " " " " slow immersion	0·0484
" " " " " " in vacuo	0·0526
" " " " " " under pressure	0·0702
Coefficient of saturation, one hour	0·29
" " " two hours	0·41
" " " slow immersion	0·69
" " " in vacuo	0·74
Crushing strength, lbs. per sq. in., dry	46,518·
" " " " wet	44,734·
" " " " wet after freezing	38,011·
Transverse strength, lbs. per sq. in.	5,419·
Shearing strength, lbs. per sq. in.	2,495·
Loss on corrosion, grams per sq. in.	0·0016
Drilling factor, mm.	3·0
Chiselling factor, grams	0·00

No. 1041.—This gneiss is quite the same as No. 1040 except that the greyish bands are much more prominent than the red.

Pre-Cambrian gneiss. Quarry of the Lake Winnipeg Shipping Company, Lake Winnipeg, Man.

No. 1039.—This specimen, from the shore opposite Dog head, represents a variety very like No. 1040: the grain is a little finer and the light coloured bands are more prominent.

The present quarry is opened across the strike at the southern end of the ridge but it is the intention of the company to open a long quarry on the east side of the elevation which will afford a good working face along the strike (Plate LII).

The present quarrying practice is as follows:—

Holes are sunk at intervals of 5 feet along the strike and 6 feet back from the face. Three-inch bits are used as starters for a depth of 2 feet; and are followed by bits of $\frac{1}{4}$ in. less diameter, until at 14 feet (the depth of the holes), $2\frac{1}{4}$ inch bits are used. Each hole is charged with 10 sticks of 60% dynamite and 6 sticks of rackrock. Mud caps of dynamite are used to break up the dislodged blocks.

The equipment is as follows:—

Mill:—Substantial building 40 ft. by 100 ft. and 75 feet high, with boiler and engine house annex, 60 ft. by 70 ft. Steam is generated by three 150 h.p. marine boilers and passes to one 250 h.p. Robb-Armstrong engine by the Robb Engine Co., Amherst, N.S. The engine is connected by belt to the main line shaft which operates all the machinery in the mill. Three Gates crushers are installed (one Allis-Chalmers 8K, and 2 Allis-Chalmers 5K), with the necessary screens, elevators, carriers, etc.

The quarry cars are elevated 14 feet by hoist and discharge automatically on the crusher floor. The stone passes through the large crusher and is raised by bucket elevator 51 feet above the crusher floor or 61 feet in all. Here the crushed stone passes through 2 rotary screens which separate it into four sizes—grit, one inch, $1\frac{1}{2}$, and 2 inch. The oversize, which is usually about one-third of the whole, is returned by spout to the two small crushers which discharge their product to the same elevator.

The sorted stone from the screens is discharged over aprons into the mill bins of 400 cubic yards capacity each. The contents of each of these bins may be passed automatically to a conveyer belt 63 feet long whereby it is elevated 24 feet and discharged on a horizontal conveyer belt 220 feet long. This belt discharges the stone into storage bins of 1,000 cubic yards capacity. The different sizes are sent to the proper bins by means of a "tripper." From the storage bins the stone passes into cars on tracks beneath, which run in a tunnel through the rock. From the cars the stone is loaded directly into barges in the harbour. In addition to the machinery mentioned above the mill contains a large Canadian Rand compressor which is not now in operation.

Quarry:—

10 quarry cars and 10 more proposed.

Radiating tracks for above.

2 steam drills, Ingersoll-Rand, No. $3\frac{1}{2}$.

2 air drills, Ingersoll-Rand.

1 rock breaker with boiler (proposed).

In addition to the mill the company has erected 14 other buildings. A steam tug and 4 barges of 750 yards capacity are used to transfer the product to Selkirk, whence the barges are towed by a smaller tug to Winnipeg.

The average production had been about 2,500 yards a week up to the time of my visit, but it was hoped that the full capacity of the mill—600 yards per day of 10 hours—would be reached by August of 1915. I understand, however, that the conditions due to the war have compelled a temporary closing of the plant.

The prices, delivered in Winnipeg, are as follows:—

2 in. stone	—$2	per cubic yard.	
1½ " "	—$2.25	" "	"
1 " "	—$2.50	" "	"
Dust or grit	—$2.75	" "	"

CHAPTER VI.

VOLCANIC ROCKS OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Rocks of this class are rare in the three provinces. The Pre-Cambrian region east of Lake Winnipeg is not known to present any examples and Alberta does not extend far enough westward to touch the great volcanic regions of British Columbia.

CROWSNEST AREA.

Rocks of igneous origin are rare in the Rocky mountains of Alberta although they are common in the more western parts of the Cordillera in British Columbia. The only locality in Alberta that has attracted any attention lies in the general region of the Crowsnest pass. Rocks of volcanic origin occur at intervals over an area of about 500 square miles and are well exposed on York creek near Blairmore and on the line of the Canadian Pacific railway west of Coleman. These rocks, now known as the "Crowsnest volcanics," have been described in detail by W. W. Leach[1], C. W. Knight[2], and J. D. MacKenzie[3], but none of these authors make any reference to the possibility of using these stones for decorative purposes. My own brief examination of the exposures along the railway would lead to the conclusion that the stones are too dull and unattractive in appearance and the formations too much shattered to give any promise for the production of ornamental material. For a full account of these rocks the reader is referred to the works cited above: the following notes indicate the characters of two exposures along the railway which may be regarded as typical from our present point of view.

One and a half miles west of Coleman.

The rocks at this point occur in thin sheets associated with shale and also in heavier layers from which it would be possible to obtain fair sized blocks. The stone shows a distinct agglomerate structure being composed of rounded pieces imbedded in a matrix of a similar lithological character. Even on fresh fracture the stone is dull and unattractive: it presents no possibilities as decorative material (1370).

The stone: No. 1370.—A hard, rather dirty reddish rock of crystalline structure. In a general way it has the appearance of a medium-grained, semi-decomposed granite. Under the microscope the rock shows crystals of orthoclase, probably sanidine in part, aegerite-augite, small and large crystals of melanite and a few small augites, all embedded in a partially

[1] Geol. Sur. Can., Ann. Rep., Vol. XV, p. 171 A.
[2] Can. Rec. Sci., Vol. 9, No. 5, pp. 265-278, 1905.
[3] Geol. Sur. Can., Museum Bull. No. 4, 1914.

devitrified base. The rock seems to belong to the type of "melanite-bearing trachyte" described by MacKenzie on page 17 of Museum Bulletin No. 4 of the Geological Survey of Canada. I am informed by Mr. C. B. Hamil who has worked recently in this district that this rock shows clastic structure: in this case it cannot be correctly designated a trachyte although some of the included fragments are of that type.

Two miles west of Coleman, Alberta.

An extensive outcrop occurs at this point and rises into a great ridge to the north. As far as could be ascertained the stone is all in thin sheets and excessively shattered. The material itself is of unattractive appearance and is probably of no use for our purposes (1371).

The stone: No. 1371.—A hard rock of a general greenish-black colour. It shows scattered lighter coloured crystals of feldspar and inclusions of other rocks—some resembling pink granite and some of a light green colour and fine-grained compact structure. Under the microscope a dark and dirty clastic base is seen with numerous broken orthoclase crystals, large crystals of analcite partially altered to calcite, and aegerite-augite in an altered condition. The rock is to be ascribed to the tuffs and is of the general type of the orthoclase or sanidine tuffs described by MacKenzie.

CHAPTER VII.

MISCELLANEOUS BUILDING STONES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

The Rocky mountains of Alberta present certain types of stone, of possible value for structural purposes, which do not fall within the classes already discussed. These miscellaneous stones are described below as follows:

Conglomerate schist of the Corrall Creek formation.

Conglomerate schist of the Cambrian system.

St. Piran quartzite of the Cambrian system.

Rocky Mountain quartzite of the Carboniferous system.

Conglomerate Schist of the Corrall Creek Formation.

Kicking Horse Pass Area.

Pre-Cambrian rocks are exposed along the main line of the Canadian Pacific railway from a point a little east of Laggan to the summit. Two members are recognized—an upper shaly formation, the Hector, and a lower, coarse, quartzitic sandstone, the Corrall Creek.

Two miles east of Laggan the Corrall Creek formation is exposed in a rock cut and a small amount of quarrying has been done here. The formation shows a slight schistosity with a northwest strike: numerous quartz stringers run with the schistosity and a set of nearly vertical joints cuts the formation in the same direction. A second set of vertical joints crosses at N.50°E. A distinct bedding quite independent of the schistosity is observed: on the face of the old quarry these beds are of 4 feet, 4 feet and 12 feet respectively and are separated by shaly partings. Although certain parts of the exposure show excessive fracturing it would be quite possible to quarry blocks of large size.

The stone varies greatly in grain throughout the exposure: No. 1316 is the most abundant type and No. 1317 is an example of the finer grained stone. Pyrite is common and by oxidation produces dirty brown spots on exposed surfaces. All varieties of the stone tend to become brown on exposure and weathered surfaces show a pitted appearance due to differential weathering.

The stone from this quarry was used for the bridge piers near Laggan. The caps have been cut and show the characteristic brownish colour but some of the rock face in less exposed position is almost as bluish in colour as when freshly quarried. The stone is undoubtedly very solid and durable, but under the influence of the weather, particularly in exposed position, it very gradually assumes a brownish colour.

The exposures east of the summit present a similar rock (1320) in beds dipping about 30° to the southwest: the beds vary in thickness and the stone shows all gradations from a coarse sandstone to a fine quartzite. The formation is badly shattered but it would be possible to procure blocks of reasonable size. Some development must be done before the site could be regarded as a possible location for a quarry.

The stone: No. 1316.—To the naked eye this stone appears to be a closely set aggregate of clear white feldspar and bluish quartz fragments cemented by a small amount of dark glistening matrix which seems to be of a sericitic nature. The larger fragments are sometimes more than a half inch in their longer diameter. The fresh stone is hard and of a general bluish colour with some evidence of schistose structure. A microscopic examination shows fragments of quartz up to 5 mm. in diameter but these are not always one individual crystal: from these larger fragments the quartz grains range down to very small size. Feldspar grains in a more or less altered condition occur in much less amount. Still larger fragments are present and show a very fine-grained aggregate of quartz and other minerals and evidently represent an original quartzite. An indeterminable muddy base is present and in places it is converted into secondary mica in crystals 4 and 5 mm. long.

Conglomerate Schists of the Cambrian System.

Grand Trunk Pacific Railway Area.

The first exposure of the Bow River series (Lower Cambrian) observed along the line of the Grand Trunk Pacific railway through the Yellowhead pass is at mile 1025½. From this point to the summit all accessible exposures belong to this series, which consists essentially of hard slates interstratified with a greenish rock, showing all gradations from a fine-grained quartzite to a coarse conglomerate. The prevailing colour of this rock is greenish and it has a uniform tendency to weather yellow and finally dirty brown. In places the stone is somewhat schistose and shows shiny scales of secondary mica. The very coarse types present no possibilities as building stone but some of the thicker layers of the finer grained phases, which are accessible at many points, would yield stone suitable for heavy construction. The following brief notes serve to indicate the actual exposures along the railway but it is quite likely that more favourable locations could be found in the neighbouring ranges.

Mile 1025½.—Conglomerate of greenish colour weathering reddish and pitted. The exposure is 50 yards long and presents a face of 75 feet in height (1232).

Mile 1030.—Hard, light greenish phases of the same rock but of finer grain resembling quartzite. The beds dip at high angles but heavy blocks could be obtained here.

Mile 1036.—Finer grained phases like No. 1256 but varying in colour and in grain.

Mile 1037.—Conglomerate phase (1258).

Mile 1039½.—The underlying rock is a dark slate above which are thick beds of one to 3 feet or more of a medium-grained phase. The layers are well defined and dip at low but varying angles. Joints are irregular but they would not prevent the quarrying of large blocks. In colour the beds vary from light green to a greenish-grey: they vary also in grain and in the amount of cementing matter present. No. 1255 is a light variety and No. 1256 is an average example which has been tested in full as typical of this stone. The weathering properties are not good as all phases tend to weather red and spotted at first and later to assume a dirty, brownish-red colour.

Mile 1043½.—Laminated, grey, shaly rock passing into slate, sheared, and cut by numerous diagonal joints (1253). Bands of the stone under consideration (1254) are interbedded with the shales in layers up to 4 feet thick. These bands would yield large blocks but quarrying would be difficult on account of the predominance of the shaly stone.

The stone: No. 1256.—This rock is a coarse, hard, indurated sandstone passing into a conglomerate and rendered somewhat schistose by pressure: it is almost a quartzite but the presence of considerable cementing material between the grains of quartz renders that name somewhat inapplicable. The stone is sometimes referred to as a conglomerate schist. Viewed with the naked eye the smoothed surface has a general dark, bluish-grey appearance with fine inosculating whitish lines. The freshly fractured stone shows large grains of clear or slightly milky quartz cemented in an aggregate of smaller quartz fragments and a small amount of other material. The stone is very like the Corrall Creek conglomerate from the Kicking Horse pass but it is scarcely as "clean" a variety. Under the microscope the only definitely determinable mineral is quartz in large fragments: the section shows some as great as 2 mm. in diameter. Numerous small quartz grains appear between the larger ones. Some large crystals of an excessively altered mineral, probably feldspar, are seen. The matrix is fairly abundant and shows a considerable amount of iron oxide. The corrosion test has the effect of turning the cementing matter to a bright yellow colour with a consequent spotted effect.

The physical properties are as follows:—

Specific gravity	2·719
Weight per cubic foot, lbs	168·91
Pore space, per cent	0·483
Ratio of absorption, per cent, one hour	0·103
" " " " two hours	0·121
" " " " slow immersion	0·16
" " " " in vacuo	0·16
" " " " under pressure	0·178

Coefficient of saturation, one hour	0·58
" " " two hours	0·68
" " " slow immersion	0·9
" " " in vacuo	0·9
Crushing strength, lbs. per sq. in., dry	19,615·
" " " " wet	13,758·
" " " " wet after freezing	16,743·
Transverse strength, lbs. per sq. in	2,889·
Shearing strength, lbs. per sq. in	3,280·
Loss on corrosion, grams per sq. in	0·0108
Drilling factor, mm	6·2
Chiselling factor, grams	0·00

No. 1257.—A fine-grained, hard, schistose type of greyish-blue colour. With the hand lens it appears to be a fine aggregate of quartz fragments with a little bluish-grey cementing material. When broken parallel to the schistosity the cement is more prominent and shows glistening flakes of some whitish secondary mica.

No. 1258.—This is the same type of rock as Nos. 1256 and 1257: it is much coarser, however, with fragments of quartz, sometimes a half inch in diameter. The cementing matter is much more abundant and of a bluish-green colour. Some of the quartz fragments are pink, giving the stone a more distinctly spotted appearance.

No. 1253.—A greyish slate of poor cleave.

No. 1254.—A medium-grained phase of the conglomerate with a large amount of the cementing matter which is here of a very dark colour.

No. 1255.—A medium-grained phase of the conglomerate in which the cementing matter is meagre and much oxidized giving a brownish colour to the stone.

No. 1232.—This rock is essentially a quartzite with fragments of bluish quartz as great as a half inch in diameter imbedded in a mass of smaller fragments which do not show a blue colour. The cementing material is light in colour and spare in amount. Minute grains of pyrite are probably present in the fresh rock but the specimens show only small brown dots due to the decay of this mineral. The rock is very tough and hard.

Quartzite of the St. Piran Formation.

Lake Louise Area.

The Lower Cambrian rocks consist largely of quartzites: they are developed to an enormous thickness and are most easily accessible in the region of Lake Louise. The most important member and the only one of present interest is the St. Piran formation which consists largely of massive quartzites to a thickness of 2,705 feet. At the southwest corner of Lake

St. Piran quartzite. Chalet at Lake Louise, Alberta.

Louise the formation is exposed in vertical cliffs. The beds vary in thickness from a few inches to 2 feet or more and dip at a low angle to the southwest. Pronounced joints strike N.50°E. vertically and a minor set crosses at right angles. Enormous quantities of stone are available but the problem of quarrying in the side of a great mountain would soon be presented if extensive operations were ever attempted.

The stone is a very hard massive quartzite of a prevailing pink tint: it has been quarried, largely from the talus, and used in the construction of the chalet on Lake Louise (Plate LIII). The stone is much too hard to be chiselled but it makes attractive and unique rock face work. That the stone is not without value as a decorative material is proved by the mantel in the ball room of the chalet.

A coarser type of quartzite, devoid of attractive colours and probably derived from a higher level, is common in the talus around Lake Louise (1319).

The stone: No. 1318.—As a single example would scarcely serve to illustrate this material several specimens are described below under the same number.

All the samples are fine-grained quartzites with more or less development of a laminated structure: they are all very hard but the coherence varies with the degree of lamination as there is a tendency to part in this direction. The chief variation is in the degree to which the stone is coloured pink. Some examples are white; others blotched with pink; others fairly uniform pink, and others pink and white banded. In extreme cases of the last type the colouring matter is chocolate-coloured and occurs in distinct, thin, slaty laminae.

No. 1319.—A hard, greyish, fine-grained quartzite of prevailing dark colour but marked by angular spots that are almost white. These spots seem to differ from the rest of the rock only in the absence of the dark-coloured cementing material.

Rocky Mountain Quartzite.

This formation is somewhat irregular in its development in different parts of the mountains. In places it forms a distinct horizon at the base of the shaly series overlying the Upper Banff limestone but in other place it seems to be more or less interbedded with the shales. The stone is very hard, usually much fractured, weathers yellowish and is of little interest from our point of view. Owing to its hard and resistant properties it forms the crest of many of the eastern ranges.

Lake Minnewanka Area.

A good typical exposure of the quartzite is seen in the valley of Cascade creek near Lake Minnewanka. The stone is bluish when fresh but it has a tendency to weather grey and sometimes reddish (1311). The quartzite beds pass imperceptibly downwards into sandy limestones which doubtless represent a transition to the Upper Banff limestone (1312).

Blocks of this quartzite, probably obtained from the talus of Mount Rundle, have been used to a small extent in the construction of the Canadian Pacific Railway hotel at Banff. These blocks show a distinct tendency to weather yellow.

The stone: No. 1311.—A very hard, fine-grained, brittle, uniform quartzite of white or slightly bluish colour with a tendency to weather greyish-yellow or even reddish. Its extreme hardness renders chiselling almost impossible but it could be well employed in rock face rubble.

No. 1312.—Similar to the above, but of a greyish colour and with a considerable amount of carbonate of lime. The upper stone has very little lime but the lower layers pass insensibly into limestone. The rock is extremely hard and could be used for rough purposes only.

Mountain Park Area.

A second typical exposure of the Rocky Mountain quartzite is seen on the railway between Mountain Park and Coal Spur in the northern part of Alberta. At mile 25¾ of this line a good outcrop exposes the following section:—

100 ft.—A hard black friable rock in heavy beds (1213).

100 ft.—Heavy bedded, whitish quartzite, weathering yellow (1212).

————Reddish, thin-bedded softer stone (1214).

————White quartzites like No. 1212.

————Shales with thick bands of a bluish-grey rock weathering very brown (1215).

————Beds like No. 1215.

————Limestones (Upper Banff).

All the beds dip westward at about 30°.

The stone: No. 1212.—A hard, very fine-grained white quartzite with indistinct laminar structure: it closely resembles the stone from Lake Minnewanka but it is less massive in structure.

No. 1213.—An extremely hard, flinty, black, fine-grained siliceous stone with a strong tendency to break parallel to certain directions when struck by the hammer.

Under the microscope is shows exceedingly fine grains of quartz—about 0·02 mm. in diameter—with very little interstitial matter but with scattered black or brown specks and occcasional larger fragments of quartz. The stone is finer in grain and with less apparent cementing material than No. 1215 described below.

No. 1214.—A hard reddish siliceous shale with a small content of carbonate of lime.

No. 1215.—A hard black rock of extremely fine grain. Under the microscope it shows minute grains of quartz—less than ·05 mm. in diameter—cemented in a moderate amount of brownish matrix.

CHAPTER VIII.

ORNAMENTAL STONES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Stones of proved value for purely ornamental purposes are not known to occur in the three provinces under review, but certain possibilities exist which require a brief account in a work of this kind. As the line between building and ornamental stone is rather indefinite, it follows that some of the rocks hitherto described may be employed for the latter purpose, *e.g.*, the Tyndall limestone, the Lake Winnipeg granite, the "manitobite" from Broadvalley, certain varieties of the red clouded Ordovician, Silurian and Devonian limestones of Manitoba, some of the finer Paskapoo sandstones and the St. Piran quartzites of the Rocky mountains. The present chapter deals only with stones not previously described and includes the following substances:—

Marble.
Gypsum and anhydrite.
Rare decorative stones.

Marble.

Marble, in the narrower sense, is crystalline limestone, possessing a fineness of grain or a beauty of colouring that fits it for use as a decorative material. Some of the stones already described approach the requisites of marble according to this description; in addition, true marbles are known to occur in the Yellowhead and Vermilion passes.

Yellowhead Pass Area.

Grant Brook, British Columbia.

The marble described below occurs on the north side of the line of the Grand Trunk Pacific railway just beyond the Alberta-British Columbia boundary. A more complete account will be given when the stones of British Columbia are reviewed. The subject is introduced here because the marble belt continues into Alberta, and, according to Dr. J. A. Allan, outcrops on the Athabaska river above the base of Mount Geikie.

The quarry is situated north of the line of the Grand Trunk Pacific railway at a point about one and a half miles east of Grant Brook, B.C. The mountain side is covered with a heavy talus to a height of several hundred feet, above which the marble rises in 4 or 5 irregular steps to the top of the ridge.

The general strike of the formation is a little south of east. The lowest rocks consist of thin-bedded, dark, crystalline limestone (1246) at first dipping 30° to the north but rapidly acquiring a steeper dip. These rocks appear for a few feet only and pass upwards into banded whitish marbles in beds of gradually increasing thickness. At a height of 6 feet, some of the beds are fully a foot thick (1247). A talus-covered interval of about 20 feet follows to the foot of the almost perpendicular ledges of heavily bedded marbles, striking east and west with a practically vertical dip.

The outer or more southerly ledge rises about 50 feet and is from 10 to 50 feet wide in massive but variable beds of reddish stone. The second ledge is somewhat higher and presents a white variety of marble in similar heavy beds. The upper ledges are of whitish stone but probably with reddish bands.

The bedding throughout is very heavy and in places it is possible that for 50 feet there is no pronounced division. The bedding planes constitute the vertical walls of the ledges. Jointing is pronounced and variable. The main series strikes a little west of north and dips at greatly varying angles to the westward. A second series with the same strike dips in the opposite direction and cuts the first series approximately at right angles. Minor diagonal jointing is also present in varying intensity. The major jointing will undoubtedly permit the extraction of large but irregular blocks, not, however, without considerable loss. The minor fracturing would probably prove a more serious objection in sawing the blocks into slabs. So little work has been done that it is impossible to determine to what extent the finer fracturing is superficial.

The red stone of the first great ledge is variable in appearance—in part homogeneous, and in part laminated. In places it is blotched with white (1252) and in others it shows interlaminated white bands. A general average will be described in full as No. 1249. In places also the stone shows greenish blotches and veinlets (1251).

The second great ledge showing white marble rises 60 or 75 feet above the red ledge, and to the westward where the red layers have been eroded it continues down to the talus-covered slope. An average sample will be described as No. 1250.

The stone: All these marbles are hard and show various tints of pink and red banded or blotched with white, as well as varieties which are practically all white. A fuller description is deferred until the volume dealing with British Columbia is published.

The company has built a tramway from the foot of the cliff over the talus slope to the quarry, but, since operations ceased, it has fallen into disrepair. A few blocks were quarried and shipped as samples but I have not learned of the stone having yet been used for any commercial purpose.

VERMILION PASS AREA.

Vermilion Pass, Alberta.

On the north side of the new automobile road through the Vermilion pass, at a point about 15 miles from Castle, certain layers of Cambrian limestone, roughly estimated at 200 feet in thickness, have been converted into marble. The formation is greatly shattered and much of the stone is off colour and charged with pyrite (1334). The extent of the formation is enormous and many points are fairly accessible, but as no prospecting has been done, it is impossible at present to do more than to draw attention to the locality as a possible producer of marble.

The stone: No. 1334.—A coarse-grained, white crystalline limestone with occasional specks of white mica and brown spots which apparently have resulted from the oxidation of pyrite. The stone represented by this sample would make a building stone but it is not of the class of decorative marble.

Gypsum and Anhydrite.

Gypsum is the crystallized sulphate of calcium containing 20·9 per cent of water: anhydrite is crystallized sulphate of calcium without water and is commonly known as hard plaster. Both of these minerals, when finely crystallized and of good colour, have a value as decorative materials. The suitability of these substances to ornamental purposes is discussed in the earlier volumes of this report—See Vol. 1, page 22 and Vol. II, page 193.

The Silurian system of northern Manitoba contains numerous large deposits, some of which have been worked for the production of plaster and other gypsum products. Most of the stone is the greyish type suitable only for burning, but some fine-grained material occurs as well as the clear crystalline type known as selenite. Anhydrite occurs in association with the gypsum and also in the form of separate deposits. The localities are all included in one area as below:—

Gypsumville Area.

The gypsum-bearing area of Manitoba lies to the east of Lake Manitoba and north of Lake St. Martin: the centre of the industry is the village of Gypsumville which is connected with Winnipeg by a branch of the Canadian Northern railway.

Manitoba Gypsum Company; Wm. Martin, president, Winnipeg; T. Brommell, local manager, Gypsumville, Man.

This company holds a block of land comprising the south half of section 23 and the north quarter of section 14, and portions of section 24 and section 13, as well as part of the northwest quarter of section 23, township 33, range 8 west. Gypsum in quantities available for quarrying are known to occur over a considerable portion of this area but operations up to the present have been almost entirely confined to the large quarry near Gypsumville. In addition to this block of land the company controls a number of locations in townships 32, 33 and 35, range 9 west and in townships 32 and 33, range 8 west.

It is not the purpose of the present report to describe the gypsum bearing formation of this locality or to deal with the gypsum industry as such. An extended account of this subject by L. H. Cole has recently been published and to this the reader is referred.[1] At present we are concerned only with the possibilities for the production of gypsum of a type suitable for ornamental purposes.

The main quarry is about one-fourth mile in length in a north and south direction and is now being advanced to the west with a face of about 20 feet. The average stone is of a soft grey type, containing streaks of anhydrite and presenting no possibilities as decorative material (1159). All the stone exposed in the south three-quarters of the excavation is of this kind, but north of this stretch a more indurated and reddish tinted bed is encountered. This coloured zone is rather ill-defined but it seems to have a width of about 300 feet and an average thickness of 24 inches. The trend of the belt is towards the northwest and it appears to dip slightly in that direction. Small objects of decoration could possibly be cut from this material (1158).

At the south end of the quarry the general run of the gypsum is of the grey banded type but some large nodular masses, occasionally a half ton in weight, of pure white gypsum are encountered. This material presents possibilities for use as alabaster but I fear the condition of occurrence render impossible any attempt to save it (1157).

Drilling has revealed the existence of about 40 feet more gypsum below the floor of the present quarry. It is said that the stone is much more compact than that revealed in the present workings and that pieces which have been polished present a darker appearance. On the whole it is rather unlikely that any material of decorative quality can be procured in commercial quantities.

About 100,000 tons of gypsum are quarried annually from this locality.[2]

The stone: No. 1157.—Pure white finely crystalline gypsum of the alabaster type: if this stone could be procured in quantity it would be valuable.

No. 1158.—The rock consists of nodules of fine-grained reddish gypsum imbedded in transparent selenite of coarser grain. Unfortunately the rock contains fragments of foreign rock, *e.g.*, granite. Judging from the specimen the possibility of using this stone for ornamental purposes is not established.

No. 1159.—Fine-grained bluish anhydrite of irregular and somewhat cavernous structure. The specimen does not indicate any possibilities as a decorative stone.

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[1] Dept. Mines, Can., Mines Branch, Pub. No. 245, 1913.

[2] Geol. Sur. Can., Sum. Rep., 1912, p. 258.
Geol. Sur. Can., Sum. Rep., 1913, p. 166.

Dominion Gypsum Co., Winnipeg.

This company owns many properties in the gypsiferous area of northern Manitoba but for the purposes of this report only one need be referred to—section 4, township 33, range 8 west.

The country is heavily covered with timber and soil and presents a very uneven surface with many abrupt depressions or sink holes in the gypsum-bearing formation. No work has been done beyond the sinking of a few test pits. One of these pits, about 6 feet deep, shows the ordinary whitish-grey gypsum at the bottom which is covered by about 2 feet of coarsely crystallized selenite, the white transparent variety of crystallized gypsum. To the southwest of this point is a deep depression with a little pond at the bottom. Ordinary gypsum (1173) is exposed on the hill side, and at the bottom, near the water, more of the selenite is seen but the crystals are much smaller than in the upper pit.

The small amount of work that has been done fails to reveal the relation of the selenite to the common gypsum. I would hazard the opinion, however, that the selenite forms a cap of secondary origin lying between the gypsiferous formation and the drift. The layer of selenite does not appear to be interstratified with the gypsum but to lie unconformably on top of it and to conform with the declivity.

The selenite exposed in the upper pit could be secured in large pieces by careful quarrying. Crystals of 2 feet in length are not uncommon. Beyond the fact that the deposit is about 2 feet thick where exposed there is no evidence as to its extent.

Selenite has a possible application as a decorative stone in the making of small *objets d'art* and for inlaid work: it is also employed for certain optical instruments.

The stone: No. 1173.—Ordinary white fine-grained granular gypsum stained red in places by oxide of iron.

No. 1174.—Clear transparent crystallized selenite of a laminated type. It may be obtained in pieces 2 feet or more in length, a foot wide, and several inches thick.

Fry and Dulman, Seymour hotel, Winnipeg.

Messrs. Fry and Dulman have done a small amount of development on a deposit of anhydrite on the southeast quarter of section 10, township 33, range 8 west, with the object of ascertaining the suitability of the material as a decorative stone.

The location is about 5½ miles eastward from Gypsumville but the swampy nature of the intervening country makes communication impossible except in winter. Access to the deposit may be had in summer by a roundabout way via the north shore of Lake St. Martin. There is no road northward from the lake to the property but it is possible to get through with a team and light wagon.

In the vicinity of the deposit the country is rather rough, heavily drift-covered in part, and clothed with timber. On the location a ravine cuts through the formation in a northeast and southwest direction. The northwest bank of the ravine has been stripped for a distance of 40 or 50 feet exposing a face of 17 feet. The face thus exposed strikes N.30°E. and shows a light bluish-white, fine-grained anhydrite in beds of varying thickness but reasonable solidity. Irregular joints cut the formation and the anhydrite has been partially altered to gypsum along the joint planes. Considering the susceptibility of the stone to weathering and the superficial character of the workings, the shattering does not seem to be excessive. It is a reasonable assumption that much more solid material would be encountered by more extensive development.

Northwest of the margin of the ravine the country falls off gradually with a more pronounced slope west than north. On the area immediately bordering the ravine Mr. Fry has sunk three diamond drill holes to a maximum depth of 86 feet without passing out of the anhydrite. These holes indicate a fairly solid mass of anhydrite, whitish-blue and veined with brown towards the top and becoming bluer and less veined towards the bottom. It would appear from these holes that a considerable deposit of anhydrite is available and that it probably occurs in beds of sufficient solidity for quarrying mill blocks. The longest piece of drill core was about 10 inches. but it does not follow that the stone is thus limited in thickness. I am informed that the drills cut in a curved line and that the cores were broken in consequence.

The holes were sunk at the following points:—

(1)—16 paces, N.15°W. from the face of the escarpment at the point where the stripping was done. No detailed record was kept but anhydrite is said to have been found to a considerable depth.

(2)—59 paces due west from the first hole. The surface is here about 25 feet lower.

(3)—72 paces N.5°W. from the first hole. The surface here is 10 feet lower than at hole No. 1. The upper 15 feet showed broken stone below which solid material was found to a depth of 86 feet according to a statement of Mr. Fry. Portions of the core were obtained from different levels as below:—

18 ft.—	Specimen	No.	1167.
26 ft.—	"	"	1169.
33 ft.—	"	"	1170.
41 ft.—	"	"	1171.
49 ft.—	"	"	1168.
60 ft.—	"	"	1172.
74 ft.—	"	"	1166.

The average stone exposed on the face is a bluish to whitish anhydrite (1164), sometimes banded, sometimes clouded, and towards the top brown-veined and spotted (1165).

The stone: No. 1164. Massive fine-grained crystalline anhydrite of light bluish colour: it varies somewhat in the tone of the blue.

No. 1165.—(a) A distinctly blue type. The presence of occasional brown spots and bands detracts from the beauty of the material.

(b) A coarser grained bluish-white variety tinged with brown in places.

(c) Like 1165 (a) but mottled with white.

(d) A light blue and white type with distinct lines of pinkish-brown.

Nos. 1166-1172.—These specimens prove the continuity of blue and white fine-grained anhydrite to the depth indicated.

Rare Ornamental Stones.

Stones of the semi-precious class which might be employed for purposes of decoration are practically unknown in the three provinces under review.

Authors have drawn attention to the occurrence of common opal in the interior of fossil shells in the Edmonton and more particularly the St. Mary River series. Material of this kind may be collected on the St. Mary and Old Man rivers but there is no evidence that either the quality of the opal or its manner of occurrence would justify any attempt to exploit the deposits.

Opalized or silicified wood is not uncommon in the Edmonton formation and may be collected on the Red Deer and other rivers of Alberta. As far as I can ascertain, none of this material is of sufficient beauty for purposes of decoration.

CHAPTER IX.

SLATES OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

Slate is not known to occur in the Pre-Cambrian region of eastern Manitoba but it is abundant in the Pre-Cambrian and Cambrian strata of the Rocky mountains. Notwithstanding its common occurrence, material suitable for roofing slates or other economic purposes within the scope of this work has not yet been located. Brief notes on the slate of the Kicking Horse and Yellowhead passes are given below.

Kicking Horse Pass Area.

The Hector formation or upper division of the Pre-Cambrian rocks of the Kicking Horse pass consists largely of slates which have been quarried for cement making by the Canada Cement Company.

The quarry is situated a little to the west of Laggan and shows a face of 40 or 50 feet of slate under 10 or 15 feet of drift. The formation is excessively shattered and much affected by minute diagonal fracturing (knives). The cleave is indistinct, poor and variable. Although some large pieces as much as 5 feet square have been obtained, the imperfect cleave renders them useless for making roofing slates. The quarry presents no possibilities as a producer of marketable slate.

The stone: No. 1321.—Dark purplish slates, hard and of imperfect cleave. Diagonal "knives" are present as well as green bands.

Yellowhead Pass Area.

Slates occur at various points along the line of the Grand Trunk Pacific railway between mile 1025 and the summit. These slates are associated with the schist conglomerate described on page 262; they are mostly of a dark colour and are so fractured and with so irregular cleavage that little hope can be entertained of their use for the making of roofing slates.

CHAPTER X.

BUILDING STONES FROM THE GLACIAL DRIFT OF MANITOBA, SASKATCHEWAN, AND ALBERTA.

In recent geological times the whole area of the three provinces was covered with great glaciers. At first these glaciers advanced from the Rocky mountains over the plains, later from the highlands of Keewatin, and still later from Labrador. The Keewatin ice sheets were of enormous extent and carried boulders of Pre-Cambrian rock from the northeast to the foothills of southern Alberta. With the final retreat of the ice sheets on the advent of a warmer climate great numbers of boulders were left over the whole area of the provinces. The water resulting from the melting of the glaciers accumulated in great lakes and in these lakes were deposited silts, clays, and sands which more or less covered the boulders. The chief area occupied by these lakes lies in Manitoba and Saskatchewan of which the less elevated regions are almost destitute of boulders.

The importance of boulders as building material can scarcely be overestimated in a country where more desirable material is procurable only by transportation from a distance. The boulders of the Prairie Provinces may be regarded as of two kinds—limestone derived from Ordovician and Silurian rocks, and granites, gneisses and other crystalline rocks from the great Pre-Cambrian areas to the north and east.

Limestone Drift.

Prince Albert Area.

Prince Albert, Saskatchewan.

Northwest from Prince Albert a slightly elevated glacial ridge extends in a direction a little south of west from the property of R. Thompson (Section 18, township 51, range 27 west of 2nd meridian) for a distance of about 10 miles with a width varying from a half mile to a mile and a half. Outcrops occur on Neil McDonald's farm (Section 7) and on the Indian reserve to the north and west of J. Saunders' farm (Section 6). Low in a creek valley at this point boulders of No. 1200 were observed, but the prevailing stone is better seen on the Indian reserve across the creek. Here numerous large boulders of No. 1201 were observed: the same type of stone is said to occur in great abundance and in larger blocks about 5 miles southwest along the ridge.

The stone: No. 1200.—A hard fine-grained crystalline dolomite resembling some of the Silurian types. The specimen is badly weathered with brown and yellow staining.

No. 1201.—A fine-grained crystalline pinkish-grey dolomite strongly resembling the lighter coloured type of dolomite from the area along the Hudson Bay railway north of The Pas, Manitoba.

SASKATOON AREA.

Saskatoon, Saskatchewan.

On the southeast side of the Saskatchewan river at a point near Clarkboro an elevated ridge of glacial material containing large boulders of Silurian limestone extends, with a width varying from a half mile to a mile and a half, in a southwest direction to near the line of the Canadian Pacific railway. About 2¼ miles from Saskatoon the ridge is very rich in large boulders which have been utilized for the construction of the building of the University of Saskatchewan. Some of these boulders are said to have yielded 5 cords of stone. Most of the stone is evidently derived from the Silurian region to the north of The Pas which is described on pages 106-110. The description of the different types of stone from that area would apply equally well to the pink and red tinted stones from the present locality. The varieties from Fisher Branch are also very similar (compare Nos. 1135, 1136, 1137 and 1138 page 105.)

The buildings of the University of Saskatchewan are constructed for the most part of the pinkish Silurian limestone; but, unfortunately, other varieties of stone have been used, particularly a yellowish cavernous type resembling the Cincinnatian stone from Stony mountain in Manitoba. As the weathering qualities of these stones are by no means the same it is to be expected that differences of colour will arise. The older buildings are already showing signs of colour changes, but up to the present, the effect of weathering has been to subdue the difference in colour of the different types of stone. I am inclined to think, however, that long continued exposure will make the Silurian stone much lighter in colour while the Cincinnatian material will rust to dirty shades (Plate LIV).

Large boulders of limestone were observed along the line of the Canadian Northern between Warman and the crossing of the Saskatchewan river near Ceepee: they have been used for lime burning at different points but many of them are of sufficient size to yield good coursing stone. I am informed that to the west of this district large limestone boulders are of common occurrence over the southern half of township 43 and all of township 42 in ranges 14, 15, 16, 17, 18, 19, and 20 west of the second meridian.

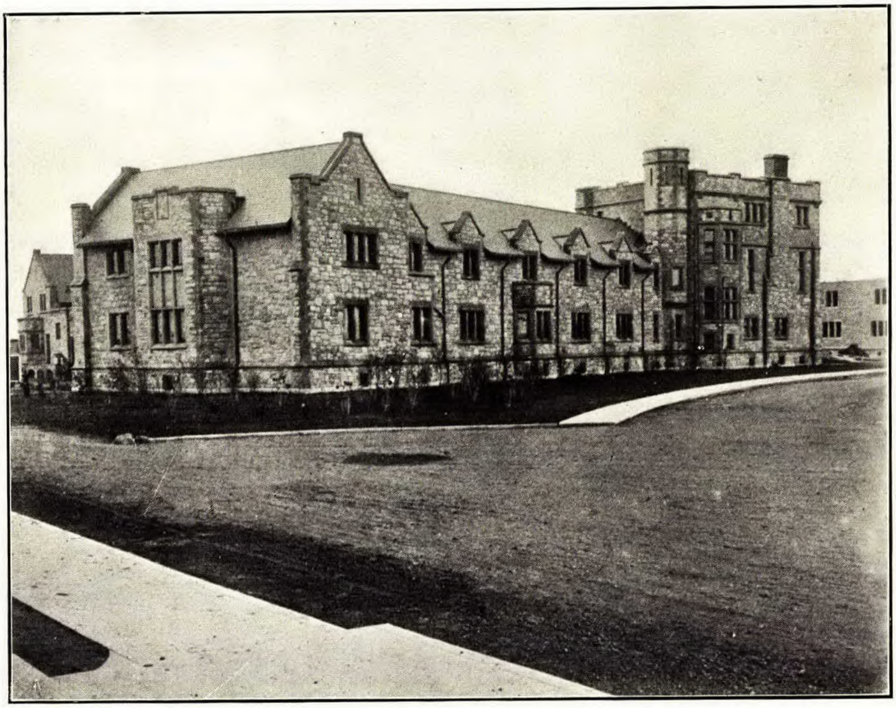
Limestone boulders are common in the vicinity of Young, Sask. They have been used for lime burning and to a limited extent for building purposes.

KILLARNEY AREA.

Honourable George Lawrence, Northeast quarter Section 7, Township 2, Range 16 west.

At the extreme north edge of this property a very large boulder of Silurian limestone lies buried in the drift. Originally only the upper point

PLATE LIV.



Silurian limestone drift. Dormitories, University of Saskatchewan, Saskatoon, Sask.

was exposed, but stripping has revealed a surface 25 feet by 12 feet without disclosing the entire extent. The dimensions are therefore unknown. The stratification planes of the stone dip at an angle of 3 or 4 degrees a little west of south. The beds are from 10 to 14 inches thick and are crossed by distinct joints, particularly at N.10°W.

The stone is solid and of a prevailing greyish colour but softer yellow spots appear in places and reddish bands are not uncommon. The material is hard and rather splintery and consequently hard to dress but it is very durable and makes good rock face work.

A considerable quantity of stone has been quarried and employed with success for building purposes in Killarney. Many buildings mainly constructed from granite field-stones have sills, copings, corners, etc., cut from this stone. As far as can be observed there is much good stone still available but of course the supply is limited.

The occurence of a boulder of this size is not unknown but it is rare. That a boulder of limestone, cut by numerous joints and with distinct planes of parting on the beddings, should have held together in glacial transportation is remarkable. A further peculiar feature is that the drift in the locality contains few Silurian boulders and a deep ravine within a few yards of the outcrop shows no evidence of such stones, nor are any found among the numerous stones in the creek at the bottom of the ravine. It might be suggested that the outcrop represents the top of an island in the Cretaceous seas but this explanation is too remote and altogether unlikely in view of the existence of the deep ravine without further exposures.

The stone: No. 1196.—A fine-grained crystalline dolomitic limestone of a light greyish colour but indistinctly mottled with pink: it resembles the limestone from Fisher Branch and the Hudson Bay railway. The stone is hard but it is massive and suitable for rock face work.

Pre-Cambrian Drift.

Boulders of granite, and other Pre-Cambrian rocks are scattered over many parts of the three provinces but they are most abundant and more easily accessible outside the area covered by the great post glacial lakes (see page 31). The following list contains the more important localities observed in the course of my itinerary: it is in no sense complete but is merely the result of observation from trains:—

Manitoba.

Numerous boulders occur along the Pembina branch of the Canadian Pacific railway, more particularly in the neighborhood of Pembina mountains. Buildings of granite boulders were noted in Thornhill, Crystal City, Morden, Killarney, Clearwater, and other places. Many buildings are constructed of boulders of granite and gneiss which have been squared for ashlar: the trimmings are usually of limestone. A good example is the court house in Morden.

The mission church at Kulyerville on Lake Winnipegosis is built of granitic and gneissoid boulders.

The city of Winnipeg crushes granitic boulders obtained from the top of Stony mountain for use in making macadam.

Saskatchewan.

Boulders are collected in the vicinity of Moosejaw and are now used chiefly for macadam: formerly they were employed for structural purposes, and may be seen in the old Presbyterian church.

On the Moosejaw-Portal branch of the Canadian Pacific railway boulders were observed in great abundance practically all along the line. These boulders have been used for building in many places, *e.g.* Yellowgrass, Weyburn, Estevan, and Roche Percée.

Many boulders were observed along the main line of the Canadian Pacific railway east of Regina. Buildings of these stones were noted in Indian Head, Sintaluta, Hargrave, Elkhorn, and Virden.

On the line of the Canadian Northern railway west from Regina, numerous boulders were observed at Lumsden, Disley, and at points still farther west and north. The school at Chamberlain is constructed of dressed stone from boulders of gneiss and granite. Beyond Craik, the boulders are less in evidence, probably because the line of railway is farther from the zone of erosion of the river where the covering of Lake Agassiz deposits has been removed.

Alberta.

Many boulders were observed along the railway from L[illegible]dge to Coutts: they are numerous south of Stirling and increase in abundance towards Coutts.

On approaching the foothills, boulders of Pre-Cambrian stone become more numerous and are often represented by very large masses.

CANADA

DEPARTMENT OF MINES

MINES BRANCH

HON. P. E. BLONDIN, MINISTER; R. G. McCONNELL, DEPUTY MINISTER.

EUGENE HAANEL, PH.D., DIRECTOR

1916

H. E. Baine, Chief Draughtsman.

Base map from plates of the Department of the Interior.

MAP OF

ALBERTA, SASKATCHEWAN AND MANITOBA

SHOWING QUARRIES AND CHIEF ROCK OUTCROPS REFERRED TO IN REPORT No. 388

Scale, $\frac{1}{2,217,600}$

Miles

25 20 15 10 5 0 25 50 75 100 125 150

35 MILES TO 1 INCH

PLATE LV.

No. 1—Winnipeg sandstone, Punk island, Lake Winnipeg (1020).
No. 2—Boissevain sandstone, John Robinson's quarry, Boissevain, Man. (1187).
No. 3—Dakota sandstone, McLeod river, Alberta, (1224).
No. 4—Dakota sandstone, Coleman, Alberta, (1364).
No. 5—Blue Paskapoo sandstone, Macleod Quarrying and Contracting Co., Monarch, Alberta, (1360).
No. 6—Buff Paskapoo sandstone, Macleod Quarrying and Contracting Co., Monarch Alberta, (1361).

PLATE LV.

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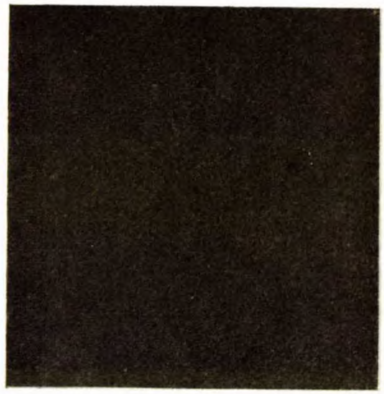

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Plate LVI.

No. 1—Paskapoo sandstone, Crowsnest Stone Co., Brocket, Alberta, (1388).
No. 2—Paskapoo sandstone, Porcupine hills, Alberta, (1357).
No. 3—Paskapoo sandstone, Wm. Oliver's quarry, Calgary, Alberta, (1285).
No. 4—Paskapoo sandstone, old quarries at Glenbow, Alberta, (1294).
No. 5—Paskapoo sandstone, Shelley Quarry Co., No. 1 quarry, Cochrane, Alberta, (1299).
No. 6—Paskapoo sandstone, Shelley Quarry Co., No. 3 quarry, Cochrane, Alberta, (1301).

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APPENDIX I.

TABLE I.

The Specific Gravity, Weight per Cubic Foot, Pore Space, Ratio of Absorption, and Coefficient of Saturation of Stones from Manitoba and Alberta.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation.
1018	Lake Winnipeg Shipping Co.	Lake Winnipeg	Ordovician	2·745	164·194	4·07	1·55	0·84
1047	Wallace Sandstone Co.	Tyndall	"	2·767	151·54	12·17	5·01	0·76
1048	Wallace Sandstone Co.	Tyndall	"	2·741	152·88	10·55	4·296	0·89
1058	City of Winnipeg	Stony mountain-Winnipeg	"	2·837	156·822	11·45	4·56	0·673
1002	Winnipeg Supply and Fuel Co.	Stonewall-Gunton	Silurian	2·85	155·657	12·51	5·04	0·64
1013	Manitoba Quarries	Stonewall-Gunton	Silurian	2·845	167·47	5·705	2·126	0·80
1014	Manitoba Quarries	Stonewall-Gunton	Silurian	2·855	170·053	4·53	1·66	0·84
1015	Manitoba Quarries	Stonewall-Gunton	Silurian	2·85	160·995	9·51	3·68	0·435
1114	Grand rapids, Saskatchewan river	Lake Winnipegosis-Saskatchewan river	Silurian	2·867	175·3939	2·00	0·711	0·85
1119	Cedar lake	Lake Winnipegosis-Saskatchewan river	Silurian	2·843 2·846	175·054 173·248	1·36 2·5	0·486 0·9	0·36(?)[1] 0·2 (?)
1131	W. J. Long	Inwood-Broadvalley	Silurian	2·853	155·446	12·72	5·12	0·76
1144	Manitobite Stone Works	Inwood-Broadvalley	Silurian	2·839	156·419	11·74	4·68	0·59
1160	Old Gypsumville	Fairford	Silurian	2·85	170·513	4·16	1·52	0·66
1123	Mile 42, Hudson Bay Ry.	Hudson Bay Railway	Silurian	2·852	177·143	0·503	0·177	0·94
1153	Canada Cement Co.	Steep Rock	Devonian (Elm Point)	2·701	167·41	0·595	0·222	0·7

[1] The cavernous nature of this stone makes agreement in duplicate impossible except for specific gravity where the porosity is eliminated.

LIMESTONES—*Continued*

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
			Manitoba.					
1086	Whiteaves point, Lake Winnipegosis.........	Lake Winnipegosis.....	Devonian.... (Winnipegosan)	2·849	170·777	3·978	1·484	0·49
1082	Point Wilkins, Lake Winnipegosis............	Lake Winnipegosis.....	Devonian.... (Manitoban)	2·77	166·47	3·73	1·4	0·82
1083	Point Wilkins, Lake Winnipegosis............	Lake Winnipegosis.....	Devonian.... (Manitoban)	2·711	163·415	3·44	1·31	0·66
1085	Point Wilkins, Lake Winnipegosis............	Lake Winnipegosis.....	Devonian.... (Manitoban)	2·696	163·689	2·74	1·04	0·86
1097	Brabant Pt., Lake Winnipegosis..............	Lake Winnipegosis.....	Devonian.... (Manitoban)	2·84	169·678	4·293	1·493	0·24
1079	Kettle hill, Swan lake....	Lake Winnipegosis.....	Devonian....	2·841	167·02	5·82	2·14	0·6
			Alberta.					
1336	Canada Cement Co., Exshaw................	Canadian Pacific Ry...	Devonian.... (L. Banff)	2·723	169·43	0·328	0·12	0·69
1315	Banff.................	Canadian Pacific Ry...	Carboniferous (U. Banff)	2·706	167·44	0·88	0·329	0·57
1272	Nordegg................	Nordegg.............	Permo-Triassic...	2·683	164·14	1·88	0·715	0·77
1302	Banff.................	Canadian Pacific Ry...	Permo-Triassic...	2·764	172·04	0·292	0·106	0·86

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1020	Punk island, L. Winnipeg	Lake Winnipeg........	Ordovician...	2·635	140·56	14·55	6·465	0·9
1187	John Robinson, Boissevain	Turtle mountain	Cretaceous...	2·71	158·63	6·12	2·405	0·93

Alberta.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1364	Coleman...............	Crowsnest...........	Cretaceous.. (Dakota)	2·712	163·24	3·58	1·37	0·9
1233	Mile 984, Grand Trunk Pacific Railway.......	Grand Trunk Pacific Railway...........	Cretaceous.. (Dakota)	2·714	154·85	8·60	3·383	0·92
1221	Mile 22, Coal Spur-Mountain Park railway......	Mountain Park........	Cretaceous.. (Dakota)	2·708	158·37	6·32	2·491	0·94
1224	McLeod river...........	Mountain Park........	Cretaceous.. (Dakota)	2·669	161·25	3·22	1·24	0·94
1268	Mile 156½, C.N.R. to Nordegg..............	Rocky Mountain House	Cretaceous.. (Edmonton)	2·687	137·07	18·40	8·39	0·86
1360	Macleod Quarrying and Contracting Co........	Monarch............	Tertiary.... (Paskapoo)	2·691	138·64	17·47	7·86	0·71
1361	Macleod Quarrying and Contracting Co........	Monarch............	Tertiary.... (Paskapoo)	2·688	140·02	16·56	7·36	0·79
1363	Mrs. Arnold...........	Monarch............	Tertiary.... (Paskapoo)	2·713	142·21	16·03	7·0	0·87
1357	Porcupine hills..........	Macleod-Brocket......	Tertiary.... (Paskapoo)	2·672	143·76	13·81	6·0	0·78

SANDSTONES—*Continued.*

Alberta.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1388	Crowsnest Stone Co.	Macleod-Brocket......	Tertiary.... (Paskapoo)	2·682	147·57	11·86	5·02	0·74
1354	Wm. Brazier, High River.	High River..........	Tertiary.... (Paskapoo)	2·683	139·0	17·01	7·64	0·78
1285	Wm. Oliver and Co., Calgary................	Calgary.............	Tertiary.... (Paskapoo)	2·683	130·51	22·08	10·56	0·68
1286	Wm. Oliver and Co., Calgary................	Calgary.............	Tertiary.... (Paskapoo)	2·694	155·61	7·47	3·00	0·89
1279	J. A. Lewis, Rocky View..	Calgary.............	Tertiary.... (Paskapoo)	2·692	132·45	21·37	10·09	0·71
1294	C. de Lavergne, Glenbow	Glenbow-Cochrane.....	Tertiary.... (Paskapoo)	2·665	134·19	19·34	8·98	0·68
1299	Shelley Quarry Co.......	Glenbow-Cochrane.....	Tertiary.... (Paskapoo)	2·675	134·16	19·54	9·08	0·73
1301	Shelley Quarry Co.......	Glenbow-Cochrane.....	Tertiary.... (Paskapoo)	2·669	138·32	16·98	7·64	0·71
1275	Wm. Gunston, Innisfail..	Red Deer............	Tertiary.... (Paskapoo)	2·687	125·17	25·38	12·66	0·72
1202	Pembina Quarries, Entwistle................	Entwistle............	Tertiary.... (Paskapoo)	2·703	115·47	31·57	17·07	0·74
1203	Pembina Quarries, Entwistle................	Entwistle............	Tertiary.... (Paskapoo)	2·704	146·40	13·27	5·66	0·94
1204	Pembina Quarries, Entwistle................	Entwistle............	Tertiary.... (Paskapoo)	2·720	115·78	31·81	17·157	0·83

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1033	Rabbit point, L. Winnipeg	Lake Winnipeg........	Pre-Cambrian	2·712	168·07	0·606	0·225	0·69
1040	L. Winnipeg Shipping Co.	Lake Winnipeg........	Pre-Cambrian	2·666	166·11	0·193	0·07	0·69

Alberta.

No.	Owner or Locality	Area	Geological System	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1256	Mile 1025, Grand Trunk Pacific Railway	Grand Trunk Pacific Railway............	Cambrian ..	2·719	168·91	0·483	0·178	0·9

TABLE II.

The Ratio of Absorption and the Coefficient of Saturation under different conditions—one hour soaking, two hours soaking, slow immersion and long soaking, in vacuo, and under pressure.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1018	Lake Winnipeg Shipping Co..	Lake Winnipeg...	0·992	1·22	1·31	1·51	1·55	0·64	0·79	0·84	0·97
1047	Wallace Sandstone Co........	Tyndall.........	1·076	2·702	3·816	4·57	5·01	0·21	0·54	0·76	0·91
1048	Wallace Sandstone Co........	Tyndall.........	1·595	2·296	3·841	4·296	4·296	0·37	0·53	0·89	1·00
1058	City of Winnipeg............	Stony mountain-Winnipeg......	2·093	2·667	3·071	4·55	4·56	0·459	0·585	0·673	0·99
1002	Winnipeg Supply and Fuel Co.	Stonewall-Gunton	2·16	2·88	3·22	4·69	5·04	0·43	0·57	0·64	0·93
1013	Manitoba Quarries...........	Stonewall-Gunton	0·918	1·21	1·712	1·78	2·126	0·43	0·57	0·80	0·83
1014	Manitoba Quarries...........	Stonewall-Gunton	0·935	1·18	1·4	1·53	1·66	0·57	0·71	0·84	0·92
1015	Manitoba Quarries...........	Stonewall-Gunton	0·507	1·195	1·603	3·23	3·68	0·137	0·326	0·435	0·877
1114	Grand rapids, Saskatchewan river....................	Lake Winnipegosis-Saskatchewan river.....	0·078	0·123	0·609 ?	0·467	0·711	0·109	0·17	0·85 ?	0·65
1119	Cedar lake..................	Lake Winnipegosis-Saskatchewan river......	0·231	0·271	....	0·583	0·693	0·345	0·405	....	0·825[1]
1131	W. J. Long..................	Inwood-Broadvalley.........	0·329	1·425	3·905	5·07	5·12	0·064	0·28	0·76	0·99
1144	Manitobite Stone Works.....	Inwood-Broadvalley....	2·343	2·355	2·78	4·67	4·68	0·5	0·5	0·59	0·99

[1] The figures given here are the averages of several experiments which vary greatly. This stone is so cavernous that it is impossible to determine these factors with accuracy.

1160	Old Gypsumville...........	Fairford.........	0·514	0·68	1·01	1·28	1·52	0·34	0·44	0·66	0·83
1123	Mile 42, Hudson Bay Ry.....	Hudson Bay Railway.......	0·068	0·094	0·167	0·16	0·177	0·39	0·53	0·94	0·9
1153	Canada Cement Co..........	Steep Rock......	0·119	0·155	0·156	0·218	0·222	0·54	0·7	0·7	0·98
1086	Whiteaves point, Lake Winnipegosis.................	Lake Winnipegosis...........	0·268	0·381	0·734	1·137	1·484	0·18	0·26	0·49	0·77
1082	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis..........	0·819	0·973	1·156	1·244	1·4	0·58	0·69	0·82	0·88
1083	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis..........	0·786	0·980	0·87?	1·283	1·31	0·6	0·74	0·66?	0·98
1085	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis........	0·435	0·576	0·892?	1·995	1·04	0·41	0·55	0·86?	0·95
1097	Brabant point, Lake Winnipegosis.................	Lake Winnipegosis........	0·495	0·681	0·368	1·433	1·493	0·33	0·46	0·24?	0·94
1079	Kettle hill, Swan lake........	Lake Winnipegosis........	0·996	1·114	1·27	2·108	2·14	0·46	0·52	0·6	0·96

Alberta.

1336	Canada Cement Co., Exshaw	Canadian Pacific Railway.......	0·024	0·029	0·083	0·10	0·12	0·2	0·24	0·69	0·83
1315	Banff......................	Canadian Pacific Railway.......	0·15	0·15	0·189	0·301	0·329	0·45	0·45	0·57	0·91
1272	Nordegg...................	Nordegg.........	0·291	0·39	0·55	0·551	0·715	0·4	0·54	0·77	0·77
1302	Banff......................	Canadian Pacific Railway.......	0·018	0·222	0·091	0·091	0·106	0·17	0·20	0·86	0·86

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Ratio of Absorption, per cent. One hour	Two hours	Slow immersion	In vacuo	Under pressure	Coefficient of Saturation One hour	Two hours	Slow immersion	In vacuo
1020	Punk island	Lake Winnipeg	3·352	3·54	5·87	6·01	6·465	0·518	0·55	0·90	0·93
1187	John Robinson, Boissevain	Turtle mountain	2·043	2·06	2·26	2·318	2·405	0·84	0·85	0·93	0·96

Alberta.

No.	Owner or Locality	Area	Ratio of Absorption, per cent. One hour	Two hours	Slow immersion	In vacuo	Under pressure	Coefficient of Saturation One hour	Two hours	Slow immersion	In vacuo
1364	Coleman	Crowsnest	0·559	0·63	1·23	1·37	1·37	0·41	0·46	0·9	1·0
1233	Mile 984, G.T.P.R.	Grand Trunk Pacific R.	1·2	1·6	3·11	3·29	3·383	0·35	0·47	0·92	0·94
1221	Mile 22, Coal Spur-Mt. Park	Mountain Park	1·06	1·15	2·34	2·42	2·49	0·42	0·46	0·94	0·97
1224	McLeod river	Mountain Park	0·85	0·98	1·17	1·17	1·24	0·68	0·79	0·94	0·94
1268	Mile 156½, C.N.R. to Nordegg	Rocky Mountain House	5·56	6·11	7·25	8·25	8·39	0·66	0·72	0·86	0·96
1360	Macleod Quarrying and Contracting Co.	Monarch	3·13	3·53	5·59	7·86	7·86	0·39	0·44	0·71	1·0
1361	Macleod Quarrying and Contracting Co.	Monarch	3·72	4·14	5·87	7·26	7·36	0·50	0·56	0·79	0·98
1363	Mrs. Arnold	Monarch	4·95	5·00	6·107	6·97	7·00	0·7	0·71	0·87	0·99
1357	Porcupine hills	Macleod-Brocket	3·96	4·05	4·68	5·98	6·00	0·66	0·67	0·78	0·99
1388	Crowsnest Stone Co.	Macleod-Brocket	3·02	3·25	3·72	5·00	5·02	0·6	0·64	0·74	0·99
1354	Wm. Brazier, High River	High River	5·02	5·09	5·97	7·60	7·64	0·65	0·66	0·78	0·99
1285	Wm. Oliver and Co., Calgary	Calgary	6·62	6·62	7·21	10·45	10·56	0·62	0·62	0·68	0·99
1286	Wm. Oliver and Co., Calgary	Calgary	2·11	2·11	2·69	2·92	3·00	0·70	0·70	0·89	0·99
1279	J. A. Lewis, Rocky View	Calgary	6·53	6·59	7·21	9·94	10·09	0·64	0·65	0·71	0·98
1294	C. de Lavergne, Glenbow	Glenbow-Cochrane	4·09	4·51	6·14	8·92	8·98	0·45	0·50	0·68	0·99
1299	Shelley Quarry Co.	Glenbow-Cochrane	5·61	5·61	6·66	9·07	9·08	0·61	0·61	0·73	0·99
1301	Shelley Quarry Co.	Glenbow-Cochrane	4·55	4·65	5·47	7·62	7·64	0·59	0·60	0·71	0·99

1275	Wm. Gunston, Innisfail......	Red Deer........	8·35	8·57	9·13	12·51	12·66	0·66	0·68	0·72	0·98
1202	Pembina Quarries...........	Entwistle........	11·45	11·45	12·76	16·76	17·07	0·67	0·67	0·74	0·98
1203	Pembina Quarries...........	Entwistle........	2·41	2·63	5·34	5·48	5·66	0·42	0·46	0·94	0·96
1204	Pembina Quarries...........	Entwistle........	12·38	12·77	14·42	16·69	17·157	0·73	0·74	0·83	0·97

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

No.	Owner or Locality	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1033	Rabbit point, L. Winnipeg....	Lake Winnipeg...	0·136	0·141	0·155	0·187	0·225	0·60	0·64	0·69	0·83
1040	Lake Winnipeg Shipping Co..	Lake Winnipeg...	0·020	0·029	0·048	0·052	0·070	0·29	0·41	0·69	0·74

Alberta.

1256	Mile 1025, Grand Trunk Pacific Railway..............	Grand Trunk Pacific Railway...	0·103	0·121	0·16	0·16	0·178	0·58	0·68	0·9	0·9

TABLE III.

The Crushing Strength of Stones from Manitoba and Alberta.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1018	Lake Winnipeg Shipping Co....	Lake Winnipeg	Ordovician...	24,208	Spread at one side shortly before collapse.
1047	Wallace Sand-stone Co.....	Tyndall........	"	10,030	Sudden collapse, crumbled; small upper and lower wedges.
1048	Wallace Sand-stone Co.......	Tyndall........	"	10,006	Crumbled; small upper cone, numerous small wedges.
1058	City of Winnipeg......	Stony mountain-Winnipeg..	"	11,818	Yielded gently; long thin, vertical wedges.
1002	Winnipeg Supply and Fuel Co.	Stonewall-Gunton........	Silurian......	27,095	Yielded gradually; small vertical wedges.
1013	Manitoba Quarries	Stonewall-Gunton........	"	30,980	Upper flat cone, powder below.
1014	Manitoba Quarries.......	Stonewall-Gunton........	"	27,000	Failed under sustained load, probably low; large lower pyramid.
1015	Manitoba Quarries.......	Stonewall-Gunton........	"	32,918	Small upper cone, fine powder below.
1114	Grand rapids, Saskatchewan river..........	L. Winnipegosis–Saskatchewan river..........	"	52,708+	Surpassed the limit of the machine; no flaw or crack developed.
1119	Cedar lake.....	L. Winnipegosis–Saskatchewan river..........	"	36,000	Variable results with duplicates owing to the cavernous nature of the stone.
1131	W. J. Long.....	Inwood-Broadvalley....	"	14,325	Squeezed out at sides before collapse; small upper cone, wedges and powder.
1144	Manitobite Stone Works...	Inwood-Broadvalley....	"	30,000	Failed under sustained load at 29,000 lbs.; small wedges only.
1160	Old Gypsum-ville...........	Fairford	"	41,928	Little wedges and powder.
1123	Mile 42, Hudson Bay Railway	Hudson Bay Railway.......	"	40,549	Yielded from one side; result possibly a little too low. Powder.

LIMESTONES—*Continued*

Manitoba.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1153	Canada Cement Co.	Steep Rock	Devonian (Elm Point)	31,507	Exploded; powder and sharp vertical wedges.
1086	Whiteaves pt., L. Winnipegosis	Lake Winnipegosis	Devonian (Winnipegosan)	47,883	Sudden collapse; powder only.
1082	Point Wilkins, L. Winnipegosis	Lake Winnipegosis	Devonian (Manitoban)	17,422	Chipped out at sides before collapse; powder and small wedges.
1083	Point Wilkins, L. Winnipegosis	Lake Winnipegosis	Devonian (Manitoban)	21,297	Corner broke before collapse, result is probably a little low; imperfect lower pyramid.
1085	Point Wilkins, L. Winnipegosis	Lake Winnipegosis	Devonian (Manitoban)	19,682	Small upper cone, sharp fragments.
1097	Brabant point, L. Winnipegosis	Lake Winnipegosis	Devonian (Manitoban)	45,587	Fine vertical cracks or lines appeared early but the collapse was sudden; powder.
1079	Kettle hill, Swan lake	Lake Winnipegosis	Devonian	37,275	Small upper and lower wedges.

Alberta.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1336	Canada Cement Co. (Exshaw)	Canadian Pacific Railway	Devonian (L. Banff)	27,174	Exploded; small sharp fragments.
1315	Banff	Canadian Pacific Railway	Carboniferous (U. Banff)	17,772	Possibly a little too low; small fragments.
1272	Nordegg	Nordegg	Permo-Triassic	52,400+	Surpassed limit of machine; cracked a little.
1302	Banff	Canadian Pacific Railway	Permo-Triassic	50,000	Exploded; small fragments.

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1020	Punk island, L. Winnipeg	Lake Winnipeg	Ordovician	6,438	Failed a little before collapse; large upper wedge.
1187	John Robinson, Boissevain	Turtle mountain	Cretaceous	19,703	Sudden collapse; powder and small wedges.

Alberta.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1364	Coleman.......	Crowsnest.....	Cretaceous (Dakota)....	22,500	Cracked just before collapse; imperfect lower pyramid.
1233	Mile 984, Grand Trunk Pacific Ry...........	Grand Trunk Pacific Railway......	"	17,880	Sudden collapse; fragments only.
1221	Mile 22, Coal Spur-Mountain Pk. branch of G.T.P.........	Mountain Park...........	"	19,362	Flat lower pyramid.
1224	McLeod river..	Mountain Park.	"	20,186	Numerous small wedges.
1268	Mile 156½ C.N.R. to Nordegg.......	Rocky Mountain House.........	Cretaceous (Edmonton) .	5,253	Gentle collapse; large lower pyramid.
1360	Macleod Quarrying and Contracting Co.	Monarch.......	Tertiary (Paskapoo)	7,092	Sudden collapse; good upper pyramid.
1361	Macleod Quarrying and Contracting Co.	Monarch.......	"	6,796	Sudden collapse; vertical prisms.
1363	Mrs. Arnold.....	Monarch.......	"	7,470	Irregular wedges.
1357	Porcupine hill..	Macleod-Brocket........	"	9,841	Numerous vertical wedges.
1388	Crowsnest Stone Co......	Macleod-Brocket........	"	12,397	Small upper cone.
1354	Wm. Brazier, High River.....	High River.....	"	7,964	Small wedges only.
1285	Wm. Oliver & Co., Calgary...	Calgary........	"	5,647	Wedges only.
1286	Wm. Oliver & Co., Calgary....	Calgary........	"	14,089	Wedges and sharp fragments.
1279	J. A. Lewis, Rocky View....	Calgary........	"	6,224	Good upper pyramid.
1294	C. de Lavergne, Glenbow.......	Glenbow-Cochrane......	"	7,631	Upper pyramid.
1299	Shelley Quarry Co., Cochrane..	Glenbow-Cochrane......	"	8,807	Small upper cone, lower wedges.
1301	Shelley Quarry Co., Cochrane .	Glenbow-Cochrane......	"	10,427	Small upper cone.
1275	Wm. Gunston, Innisfail.......	Red Deer......	"	4,905	Small lower pyramid.
1202	Pembina Quarries, Entwistle..	Entwistle......	"	1,253	Gentle yield; poor lower pyramid.
1203	Pembina Quarries, Entwistle..	Entwistle......	"	5,893	Large lower pyramid.
1204	Pembina Quarries, Entwistle..	Entwistle......	"	1,793	Good upper pyramid.

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1033	Rabbit point, L. Winnipeg ...	Lake Winnipeg......	Pre-Cambrian....	29,526	Chipped before collapse; powder.
1040	Lake Winnipeg Shipping Co. ..	Lake Winnipeg......	"	46,518	Crushed to fine powder.

Alberta.

No.	Owner or Locality	Area	Geological System	Crushing strength, lbs. per sq. in.	Remarks
1256	Mile 1025, Grand Trunk Pacific Ry. ...	Grand Trunk Pacific Railway	Cambrian....	19,615	Large upper wedge.

TABLE IV

The Comparative Crushing Strength of Stones from Manitoba and Alberta, dry, wet, and wet after being frozen forty times.[1]

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Crushing strength, lbs. per sq. in.			Differences, lbs. per sq. in.		Remarks
			Dry	Wet	Wet after freezing	Dry and wet	Wet and frozen	
1018	Lake Winnipeg Shipping Co...........	Lake Winnipeg....	24,208	17,400	18,700	6,808	....	Anomalous result; no apparent reason. The dry-wet difference is probably too great.
1047	Wallace Sandstone Co..	Tyndall..........	10,030	8,000	8,818	2,030	....	It is impossible to make comparable cubes of a mottled stone.
1048	Wallace Sandstone Co..	Tyndall..........	10,006	8,357	9,012	1,649	....	See remark above. The frozen cube is apparently stronger.
1058	City of Winnipeg......	Stony Mt.-Winnipeg...........	11,818	10,089	10,795	1,729	....	Practically uninjured by the freezing operation.
1002	Winnipeg Supply and Fuel Co...........	Stonewall-Gunton.	27,095	23,700	17,477	3,395	6,223	The wet cubes squeezed out at sides.
1013	Manitoba Quarries.....	Stonewall-Gunton.	30,980	25,831	27,833	5,149	....	Both wet cubes yielded before collapse.
1014	Manitoba Quarries.....	Stonewall-Gunton.	27,000	25,656	19,879	1,344	5,777	The frozen cube yielded from one side. The result is probably low.

[1] These figures represent the direct results of experiments; they must not be taken too literally, but must be considered with due regard to the remarks on pages 12 and 13.

1015	Manitoba Quarries.....	Stonewall-Gunton.	32,918	18,000	25,140	....	....	The anomaly is so serious that the differences are not recorded.
1114	Grand rapids, Saskatchewan river........	Lake Winnipegosis-Saskatchewan river...........	52,708	44,430	48,334	....	....	At such high pressures comparative results are impossible. The instrumental error exceeds the effect of soaking, etc.
1119	Cedar lake............	Lake Winnipegosis-Saskatchewan river...........	36,000	36,320	16,500	....	....	Very cavernous stone, comparative figures are impossible.
1131	W. J. Long...........	Inwood-Broadvalley.....	14,325	15,783	12,618	....	3,165	Both wet cubes yielded before final collapse.
1144	Manitobite Stone Works..............	Inwood-Broadvalley.....	30,000	27,029	28,977	2,971	....	No apparent reason for the greater strength of frozen cube.
1160	Old Gypsumville......	Fairford..........	41,828	28,363	29,628	....	....	Wet cube failed under sustained load. The result is probably low.
1123	Mile 42, Hudson Bay Ry.................	Hudson Bay Railway............	40,549	38,100	37,714	2,449	386	At such high pressures the differences are not very significant.
1153	Canada Cement Company...............	Steep Rock.......	31,507	29,452	23,318	2,055	6,134	Good sudden failure with both wet cubes.
1086	Whiteaves pt., Lake Winnipegosis........	Lake Winnipegosis	47,883	31,423	35,972	....	....	Wet cube spread before collapse; result low.
1082	Point Wilkins, Lake Winnipegosis........	Lake Winnipegosis	17,422	13,068	11,439	4,354	1,629	Frozen cube exfoliated under pressure.
1083	Point Wilkins, Lake Winnipegosis........	Lake Winnipegosis	21,297	22,045	19,470	....	2,575	Flaws developed during the freezing.

LIMESTONES—*Continued.*

No.	Owner or Locality	Area	Crushing strength, lbs. per sq. in.			Differences, lbs. per sq. in.		Remarks
			Dry	Wet	Wet after freezing	Dry and wet	Wet and frozen	
	Manitoba.							
1085	Point Wilkins, Lake Winnipegosis........	Lake Winnipegosis	19,682	14,427	13,654	5,255	773	Both wet cubes yielded before collapse.
1097	Brabant Point, Lake Winnipegosis........	Lake Winnipegosis	45,587	25,400	37,332	....	....	Wet cube squeezed out at cavern in one side. The result is undoubtedly too low.
1079	Kettle hill, Swan lake..	Lake Winnipegosis	37,275	28,109	30,013	....	....	Wet cube result is evidently too low. Cracked at sides before collapse.
	Alberta.							
1336	Canada Cement Co. (Exshaw)...........	Canadian Pacific Railway........	27,174	21,429	20,072	5,745	1,357	Fairly good failures. Frozen cube went a little from one side.
1315	Banff................	Canadian Pacific Railway........	17,772	18,369	14,660	....	3,709	All tests apparently good.
1272	Nordegg..............	Nordegg..........	52,400	46,388	....	6,102	....	Results of little value at such high pressures.
1302	Banff................	Canadian Pacific Railway........	50,000	50,669	40,937	....	9,732	Results of little value at such high pressures.

SANDSTONES.

No.	Owner or Locality	Area	Dry	Wet	Wet after freezing	Dry and wet	Wet and frozen	Remarks
	Manitoba.							
1020	Punk island, L. Winnipeg................	Lake Winnipeg....	6,438	6,798	5,941	....	857	Tests all apparently good with sudden failures in each case.
1187	John Robinson, Boissevain..............	Turtle mountain..	19,703	13,181	14,729	6,522	....	All good tests with sudden failures.

Alberta.

1364	Coleman	Crowsnest	22,500	20,789	19,534	1,711	1,255	Wet cubes yielded gradually.
1233	Mile 984, G.T.P.R.	Grand Trunk Pacific Railway	17,880	13,074	9,477	4,806	3,597	Tests all good.
1221	Mile 22, Coal Spur-Mountain Park br'ch of G.T.P.R.	Mountain Park	19,363	14,114	11,481	5,249	2,633	All tests fairly good; frozen cube cracked a little before collapse.
1224	McLeod river	Mountain Park	20,186	15,680	17,042	4,506	....	The wet test is evidently low; yielded at one side first.
1268	Mile 156½ C.N.R. to Nordegg	Rocky Mountain House	5,253	2,943	1,960	2,310	983	All cubes yielded gradually without jar.
1360	Macleod Quarrying and Contracting Co.	Monarch	7,092	3,963	2,976	3,129	987	Both wet cubes cracked a little before collapse.
1361	Macleod Quarrying and Contracting Co.	Monarch	6,796	3,993	3,679	2,803	314	All good tests; gentle yield.
1363	Mrs. Arnold	Monarch	7,470	5,427	4,912	2,043	515	All good tests; gentle yield.
1357	Porcupine hill	Macleod-Brocket	9,841	5,803	4,985	4,038	818	All tests satisfactory.
1388	Crowsnest Stone Co.	Macleod-Brocket	12,397	8,646	8,064	3,751	582	All tests satisfactory.
1354	Wm. Brazier	High River	7,964	5,324	3,337	2,640	1,987	Frozen cube cracked slightly before collapse.
1285	Wm. Oliver, Calgary	Calgary	5,647	4,144	2,677	1,503	1,467	Frozen cube cracked slightly before collapse.
1286	Wm. Oliver, Calgary	Calgary	14,089	11,246	10,574	2,843	872	Wet cube cracked slightly before collapse.
1279	J. A. Lewis, Rocky View	Calgary	6,224	3,604	2,887	2,620	717	Wet cube is possibly somewhat low; it yielded a little before final collapse.
1294	C. de Lavergne	Glenbow-Cochrane	7,631	5,640	3,896	1,991	1,744	All tests are apparently satisfactory.
1299	Shelley Quarry Co.	Glenbow-Cochrane	8,807	6,231	3,490	2,576	2,741	The frozen cube was badly exfoliated on freezing, making a poor bearing face whereby the loss on freezing is probably increased.

SANDSTONES—*Continued.*

Alberta.

No.	Owner or Locality	Area	Crushing strength, lbs. per sq. in.			Differences, lbs. per sq. in.		Remarks
			Dry	Wet	Wet after freezing	Dry and wet	Wet and frozen	
1301	Shelley Quarry Co.....	Glenbow-Cochrane	10,427	7,783	4,934	2,644	2,849	Frozen cube cracked before final collapse. Cube was not so badly exfoliated as 1299.
1275	Wm. Gunston, Innisfail	Red Deer.........	4,905	3,283	0,000	1,622	3,283	The frozen cube disintegrated so badly that no test could be made on the small piece remaining.
1202	Pembina Quarries, Entwistle.............	Entwistle.........	4,945	3,100	0,000	1,845	3,100	Frozen cube completely broke down to sand.
1203	Pembina Quarries, Entwistle.............	Entwistle.........	5,893	3,264	0,000	2,629	3,264	About one-half of the cube disintegrated. No test possible.
1204	Pembina Quarries, Entwistle.............	Entwistle.........	1,793	600	0,000	1,193	600	Frozen cube completely broke down to sand.

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

No.	Owner or Locality	Area	Dry	Wet	Wet after freezing	Dry and wet	Wet and frozen	Remarks
1033	Rabbit pt., L. Winnipeg	Lake Winnipeg....	29,526	23,519	23,199	6,007	320	Tests satisfactory; there was a little exfoliation of the frozen cube before collapse.
1040	Lake Winnipeg Shipping Co............	Lake Winnipeg....	46,518	44,734	38,011	1,784	6,723	The frozen cube showed signs of failure before the collapse.

Alberta.

1256	Mile 1025, Grand Trunk Pacific Ry..........	Grand Trunk Pacific Railway.....	19,615	13,758	16,743	5,857	....	The wet cubes squeezed out and crumpled near the bearing faces. The result in the case of the wet cube is undoubtedly low.

TABLE V.

The Transverse Strength of Stones from Manitoba and Alberta.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture.
1018	Lake Winnipeg Shipping Co....	Lake Winnipeg......	Ordovician	2,375	Slightly uneven; on central line above, slightly off below.
1047	Wallace Sandstone Co.......	Tyndall........	"	1,382	Slightly uneven; 0·3 in. from line on one side and 0·8 in. on the other.
1048	Wallace Sandstone Co.......	Tyndall........	"	1,297	Uneven; slightly diagonal to line.
1058	City of Winnipeg......	Stony mountain-Winnipeg...	"	1,238	Very uneven and off the line.
1002	Winnipeg Supply and Fuel Co.	Stonewall-Gunton........	Silurian......	2,184	Parallel to line but 1·25 in. to one side; uneven below.
1013	Manitoba Quarries.......	Stonewall-Gunton........	"	759	Extremely uneven and curved; below 0·5 in. off line.
1014	Manitoba Quarries.......	Stonewall-Gunton........	"	2,549	Slightly uneven; on line at one side, 0·2 in. off on other.
1015	Manitoba Quarries.......	Stonewall-Gunton........	"	1,316	Very uneven; on line at one side, 1·2 in. off on the other.
1114	Grand rapids, Saskatchewan river..........	L. Winnipegosis–Saskatchewan river......	"	5,304	Almost flat; slightly diagonal to line.
1119	Cedar lake.....	L. Winnipegosis–Saskatchewan river......	"	3,797	Slightly uneven and slightly diagonal to line.
1131	W. J. Long.....	Inwood-Broadvalley....	"	1,379	Wavy uneven; off line 0·2 in. on one side and 1·5 on the other.
1144	Manitobite Stone Works...	Inwood-Broadvalley....	"	2,108	Almost flat; slightly diagonal to line.
1160	Old Gypsumville...	Fairford.......	"	3,351	Uneven; on line on one side, on the other 0·25 in. off.

LIMESTONES—*Continued*

Manitoba.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture
1123	Mile 42, Hudson Bay Railway ..	Hudson Bay Railway	Silurian.....	2,641	Angular uneven, parallel to line but 0·5 in. off.
1153	Canada Cement Co...........	Steep Rock....	Devonian (Elm Point)	2,202	Splintery; runs off on bedding planes; highly diagonal to vertical central line.
1086	Whiteaves pt., L. Winnipegosis	L. Winnipegosis	Devonian.. (Winnipego-san).........	3,186	Uneven; off line on both sides 0·3 in.; straight above, diagonal below.
1082	Point Wilkins, L. Winnipegosis	L. Winnipegosis	Devonian (Manitoban)	1,485	Sharp, angular, uneven; off line 0·25 in. on one side and 0·8 in. on the other.
1083	Point Wilkins, L. Winnipegosis	L. Winnipegosis	Devonian (Manitoban)	2,790	Angular uneven; 0·25 in. off line above, 0·7 in. off below.
1085	Point Wilkins, L. Winnipegosis	L. Winnipegosis	Devonian (Manitoban)	802	Extremely uneven; on line on one side, 1·5 in. off on the other.
1097	Brabant point, L. Winnipegosis	L. Winnipegosis	Devonian (Manitoban)	2,991	Almost flat and smooth; slightly diagonal to central line.
1079	Kettle hill, Swan lake......	L. Winnipegosis	Devonian.	2,571	Almost flat and nearly on line.

Alberta.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture
1336	Canada Cement Co. (Exshaw).	Canadian Pacific Railway....	Devonian (L. Banff)....	1,779	Very uneven; above 1·25 and 0·7 in. off line, below 1 in. and 2·3 in. off.
1315	Banff..........	Canadian Pacific Railway ...	Carboniferous (U.Banff)	1,969	Hackly; 0·7 in. off line; determined by pits.
1272	Nordegg.......	Nordegg.......	Permo-Triassic	6,302	Almost flat; slightly diagonal to line.
1302	Banff..........	Canadian Pacific Railway....	Permo-Triassic......	6,657	Almost flat; on line above, slightly off below.

SANDSTONES.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture.
			Manitoba.		
1020	Punk island, L. Winnipeg....	L. Winnipeg....	Ordovician...	575	Somewhat uneven; slightly diagonal to line.
1187	John Robinson. Boissevain.....	Turtle mountain.....	Cretaceous...	1,151	Fairly even and almost on line.
			Alberta.		
1364	Coleman.......	Crowsnest.....	Cretaceous... (Dakota)	3,081	Uneven; slightly diagonal to line.
1233	Mile 984, Grand Trunk Pacific Railway	Grand Trunk Pacific Railway.......	"	1,765	Even and straight; almost on line.
1221	Mile 22, Coal Spur-Mountain Pk. branch of G.T.P.........	Mountain Park..........	"	2,243	On line; slightly wavy.
1224	McLeod river..	Mountain Park	"	1,510	Irregular; slightly diagonal to line.
1268	Mile156½ C.N.R. to Nordegg.......	Rocky Mountain House.....	Cretaceous (Edmonton)	445	Slightly uneven; almost on line.
1360	Macleod Quarrying and Contracting Co.	Monarch......	Tertiary (Paskapoo)...	308	Slightly uneven; crosses line diagonally at a low angle.
1361	Macleod Quarrying and Contracting Co.	Monarch.......	"	556	Very uneven; on line at one side, 0·2 in. off on the other.
1363	Mrs. Arnold....	Monarch.......	"	468	Slightly uneven; almost on line.
1357	Porcupine hill..	Macleod-Brocket........	"	501	Almost flat; on line at one side, 0·25 in. off on the other.
1388	Crowsnest Stone Co......	Macleod-Brocket........	"	663	Very slightly uneven; on line at one side, 0·2 in. off on other.
1354	Wm. Brazier, High River	High River	"	478	On line; even above, uneven below.
1285	Wm. Oliver & Co., Calgary...	Calgary........	"	467	Straight and even; on line at one side, 0·3 in. off on the other.
1286	Wm. Oliver & Co., Calgary...	Calgary........	"	1,158	Fairly even; on line at one side, 0·4 in. off on the other.

SANDSTONES—*Continued*

Alberta.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture
1279	J. A. Lewis, Rocky View....	Calgary........	Tertiary (Paskapoo)	329	On line; even above, slightly uneven below.
1294	C. de Lavergne, Glenbow.......	Glenbow-Cochrane......	"	554	Almost on line; slightly uneven.
1299	Shelley Quarry Co., Cochrane..	Glenbow-Cochrane......	"	657	Slightly uneven; on line at one side, 0·25 in. off on the other.
1301	Shelley Quarry Co., Cochrane..	Glenbow-Cochrane......	"	660	Wavy; crosses line at low angle.
1275	Wm. Gunston, Innisfail.......	Red Deer......	"	366	Uneven; slightly diagonal to line.
1202	Pembina Quarries, Entwistle..	Entwistle......	"	147	Uneven; on line above, 0·2 in. off below.
1203	Pembina Quarries Entwistle..	Entwistle......	"	625	Slightly uneven; on line.
1204	Pembina Quarries, Entwistle..	Entwistle......	"	261	Slightly uneven; on line at one side, 0·2 in. off on the other.

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture
1033	Rabbit point, L. Winnipeg....	Lake Winnipeg......	Pre-Cambrian....	1,700	Hackly; on line at one side, 0·2 in. off on the other.
1040	Lake Winnipeg Shipping Co....	Lake Winnipeg......	"	5,419	Fairly straight; even and flat; 0·15 in. off the line.

Alberta.

No.	Owner or Locality	Area	Geological System	Transverse Strength; Modulus of Rupture, lbs. per sq. in.	Character of Fracture
1256	Mile 1025, Grand Trunk Pacific Railway	Grand Trunk Pacific Railway.......	Cambrian....	2,886	Hackly; slightly diagonal to central line.

TABLE VI.

The Shearing Strength of Stones from Manitoba and Alberta.

LIMESTONES.

No.	Owner or Locality	Area	Geological System	Shearing Strength, lbs. per sq. in.
		Manitoba.		
1018	Lake Winnipeg Shipping Co.	Lake Winnipeg.......	Ordovician.......	2,835
1047	Wallace Sandstone Co.......	Tyndall..............	"	1,063
1048	Wallace Sandstone Co.......	Tyndall..............	"	1,048
1058	City of Winnipeg...........	Stony Mt.-Winnipeg..	"	866 978
1002	Winnipeg Supply and Fuel Co.....................	Stonewall-Gunton.....	Silurian..........	1,072
1013	Manitoba Quarries..........	Stonewall-Gunton.....	"	943
1014	Manitoba Quarries..........	Stonewall-Gunton.....	"	2,148
1015	Manitoba Quarries..........	Stonewall-Gunton.....	"	3,030
1114	Grand rapids, Saskatchewan river....................	Lake Winnipegosis—Saskatchewan river...	"	2,050
1119	Cedar lake, Man............	Lake Winnipegosis—Saskatchewan river...	"	3,780
1131	W. J. Long, Winnipeg.......	Inwood-Broadvalley. .	"	1,238
1144	Manitobite Stone Works.....	Inwood-Broadvalley .	"	946
1160	Old Gypsumville............	Fairford.............	"	2,693
1123	Mile 42, Hudson Bay Ry.....	Hudson Bay Railway..	"	3,805
1153	Canada Cement Co..........	Steep Rock..........	Devonian (Elm Point).....	1,706
1086	Whiteaves point, Lake Winnipegosis.................	Lake Winnipegosis....	Devonian (Winnipegosan) .	1,756
1082	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis....	Devonian (Manitoban).....	890
1083	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis....	Devonian (Manitoban).....	2,415
1085	Point Wilkins, Lake Winnipegosis.................	Lake Winnipegosis....	Devonian (Manitoban).....	1,649
1097	Brabant point, Lake Winnipegosis.................	Lake Winnipegosis....	Devonian (Manitoban).....	3,065
1079	Kettle hill, Swan lake........	Lake Winnipegosis....	Devonian........	1,990
		Alberta.		
1336	Canada Cement Co., Exshaw, Alberta..................	Canadian Pacific Railway.............	Devonian (Lower Banff)...	2,975
1315	Banff, Alberta..............	Canadian Pacific Railway...........	Carboniferous (Upper Banff)...	1,600
1272	Nordegg, Alberta...........	Nordegg.............	Permo-Triassic...	5,720
1302	Banff, Alberta..............	Canadian Pacific Railway	Permo-Triassic	5,222

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Geological System	Shearing Strength, lbs. per sq. in.
1020	Punk island, Lake Winnipeg .	Lake Winnipeg.......	Ordovician.......	599
1187	John Robinson, Boissevain, Man....................	Turtle mountain......	Cretaceous.......	866

Alberta.

No.	Owner or Locality	Area	Geological System	Shearing Strength, lbs. per sq. in.
1364	Coleman, Alberta...........	Crowsnest...........	Cretaceous (Dakota)	3,630
1233	Mile 984, Grand Trunk Pacific Railway.............	Grand Trunk Pacific Railway...........	"	1,680
1221	Mile 22, Coal Spur-Mountain Park branch of G.T.P.R...	Mountain Park.......	"	679
1224	McLeod river.............	Mountain Park.......	"	1,260
1268	Mile 156½, Canadian Northern Ry. Rocky Mountain House to Nordegg........	Rocky Mountain House.............	Cretaceous (Edmonton)......	398
1360	Macleod Quarrying and Contracting Co.............	Monarch............	Tertiary (Paskapoo).......	459
1361	Macleod Quarrying and Contracting Co.............	Monarch............	"	512
1363	Mrs. Arnold...............	Monarch............	"	334
1357	Porcupine hills.............	Macleod-Brocket.....	"	491
1388	Crowsnest Stone Co.........	Macleod-Brocket.....	"	682
1354	Wm. Brazier, High River....	High River..........	"	295
1285	Wm. Oliver & Co., Calgary .	Calgary.............	"	408
1286	Wm. Oliver & Co., Calgary .	Calgary.............	"	992
1279	J. A. Lewis, Rocky View.....	Calgary.............	"	455
1294	C. de Lavergne, Glenbow....	Glenbow-Cochrane.. .	"	497
1299	Shelley Quarry Co., Cochrane	Glenbow-Cochrane....	"	707
1301	Shelley Quarry Co., Cochrane	Glenbow-Cochrane....	"	587
1275	Wm. Gunston, Innisfail	Red Deer............	"	305
1202	Pembina Quarries, Entwistle	Entwistle............	"	105
1203	Pembina Quarries, Entwistle	Entwistle............	"	480
1204	Pembina Quarries, Entwistle	Entwistle............	"	201

GRANITE, GNEISS, AND MISCELLANEOUS ROCKS.

Manitoba.

No.	Owner or Locality	Area	Geological System	Shearing Strength, lbs. per sq. in.
1033	Rabbit point, Lake Winnipeg	Lake Winnipeg.......	Pre-Cambrian....	1,765
1040	Lake Winnipeg Shipping Co..	Lake Winnipeg.......	"	2,495

Alberta.

No.	Owner or Locality	Area	Geological System	Shearing Strength, lbs. per sq. in.
1256	Mile 1025, Grand Trunk Pacific Railway.............	Grand Trunk Pacific Railway...........	Cambrian........	3,280

TABLE VII.

The Chiselling and the Drilling Factors of Stones from Manitoba and Alberta.

The following table is to be considered with due regard to the explanations of these factors given in previous volumes and on pages 16-19. The fact that duplicate experiments vary, in some cases considerably, is evidence that the figures are to be regarded as a fair approximation only. The lack of agreement between the drilling and chiselling factors is not an evidence of inaccuracy but is due to the fact that these factors depend on different physical properties of the stone: a hard compact brittle limestone can scarcely be chiselled under the condition of the test, but it may be drilled with reasonable facility.

Care must be taken not to compare the figures given below with those of earlier volumes, as the tests have been made under different conditions (see pages 16-19). The "drilling factor" as herein given is the depth in millimetres of the hole drilled by a half-inch drill under 60 lbs. air pressure and weighted down by 8 lbs. for 30 seconds. The chiselling factor was determined under two sets of conditions: in column I the figures were obtained under 60 lbs. air pressure, 8 lbs. weight, and an inclination of the chisel at 54½°; the figures in column II were obtained under 40 lbs. air pressure, 3½ lbs. weight, and an inclination of 51°. The results in either column are comparable among themselves but there is no necessary relation between the figures of column I and those of column II.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Drilling Factor, mm. per 30 sec.	Chiselling Factor, grams per three inches per ten seconds		
				I	II	Remarks
1018	Lake Winnipeg Shipping Co.....	Lake Winnipeg......	11·3	4·9		Good even track; very small side chips.
1047	Wallace Sandstone Co.........	Tyndall............	30·0	11·3		Chisel dug in and threw chips sharply in front; small side chips only.
1048	Wallace Sandstone Co.........	Tyndall............	20·0	9·9		Similar to No. 1047.
1058	City of Winnipeg..............	Stony Mt.-Winnipeg.	13·2	5·8		Jumpy and irregular track; small side chips.
1002	Winnipeg Supply and Fuel Co..	Stonewall-Gunton...	10·0	4·4		Good track but somewhat jumpy.
1013	Manitoba Quarries.............	Stonewall-Gunton...	2·6	2·7		Tool dulled rapidly and ceased to cut.
1014	Manitoba Quarries.............	Stonewall-Gunton...	11·6	0·15		Chisel merely abraded the surface.
1015	Manitoba Quarries.............	Stonewall-Gunton...	4·5	0·18		Chisel merely abraded the surface.
1114	Grand rapids, Saskatchewan river	Lake Winnipegosis-Saskatchewan river	7·0	0·00		No weighable loss.
1119	Cedar lake....................	Lake Winnipegosis-Saskatchewan river	2·0	0·5		Scarcely abraded.
1131	W. J. Long....................	Inwood-Broadvalley .	20·7	7·05		Variable track, part smooth and part jumpy with side chips.
1144	Manitobite Stone Works.......	Inwood-Broadvalley .	17·2	9·65		Chisel dug in and jumped; some side chips.

1160	Old Gypsumville	Fairford	12·7	0·4		Good example of a stone easy to drill but hard to chisel.
1123	Mile 42, Hudson Bay Railway	Hudson Bay Railway	5·3	0·15		Scarcely abraded by chisel.
1153	Canada Cement Co.	Steep Rock	8·0	1·1		Good smooth track; no side chips.
1086	Whiteaves point, Lake Winnipegosis	Lake Winnipegosis	7·0	0·15		Drilling duplicates varied greatly.
1082	Point Wilkins, Lake Winnipegosis	Lake Winnipegosis	11·0	12·55		The high chiselling factor is due to the plucky nature of the stone.
1083	Point Wilkins, Lake Winnipegosis	Lake Winnipegosis	....	5·74		Good even track with only slight side chipping. Stone broke in drilling.
1085	Point Wilkins, Lake Winnipegosis	Lake Winnipegosis	9·0	8·65		Jumpy and irregular track with large side chips; result high.
1097	Brabant point, Lake Winnipegosis	Lake Winnipegosis	3·0	1·15		Tool dulled rapidly and ceased to cut.
1079	Kettle hill, Swan lake	Lake Winnipegosis	4·0	1·42		Duplicate tests varied greatly; result doubtful.

Alberta.

1336	Canada Cement Co., Exshaw, Alberta	Canadian Pacific Railway	....	9·20		Very splintery; the high factor is due to chipping not to cutting. Slab broke under the drilling test.
1315	Banff, Alberta	Canadian Pacific Railway	14·0	4·75		Good track. The high drilling factor is due to the crystalline nature of the stone.
1272	Nordegg, Alberta	Nordegg	4·0	0·00		No weighable loss.
1302	Banff, Alberta	Canadian Pacific Railway	1·0	0·01		Very hard and tough under both tests.

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Drilling Factor, mm. per 30 sec.	Chiselling Factor, grams per three inches per ten seconds. I	II	Remarks
1020	Punk island, L. Winnipeg......	Lake Winnipeg.....	96·0	....		Stone crumbled and failed under both set of conditions.
1187	John Robinson, Boissevain.....	Turtle mountain....	18·2	11·97		Irregular track with some small side chips.

Alberta.

No.	Owner or Locality	Area	Drilling Factor, mm. per 30 sec.	I	II	Remarks
1364	Coleman, Alberta	Crowsnest.........	9·1	·5		Chisel merely abrades the surface.
1233	Mile 984, Grand Trunk Pacific Railway	Grand Trunk Pacific Railway..........	14·0	3·65		Track only slightly uneven.
1221	Mile 22, Coal Spur-Mountain Park Railway..............	Mountain Park......	17·5	4·75		Good even track; no side chips.
1224	McLeod river................	Mountain Park......	7·8	3·63		Good even track.
1268	Mile 156½, Rocky Mountain House-Nordegg Railway	Rocky Mountain House...........	23·2		8·08	Good track; few small side chips.
1360	Macleod Quarrying and Contracting Co..................	Monarch..........	21·4		27·4	Chisel sank in and threw large side chips; result high as to mere cutting power.
1361	Macleod Quarrying and Contracting Co..................	Monarch..........	....		8·55	Even track; small side chips.
1363	Mrs. Arnold.................	Monarch..........	27·0		19·3	Large flaky side chips.
1357	Porcupine hills..............	Macleod-Brocket....	20·0		2·0	The high drilling factor of this stone was unexpected (?)
1388	Crowsnest Stone Co..........	Macleod-Brocket....	9·6		7·45	Even track; scarcely any side chips.
1354	Wm. Brazier, High River......	High River.........	14·0		4·95	Somewhat irregular track with small side chips.
1285	Wm. Oliver and Co., Calgary...	Calgary...........	23·0		10·4	Somewhat irregular track with small side chips.
1286	Wm. Oliver and Co., Calgary...	Calgary...........	13·8		1·0	Good smooth even track.
1279	J. A. Lewis, Rocky View.......	Calgary...........	27·4		8·9	Good track but with some side chips.
1294	C. de Lavergne, Glenbow.......	Glenbow-Cochrane...	21·0		6·87	Good even track; small side chips only.

1299	Shelley Quarry Co., Cochrane...	Glenbow-Cochrane...	32·3		23·24	Large flat side chips break out on the bedding. A soft stone.
1301	Shelley Quarry Co., Cochrane...	Glenbow-Cochrane...	21·0		6·08	Good track with very small side chips. These two stones from the same quarry are very different in respect to the present tests.
1275	Wm. Gunston................	Red Deer..........	High		21·37	Soft; large side chips. Drill ran through the slab in 8 seconds.
1202	Pembina Quarries, Entwistle....	Entwistle..........	Very high		Very high	This stone is too soft to give reliable results under the conditions of the tests.
1203	Pembina Quarries, Entwistle....	Entwistle..........	12·6		7·42	Even track with few side chips.
1204	Pembina Quarries, Entwistle....	Entwistle	Very high		38·00	Doubtful test; stone crumbled. Too soft to determine the drilling factor under the conditions.

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

1033	Rabbit point, Lake Winnipeg...	Lake Winnipeg......	6·0	0·00		Too hard to give a weighable loss under the test.
1040	Lake Winnipeg Shipping Co....	Lake Winnipeg......	3·0	0·00		No weighable loss.

Alberta.

1256	Mile 1025, Grand Prunk Pacific Railway....................	Grand Trunk Pacific Railway..........	6·2	0·00		No weighable loss.

TABLE VIII.

The Change in Weight per Square Inch of Surface exposed and the Colour Changes produced by soaking specimens of Manitoba and Alberta Stones for Four Weeks in Water saturated with Oxygen and Carbonic Acid.

LIMESTONES.

Manitoba.

No.	Owner or Locality	Area	Change in Weight. grams per sq. in.		Colour Changes
			Loss	Gain	
1018	Lake Winnipeg Shipping Co....	Lake Winnipeg....	0·196		Seriously corroded; the darker parts of the mottling are less affected than the light; the bluish cast is lost; the ground mass becomes a dirty, whitish-yellow with dark specks; the dark parts have assumed a rusty brown colour.
1047	Wallace Sandstone Co.....	Tyndall......	0·158		Seriously corroded; lighter part is more etched than dark; light part shows specks resembling the dark part; dark part is very little affected.
1048	Wallace Sandstone Co.......	Tyndall......	0·182		Acts like 1047; the lighter part retains a slightly bluish cast; the darker part is a greyer brown; the two corroded specimens are more alike than the untreated specimens.
1058	City of Winnipeg......	Stony Mt.—Winnipeg....	0·015		No etching apparent; surface smooth; greenish cast yields to yellow.
1002	Winnipeg Supply and Fuel Co.	Stonewall-Gunton......	0·0086		Surface smooth with very little etching; very slightly yellow; resists well.
1013	Manitoba Quarries.......	Stonewall-Gunton......	0·0178		Surface remains smooth; no sign of etching; the general yellow tint becomes pinkish.
1014	Manitoba Quarries.......	Stonewall-Gunton......	0·0107		Surface shows no pitting or etching but it is slightly dulled with a softening of the contrast between the red and yellow. When wet no difference can be seen between the treated and untreated stone.
1015	Manitoba Quarries.......	Stonewall-Gunton......	0·0119		No etching or pitting and scarcely any colour change.

LIMESTONES—*Continued*

Manitoba.

No.	Owner or Locality	Area	Change in Weight. grams per sq. in. Loss	Gain	Colour Changes.
1114	Grand rapids, Saskatchewan river..........	Lake Winnipegosis—Saskatchewan river....	0·0089		No etching or pitting; when dry the yellow tint is somewhat lighter; when wet the yellow colour seems deeper.
1119	Cedar lake.....	Lake Winnipegosis—Saskatchewan river....	0·1518		Surface corroded with small fossil fragments in relief; fine mottling less apparent; the general effect is a whitening of the ground mass.
1131	W. J. Long.....	Inwood—Broadvalley..	0·0094		No visible change in surface or colour.
1144	Manitobite Stone Works...	Inwood—Broadvalley..	0·0108		No visible change in surface or colour.
1160	Old Gypsumville...........	Fairford.....	0·0049		Surface very little pitted or etched; vertical to the bedding a slight yellowing is observed.
1123	Mile 42, Hudson Bay Ry....	Hudson Bay Railway.....	0·0048		Very little corrosion; only slight colour changes; when wet the corroded stone parallel to the bedding can scarcely be distinguished from the untreated stone; vertical to the bedding the greyish ground mass is a little yellow; pink bandings unaffected.
1153	Canada Cement Co............	Steep Rock..	0·1178		Etched and whitened with fossil fragments in relief; greyish cast lost.
1086	Whiteaves point, Lake Winnipegosis...	Lake Winnipegosis.	0·0068		No etching or pitting; the greyish colour becomes slightly yellow.
1082	Point Wilkins, Lake Winnipegosis...	Lake Winnipegosis.	0·313		Seriously affected; surface becomes a dead opaque white; mottling obscured; included fossils show as dark lines and specks.
1083	Point Wilkins, Lake Winnipegosis...	Lake Winnipegosis.	0·1833		Surface corroded and whitened; grey colour lost; fine mottling lost; fossils show more plainly.
1085	Point Wilkins, Lake Winnipegosis...	Lake Winnipegosis.	0·2077		Surface corroded; unaffected particles stand in relief giving a rough appearance; red specks more pronounced.

LIMESTONES—*Continued*

Manitoba.

No.	Owner or Locality	Area	Change in Weight. grams per sq. in. Loss	Gain	Colour Changes
1097	Brabant point, Lake Winnipegosis...	Lake Winnipegosis.	0·00703		No etching or pitting; fine mottling more marked; slightly more yellow.
1079	Kettle hill, Swan lake.....	Lake Winnipegosis.	0·00957		No etching or pitting; slightly more yellow with some loss of contrast in the purplish mottling.

Alberta.

No.	Owner or Locality	Area	Loss	Gain	Colour Changes
1336	Canada Cement Co., Exshaw, Alberta.......	Canadian Pacific Railway.....	0·158		Etched. Loses bluish cast and assumes a dirty greyish-yellow colour with fossil fragments in relief.
1315	Banff, Alberta..	Canadian Pacific Railway.....	0·154		Strongly etched. Mottled with a dead white base and greyish crystalline fossil fragments in relief.
1272	Nordegg, Alta.	Nordegg.....	0·0354		Not etched. The bluish cast yields to a brownish.
1302	Banff, Alberta.	Canadian Pacific Railway.....	0·0363		Not etched. Much changed in colour. The dark blue becomes a light yellowish-grey.

SANDSTONES.

Manitoba.

No.	Owner or Locality	Area	Loss	Gain	Colour Changes
1020	Punk island Lake Winnipeg	Lake Winnipeg	0·0068		Surface roughened and powdery. Lighter and more yellow in colour. Yellow spots.
1187	John Robinson, Boissevain.....	Turtle mountain...	0·112		Surface slightly roughened; bluish-green cast yields to a distinct yellow.

Alberta.

No.	Owner or Locality	Area	Loss	Gain	Colour Changes
1364	Coleman, Alberta	Crowsnest	0·0017		Very little change in colour.
1233	Mile 984, Grand Trunk Pacific Railway........	Grand Trunk Pacific Railway.....	0·013		Very little change in colour.
1221	Mile 22, Coal Spur-Mountain Park Railway...	Mountain Park........	0·0116		Dulled. Not greatly changed in colour.

SANDSTONES—*Continued*

Alberta.

No.	Owner or Locality.	Area.	Change in Weight. grams per sq. in. Loss.	Gain.	Colour Changes.
1224	McLeod river...	Mountain Park........	0·00111		Dulled. The cast is less bluish owing to the turning reddish of some of the mineral grains.
1268	Mile 156½, Rocky Mountain House Nordegg Ry.....	Rocky Mountain House........	0·0194		Less greenish and darker with a cast of reddish.
1360	Macleod Quarrying and Contracting Co..........	Monarch....	0·0223		The bluish colour is lost and is replaced by greyish-yellow. It is not as yellow as No. 1361.
1361	Macleod Quarrying and Contracting Co..........	Monarch....	0·0255		Very little change in colour.
1363	Mrs. Arnold	Monarch	0·03928		Very little change in colour.
1357	Porcupine hills .	Macleod-Brocket...	0·03565		Very little change in colour.
1388	Crowsnest Stone Co......	Macleod-Brocket	0·04823		Slightly darker in colour.
1354	Wm. Brazier, High River.....	High River........	0·06892		Slightly less greenish.
1285	Wm. Oliver and Co., Calgary....	Calgary	0·06938		Very little change in colour.
1286	Wm. Oliver and Co., Calgary....	Calgary	0·06201		Perceptibly darker and more yellow.
1279	J. A. Lewis, Rocky View.....	Calgary	0·06554		Very slightly more yellow.
1294	C. de Lavergne, Glenbow........	Glenbow-Cochrane....	0·04301		Less grey and more yellow in colour.
1299	Shelley Quarry Co., Cochrane...	Glenbow-Cochrane....	0·05271		Very little change in colour
1301	Shelley Quarry Co., Cochrane...	Glenbow-Cochrane....	0·04791		Very little change in colour.
1275	Wm. Gunston, Innisfail........	Red Deer........	0·08572		Very little change in colour.
1202	Pembina Quarries, Entwistle ..	Entwistle....	0·3028		Darker, more yellow, and somewhat mottled.
1203	Pembina Quarries Entwistle.......	Entwistle....	0·16753		The bluish cast is entirely lost and the stone is much darker and more yellow.
1204	Pembina Quarries Entwistle.......	Entwistle....	0·39348		Very little change in colour but more muddy in aspect.

GRANITE, GNEISS, AND MISCELLANEOUS STONES.

Manitoba.

1033	Rabbit point, Lake Winnipeg..	Lake Winnipeg....	0·00368		No distinct change.
1040	Lake Winnipeg Shipping Co.....	Lake Winnipeg....	0·00161		No distinct change.

GRANITE, GNEISS, AND MISCELLANEOUS STONES—*Continued*

Alberta.

No.	Owner or Locality.	Area.	Change in Weight, grams per sq. in.		Colour Changes.
			Loss.	Gain.	
1256	Mile 1025, Grand Trunk Pacific Ry............	Grand Trunk Pacific Railway.....	0·01088		The matrix becomes bright yellow giving the stone a spotted aspect.

APPENDIX II.

Production of Stone in Manitoba and Alberta in 1912, 1913, and 1914.

Year	Building stone	Ornamental and monumental	Rubble	Crushed stone	Paving and curb	Furnace flux	Total
Manitoba.							
	$	$	$	$	$	$	$
1912	97,096	....	119,142	166,834	....	23	383,095
1913	162,384	450	94,270	132,800	....	....	389,904
1914	220,160	....	....	16,654	....	....	361,912
Alberta.							
1912	52,771	13,414	10,061	....	5,145	....	81,391
1913	133,030	386	23,568	....	....	....	156,984
1914	59,572	....	 700	....	....	....	60,272

APPENDIX III.

Production of Stone by Classes in Manitoba and Alberta in 1912, 1913, and 1914.

Year	Granite	Limestone	Sandstone	Total
Manitoba.				
	$	$	$	$
1912	1,523	381,572	....	383,095
1913	6,920	382,987	....	389,904
1914	15,654	346,258	....	361,912
Alberta.				
1912	....	....	81,391	81,391
1913	....	20,000	136,984	156,984
1914	....	....	60,272	60,272

APPENDIX IV.

Production of Stone in Canada by Provinces in 1914.

Province	Granite	Limestone	Marble	Sandstone	Total	Per cent.	Labour	
							Men employed	Wages
	$	$	$	$	$			$
Nova Scotia	65,727	94,239		61,124	221,090	4·1	441	120,944
New Brunswick	24,525			236,647	261,172	4·8	277	156,619
Quebec	842,845	1,326,943	98,890	17,400	2,286,078	41·8	2,400	1,145,873
Ontario	309,720	853,906	30,300	59,923	1,253,849	22·9	1,575	645,728
Manitoba	15,654	346,258			361,912	6,6	373	190,241
Alberta				60,272	60,272	1·1	78	46,943
British Columbia	918,131	51,435	3,343	51,774	1,024,683	18·7	785	565,469
Total	2,176,602	2,672,781	132,533	487,140	5,459,056		5,929	2,871,817
Per cent	39·8	48·9	2·4	8·9		100·0		

APPENDIX V.

Reference List by Numbers to the Stones described in this Report.

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1000	Limestone.........	Winnipeg Supply and Fuel Co....................	Stonewall, Man...........	80
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1002	"	"	" "	79
1003	"	"	" "	81
1004	"	"	" "	81
1005	"	"	" "	81
1006	"	"	" "	81
1007a	"	"	" "	81
1008a	"	"	" "	81
1007	"	Manitoba Quarries, Limited................	Gunton, Man.............	86
1008	"	"	" "	87
1009	"	"	" "	87
1010	"	"	" "	87
1011	"	"	" "	87
1012	"	"	" "	87
1013	"	"	" "	84
1014	"	"	" "	85
1015	"	"	" "	86
1016	"	Lake Winnipeg Shipping Co............	Big island, Lake Winnipeg.............	38
1017	"	"	" "	38
1018	"	"	" "	37
1019	"	"	" "	38
1020	Sandstone..........	....	Punk island, Lake Winnipeg.........	116
1021	Limestone.........	....	" "	40
1026	Limestone.........	....	Grindstone point, Lake Winnipeg.........	40
1027	Sandstone..........	....	" "	155
1028	"	....	" "	155
1031	Gneiss............	....	Opposite Dog head, Lake Winnipeg.........	254
1032	Granite...........	....	Rabbit point, Lake Winnipeg.........	255
1033	"	....	" "	254
1034	"	....	" "	255
1035	"	....	" "	255
1036	"	....	" "	255
1037	"	....	" "	255
1038	Gneiss............	....	Island opposite Dog head..	255
1039	"	....	Shore south of above......	255
1040	"	Lake Winnipeg Shipping Co.....................	East shore of Lake Winnipeg.............	256
1041	"	" " "	" "	256
1042	Limestone.........	....	Bull head, Lake Winnipeg.............	39
1043	Sandstone..........	....	" " "	155
1045	Limestone.........	....	" " "	39
1046	"	....	Lower Fort Garry, Man...	42
1047	"	Wallace Sandstone Co.....	Lyall, Man..............	48
1048	"	" " "	" "	51

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1052	"	Wm. Sinclair............	Tyndall, Man............	64
1053	"	" "	" "	64
1057	"	City of Winnipeg.........	Stony Mountain, Man.....	68
1058	"	" " "	" "	67
1059	"	" " "	" "	69
1060	"	" " "	" "	69
1061	"	" " "	" "	69
1062	"	Manitoba Quarries, Limited...............	Stony Mountain, Man.....	72
1063	"	" "	" " "	74
1064	"	" "	" " "	74
1065	"	" "	" " "	74
1067	"	City of Winnipeg.........	Little Stony Mountain, Man..................	71
1068	"	" "	" " "	71
1070	"	John Henderson..........	Winnipegosis, Man........	129
1072	"	....	Snake island, Lake Winnipegosis...........	130
1073	"	....	" " "	130
1074	"	....	" " "	130
1075	"	....	Pine river, Man..........	149
1076	"	....	" " "	149
1079	"	....	Kettle hill, Swan lake, Man..................	139
1080	"	....	Swan lake, Man..........	138
1081	"	....	Red Deer river, Man.....	140
1082	"	....	Point Wilkins, Lake Winnipegosis, Man.....	132
1083	"	....	" "	133
1084	"	....	" "	135
1085	"	....	" "	134
1086	"	....	Whiteaves point, Lake Winnipegosis, Man......	126
1087	"	....	" "	127
1089	"	....	Island off Whiteaves point, L. Winnipegosis .	128
1090	"	....	" "	128
1091	"	....	Birch island, Lake Winnipegosis...........	125
1092	"	....	Brabant point, Lake Winnipegosis...........	136
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1094	"	....	"	137
1096	"	....	" "	137
1097	"	....	" "	137
1098	"	....	" "	138
1099	"	....	" "	138
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1130	"	" "	" "	89
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1134	"	" "	" "	89
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1136	"	Humphrey Bryan.........	" " "	105
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1246	Marble............	....	" " "	267
1247	"	....	" " "	268
1248	"	....	" " "	268
1249	"	....	" " "	268
1250	"	....	" " "	268
1251	"	....	" " "	268
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1293	"	" "	" "	225
1294	"	C. de Lavergne	Glenbow, Alberta	230
1295	"	" "	" "	231
1296	"	" "	" "	231
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CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. McCONNELL, DEPUTY MINISTER

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS

†1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.D., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba; manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11 Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. Experiments made at Sault Ste. Marie, under Government auspices in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

† Publications marked thus † are out of print.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

†18. Graphite: its properties, occurrences, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposits of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

†21. Summary report of Mines Branch, 1907–8.

†22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side) and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907–8.

†25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a. The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908, Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep. Peat Expert.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

† Publications marked thus † are out of print.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907–08.*

†31. Production of cement in Canada, 1908.

†42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories at the Department of Mines, 1906–07–08. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analyses of oil-shales—by H. A. Leverin, Ch.E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs and peat industry of Canada, 1909–10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. Anrep. (Second edition, enlarged.)

† Publications marked thus † are out of print.

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
   Vol. I—Coal washing and coking tests.
   Vol. II—Boiler and gas producer tests.
   †Vol. III—
      Appendix I
         Coal washing tests and diagrams.
   †Vol. IV—
      Appendix II
         Boiler tests and diagrams.
   †Vol. V—
      Appendix III
         Producer tests and diagrams.
   †Vol. VI—
      Appendix IV
         Coking tests.
      Appendix V
         Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

†79. Production of iron and steel in Canada during the calendar year 1909.
†80. Production of coal and coke in Canada during the calendar year 1909.
85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Proceedings of conference on explosives. (Fourth edition).

90. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Fourth edition).

†93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

† Publications marked thus † are out of print.

102. Mineral production of Canada, 1910. Preliminary report on—by John McLeish, B.A.

†103. Summary report of Mines Branch, 1910.

104. Catalogue of publications of Mines Branch, from 1902 to 1911; containing tables of contents and lists of maps, etc.

105. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

110. Western portion of Torbrook iron ore deposits, Annapolis county, N.S. Bulletin No. 7—by Howells Frechette, M.Sc.

111. Diamond drilling at Point Mamainse, Ont. Bulletin No. 6—by A. C. Lane, Ph.D., with introductory by A. W. G. Wilson, Ph.D.

118. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

142. Summary report of Mines Branch, 1911.

143. The mineral production of Canada, 1910. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1910.*

†114. Production of cement, lime, clay products, stone, and other materials in Canada, 1910.
†115. Production of iron and steel in Canada during the calendar year 1910.
†116. Production of coal and coke in Canada during the calendar year 1910.
†117. General summary of the mineral production of Canada during the calendar year 1910.

145. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

†150. The mineral production of Canada, 1911. Preliminary report on—by John McLeish, B.A.

151. Investigation of the peat bogs and peat industry of Canada, 1910-11. Bulletin No. 8—by A. Anrep.

154. The utilization of peat for fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910-11. Report on—by B. F. Haanel, B.Sc.

167. Pyrites in Canada: its occurrence, exploitation, dressing and uses. Report on—by A. W. G. Wilson, Ph.D.

170. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

† Publications marked thus † are out of print.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201 The mineral production of Canada during the calendar year 1911. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224).

230. Economic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

† Publications marked thus † are out of print.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.
†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.
†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.
257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.
†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
Vol. I—Technology and exploitation.
Vol. II—Occurrence of petroleum and natural gas in Canada.
Also separates of Vol. II, as follows:—
Part 1, Eastern Canada.
Part 2, Western Canada.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

† Publications marked thus † are out of print.

349. Production of iron and steel in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

350. Production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

383. The production of cement, lime, clay products, stone and other structural materials, during the calendar year 1914. Bulletin on—by John McLeish, B.A.

385. Investigation of a reported discovery of phosphate at Banff, Alberta. Bulletin No. 12—by H. S. de Schmid, M.E., 1915.

401. Feldspar in Canada. Report on—by H. S. de Schmid, M.E.

406. Description of the laboratories of the Mines Branch of the Department of Mines, 1916. Bulletin No. 13.

408. Mineral production of Canada, 1915. Preliminary report on—by John McLeish, B.A.

411. Cobalt alloys with non-corrosive properties. Report on—by H. T. Kalmus, B.Sc., Ph.D.

413. Magnetic properties of cobalt and of Fe_2Co. Report on—by H. T. Kalmus, B.Sc., Ph.D.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, General list of mines (except coal and metal mines), Coal mines, Stone quarry operators, Manufacturers of clay products and of cement, Manufacturers of lime, and Operators of sand and gravel deposits. Copies of the lists may be obtained on application.

IN THE PRESS

388. The building and ornamental stones of Canada—Vol. IV: building and ornamental stones of the western provinces. Report on—by W. A. Parks, Ph.D.

419. Production of iron and steel in Canada during the calendar year, 1915. Bulletin on—by J. McLeish, B.A.

420. Production of coal and coke in Canada during the Calendar year, 1915, Bulletin on—by J. McLeish, B.A.

421. Summary report of the Mines Branch for 1915.

FRENCH TRANSLATIONS

971. (26a) Rapport annuel sur les industries minérales du Canada, pour l'année 1905.

†4. Rapport de la Commission nominée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910–11. Report on—by B. F. Haanel, B.Sc.

†156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrences, exploitation, dressing, and uses.. Report on—by A. W. G. Wilson, Ph.D.

179. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910–11. Bulletin No. 8—by A. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on —by E. Lindeman, M.E.

†196. Investigation of the peat bogs and peat industry of Canada, 1909–10, to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D

† Publications marked thus † are out of print.

†98. General map of coal fields in British Columbia. (Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 83—by Dr. J. B. Porter.)

†106. Geological map of Austin Brook iron-bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Brook iron-bearing district—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron-bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog Ontario—by A. Anrep. (Accompanying report No. 151.)

*119–137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron-bearing district Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110.)

146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†152. Map showing the location of peat bogs investigated in Ontario—by A. Anrep. (See Map No. 354.)

†153. Map showing the location of peat bogs, as investigated in Manitoba—by A. Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. Anrep.

†158. Transmission peat bog, Manitoba— " "

†159. Corduroy peat bog, Manitoba— " "

†160. Boggy Creek peat bog, Manitoba— " "

†161. Rice Lake peat bog, Manitoba— " "

†162. Mud Lake peat bog, Manitoba— " "

†163. Litter peat bog, Manitoba— " "

†164. Julius peat litter bog, Manitoba— " "

†165. Fort Frances peat bog, Ontario— " "

(Accompanying report No. 151.) [†152–†165]

*166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mile to 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman.

†173. " Crean Hill mine—by Prof. A. P. Coleman

†174. " Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.) [†172–†174]

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus * are to be found only in reports.
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†198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

224a. Mines Branch Summary report for 1912.

†226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.).

231. Economic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

260. The preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

†264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

280. The building and ornamental stones of Canada, Vol. III; Province of Quebec. Report on—by Professor W. A. Parks, Ph.D.

286. Summary Report of Mines Branch, 1913.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

307. Cataologue of French publications of the Mines Branch and of the Geological Survey, up to July, 1914.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
Vol. I—Coal washing and coking tests.
Vol. II—Boiler and gas producer tests.
Vol. III—
Appendix I
Coal washing tests and diagrams.
Vol. IV—
Appendix II
Boiler tests and diagrams.

314. Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

321. Annual mineral production of Canada, during the calendar year 1913. Report on—by J. McLeish, B.A.

IN THE PRESS

292. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others.
Vol. I.—Technology and exploitation.

306. The non-metallic minerals used in the Canadian manufacturing industries Report on—by Howells Fréchette, M.Sc.

310. The physical properties of the metal cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

MAPS

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906. (See Map No. 186).

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12 concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county. Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russell county, Ontario—by Erik Nystrom, and A. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog. Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

†41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—Erik Nystrom and A. Anrep. (Accompanying report No. 30).

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47).

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†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman. 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

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†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey, vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

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†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

†221. Dawson mining district, Yukon. Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 345.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

Note.—1. Maps marked thus * are to be found only in reports.
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†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bogs investigated in Quebec—by A. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

†270. Small Tea Field peat bog, Quebec " "

†271. Lanoraie peat bog, Quebec " "

†272. St. Hyacinthe peat bog, Quebec " "

†273. Rivière du Loup peat bog " "

†274. Cacouna peat bog " "

†275. Le Parc peat bog, Quebec " "

†276. St. Denis peat bog, Quebec " "

†277. Rivière Ouelle peat bog, Quebec " "

†278. Moose Mountain peat bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale 12½ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties, New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch. (Accompanying report No. 291).

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†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by E. Lindeman, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†327. Map showing location of Saline Springs and Salt Areas in the Dominion of Canada. (Accompanying Report No. 325.)

†328. Map showing location of Saline Springs in the Maritime Provinces. Scale 100 miles to 1 inch. (Accompanying Report No. 325.)

†329. Map of Ontario-Michigan Salt Basin, showing probable limit of productive area. Scale 25 miles to 1 inch. (Accompanying Report No. 325.)

†330. Map showing location of Saline Springs in Northern Manitoba. Scale 12½ miles to 1 inch. (Accompanying Report No. 325.)

†340. Magnetometric map of Atikokan iron-bearing district, Atikokan Mine and Vicinity. Claims Nos. 10E, 11E, 12E, 24E, 25E, and 26E, Rainy River district, Ontario. By A. H. A. Robinson, 1914. Scale 400 feet to 1 inch.

†340a. Geological map of Atikokan iron-bearing district, Atikokan Mine and Vicinity. Claims Nos. 10E, 11E, 12E, 24E, 25E, and 26E, Rainy River district, Ontario. By A. H. A. Robinson, 1914. Scale 400 feet to 1 inch.

†341. Magnetometric map of Atikokan iron-bearing district, Sheet No. 1, Claims Nos. 400R, 401R, 402R, 112X, and 403R. Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†341a. Geological map of Atikokan iron-bearing district. Sheet No. 1. Claims Nos. 400R, 401R, 402R, 112X, and 403R, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342. Magnetometric map of Atikokan iron-bearing district. Sheet No. 2. Claims Nos. 403R, 404R, 138X, 139X, and 140X, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342a. Geological map of Atikokan iron-bearing district. Sheet No. 2. Claims Nos. 403R, 404R, 138X, 139X, and 140X, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

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†343. Magnetometric map of Atikokan iron-bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†343a. Geological map, Atikokan iron-bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†354.	Index Map, showing location of peat bogs investigated in Ontario—	by A. Anrep,	1913–14.
†355.	Richmond peat bog, Carleton county, Ontario—	"	"
†356.	Luther peat bog, Wellington and Dufferin counties, Ontario—	"	"
†357.	Amaranth peat bog, Dufferin county, Ontario—	"	"
†358.	Cargill peat bog, Bruce county, Ontario—	"	"
†359.	Westover peat bog, Wentworth county, Ontario—	"	"
†360.	Marsh Hill peat bog, Ontario county, Ontario—	"	"
†361.	Sunderland peat bog, Ontario county, Ontario—	"	"
†362.	Manilla peat bog, Victoria county, Ontario—	"	"
†363.	Stoco peat bog, Hastings county, Ontario—	"	"
†364.	Clareview peat bog, Lennox and Addington counties, Ontario—	"	"
†365.	Index Map, showing location of peat bogs investigated in Quebec—	"	"
†366.	L'Assomption peat bog, L'Assomption county, Quebec—	"	"
†367.	St. Isidore peat bog, La Prairie county, Quebec—	"	"
†368.	Holton peat bog, Chateauguay county, Quebec—	"	"
†369.	Index Map, showing location of peat bogs investigated in Nova Scotia and Prince Edward Island—	"	"
†370.	Black Marsh peat bog, Prince county, Prince Edward Island—	"	"
†371.	Portage peat bog, Prince county, Prince Edward Island—	"	"
†372.	Miscouche peat bog, Prince county, Prince Edward Island—	"	"
†373.	Muddy Creek peat bog, Prince county, Prince Edward Island—	"	"
†374.	The Black Banks peat bog, Prince county, Prince Edward Island—	"	"

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†375. Mermaid peat bog, Queens county, Prince Edward Island..........................by A. Anrep, 1913–14

†376. Caribou peat bog, Kings county, Prince Edward Island— " "

†377. Cherryfield peat bog, Lunenburg County, Nova Scotia— " "

†378. Tusket peat bog, Yarmouth county, Nova Scotia— " "

†379. Makoke peat bog, Yarmouth county, Nova Scotia— " "

†380. Heath peat bog, Yarmouth county, Nova Scotia— " "

†381. Port Clyde peat bog, Shelburne county, Nova Scotia— " "

†382. Latour peat bog, Shelburne county, Nova Scotia— " "

†383. Clyde peat bog, Shelburne county, Nova Scotia— " "

†387. Geological map Banff district, Alberta, showing location of phosphate beds—by Hugh S. de Schmid, 1915. (Accompanying report No. 385.)

†390. Christina river map showing outcrops of bituminous sand along Christina valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†391. Clearwater river map, showing outcrops of bituminous sand along Clearwater valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†392. Hangingstone-Horse rivers, showing outcrops of bituminous sand along Hangingstone and Horse River valleys: contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†393. Steepbank river, showing outcrops of bituminous sand along Steepbank valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†394. McKay river, 3 sheets, showing outcrops of bituminous sand along McKay valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†395. Moose river, showing outcrops of bituminous sand along Moose valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

Address all communications to—

DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA.

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