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DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF MINES

Limestones of Canada

Their Occurrence and Characteristics

Part V

Western Canada

BY

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PREFACE

The report "Limestones of Canada" is based on a survey of the limestone resources of the country, made with the object of obtaining data on the physical and chemical characteristics of the deposits, methods of quarrying and preparing the stone for the market, the technology of lime manufacture, and on the uses of lime and limestone in various industries. The importance of limestone to the industrial life of the country may be gauged by the fact that in 1943 approximately 9,810,252 tons of limestone, including marble, was raised from Canadian quarries, which when manufactured into its primary products, such as lime, cement, and stone for various purposes, had a selling value of $24,605,796.

The survey of the limestone resources was begun in 1925 and, as the work progressed, preliminary reports[1] on the resources of the various provinces were published. A detailed report "Canadian Limestones for Building Purposes" was also published.

During the survey an investigation was made into the possibilities of making rock wool from the argillaceous dolomite of the Niagara peninsula of Ontario. The findings of this investigation were published in two preliminary reports[2] and resulted in the establishment of a rock-wool industry in Canada.

During the survey of the limestone resources the presence of brucite was discovered in Precambrian limestone in Ontario and Quebec. An investigation into the possibilities of recovering magnesia from these deposits was undertaken, and the findings were published.[3]

The present report, which has been issued in five parts as listed below, deals particularly with the occurrence and chemical and physical characteristics of the limestone in the various provinces, the data obtained on the technology and uses of lime and limestone being reserved for a later report.

Part I: Introductory.
Part II: Maritime Provinces.
Part III: Quebec.
Part IV: Ontario.
Part V: Western Canada.

The delay in issuing Part V is due partly to the undertaking of the investigation into brucitic limestone, and partly to the war, since in 1939 the preparation of this report was suspended for work more directly connected with the war effort.

It is impossible to examine all outcrops throughout a large country in which limestone is as plentiful as it is in Canada, but all active quarries, most of the inactive quarries, and many of the prominent outcrops within 3 miles of rail or water transportation were examined and sampled. Nearly all samples obtained were channel samples or the equivalent, taken across the strata at right angles to the strike. Where a difference in character, either chemical or

[1] Mines Branch, Department of Mines, Ottawa:
Report No. 682: "Limestones of Quebec and Ontario," Prelim. Rept.
Report No. 687: Invest. Min. Res. and Min. Ind. 1926, pp. 35-52, Maritime Provinces, Gaspe, and Timiskaming.
Report No. 710: Invest. Min. Res. and Min. Ind. 1928, pp. 1-18, Western Ontario and Prairie Provinces.
Report No. 719: Invest. Min. Res. and Min. Ind. 1929, pp. 43-64, British Columbia.

[2] Mem. Series No. 50: "Raw Materials for the Manufacture of Rock Wool in the Niagara Peninsula of Ontario" (1931).
Mem. Series No. 62: "Characteristics of Rock Wool Experimentally Prepared from Rock Available in the St. David's-Thorold District, Ontario" (1934).

[3] Goudge, M. F.: "A Preliminary Report on Brucite Deposits in Ontario and Quebec and their Commercial Possibilities." Bureau of Mines, Dept. of Mines and Resources. Ottawa, Mem. Series No. 75 (1939).

physical, was observed a separate sample of each kind of stone was taken. The samples, some weighing as much as 50 pounds each, were crushed to a fineness of $\frac{1}{8}$ inch or less in a small jaw crusher, and then cut down to about 2 pounds in weight by means of a Jones sampler. The 2-pound sample was pulverized to approximately 100 mesh and from this an 8-ounce sample was sent to the chemical laboratory for analysis. Interbeds of shale, quartzite, and other rocks present in the deposits were not included in the samples, because in any method of quarrying involving hand-sorting, such as is common practice in quarrying stone for lime manufacture, the shale and other rocks could be largely discarded. Thus, the chemical analyses of samples obtained from some deposits indicate a purer stone than could be obtained by non-selective methods of quarrying, as, for example, where mechanical loading is employed. It should be borne in mind that the analysis of a single sample from a deposit is merely indicative of the character of the deposit and much more detailed sampling and investigation than is practicable in a general survey of the resources is necessary to prove definitely the character of any individual deposit.

All chemical analyses of the samples, unless otherwise noted, were made by C. L. O'Brian, formerly of the Chemical Division, Bureau of Mines, Ottawa, and to him thanks are extended for co-operation in all matters pertaining to the chemical examination of limestones.

Previous reports on Canadian limestones include "The Limestones of Ontario" by the late Dr. W. G. Miller of the Ontario Department of Mines; and preliminary reports on the limestones of Ontario and Quebec by Howells Fréchette, published in the Mines Branch Summary Reports for 1914, 1915, 1917, and 1918. Much information on limestone is also given in Mines Branch report "The Building and Ornamental Stones of Canada" by Dr. W. A. Parks, published in five parts. There are also many references to limestone deposits in the publications of the Geological Survey of Canada, and of the Departments of Mines of the various provinces. These reports and references were of great assistance, particularly in the field work in connection with the present report, and indebtedness to the various authors is acknowledged. The geology of the maps in this report is based on maps issued by the Geological Survey of Canada.

The owners and operators of the various limestone properties examined were most helpful in supplying information regarding their properties and plants. Acknowledgment is made to Mr. F. V. Seibert, Industrial Commissioner, Canadian National Railways, Winnipeg, and to Mr. G. H. Hutt, Assistant Development Commissioner, Canadian Pacific Railway Company, Winnipeg, for information they supplied on limestone and marl deposits adjacent to their respective railways in Western Canada.

OTTAWA, CANADA,
December, 1944.

Limestones of Canada

Their Occurrence and Characteristics

PART V

WESTERN CANADA

CHAPTER I

INTRODUCTORY

DEFINITION AND CLASSIFICATION OF LIMESTONES

Limestones are rocks of sedimentary origin consisting mainly of calcium carbonate (calcite) or of the double carbonate of calcium and magnesium (dolomite). Based on their content of these constituents limestones may be divided into three classes:—

1. Calcium limestones, or those in which calcium carbonate greatly predominates and which contain less than 10 per cent magnesium carbonate.
2. Dolomites, or those composed almost wholly of the mineral dolomite and containing between 40 and 45·65 per cent magnesium carbonate.
3. Magnesian limestones, or those intermediate in composition between the other two classes.

The term high-calcium limestone is used in this report to donote a calcium limestone containing not more than 3 per cent total impurities and not more than 2 per cent magnesium carbonate.

The distinction between the classes is purely arbitrary. The classification was adopted after a study of the chemical analyses of 1,500 samples of limestone from all parts of Canada, which showed that most of the limestones come within the first two classes and that despite the wide range in composition allotted to the magnesian limestones, i.e. those containing from 10 to 40 per cent magnesium carbonate, this class is relatively small, particularly when only the purer limestones are considered. By "purer" limestones is meant those with less than 5 per cent total impurities. Among the impure limestones the magnesian variety is somewhat more common, but is much less so than the other types. The presence of mechanically intermixed impurities such as sand grains and argillaceous matter often masks the true character of a dolomite, and if the above classification were applied to all limestones a very impure dolomite would be grouped with the magnesian limestones even though the ratio between the calcium and magnesium components in the rock were that of a true dolomite. A scientific classification applicable to all varieties of limestone would be one based on the ratio between the calcium and magnesium components present and this would be particularly applicable to limestones containing a high percentage of impurities. Such a classification based on the amounts of calcium oxide and magnesium oxide determined by analysis would be as follows:—

1. *Calcium limestones,* those in which the ratio of CaO to MgO is greater than 10·5:1.

2. *Magnesian limestones,* those in which the ratio of CaO to MgO is less than 10·5:1 and greater than 1·76:1.

3. *Dolomites,* those in which the ratio of CaO to MgO is less than 1·76 and greater than 1·39:1.

The ratios of calcium oxide to magnesium oxide are shown in the last column of each table of analyses in this report.

For commercial purposes, however, for which pure limestones are generally required, a classification such as the first, based on the actual percentages of the carbonates of calcium and magnesium, is more convenient and useful.

A few highly metamorphosed limestones contain more than 45·65 per cent of magnesium carbonate, due apparently to replacement by magnesite (magnesium carbonate). Where the replacement is only partial such rocks are referred to as magnesian dolomites or magnesitic dolomites. Where the replacement is complete, or nearly so, the rock is termed magnesite. In some dolomite deposits an abnormally high magnesia content may be due to the presence of brucite or pyroaurite, or both.

All limestone deposits contain some sandy or clayey material, and the deposits may grade almost imperceptibly into a shale, sandstone, or other kind of rock. Usually, if the rock contains a total of 50 per cent or more of the combined carbonates of calcium and magnesium it is termed a limestone, and if it contains less it is otherwise classified.

ORIGIN OF LIMESTONE

Virtually all limestones were formed under water by the action of organic or chemical agencies, or a combination of the two, on dissolved calcareous matter, and were deposited in layers or beds usually separated by a layer of shaly material. Each bed represents a period of uninterrupted deposition and each interbed of shale represents a break in the process, or a change in conditions. The deposit may consist entirely of thick beds, or of thin beds; thick and thin beds may alternate; or the beds may become progressively thicker from the base to the top of the deposit, or vice versa. Again, where limestones have been deposited over a large area, the same bed may be thick in one place and thin in another. Every bed, in fact, is lenticular, attaining its maximum thickness where conditions were most favourable to accumulation, and thinning out toward the edges of the area. This lenticular character is typical of the great limestone formations as a whole, although in many cases the so-called lenses may be hundreds of miles across. Limestone conglomerates are formed largely by mechanical agencies whereby debris from previously formed limestones is transported to lakes or to the ocean where it again becomes consolidated.

During the process of accumulation limestone is a loose mass of shell fragments and ooze. Consolidation into solid rock may be brought about by a number of factors acting singly or in combination. Probably the chief agency is the growth of cementing crystals of calcite, or dolomite, throughout the mass. It may also be brought about by the weight of the material itself or of beds of other material deposited on top. Pressure due to earth movements plays an important part in consolidating the deposits, and the heat of igneous intrusions is also effective. The consolidation may have been only partial as with chalk, or it may have been complete as in the case of marble.

From their original position beneath the water, the deposits were raised to dry land by movements of the earth's crust and many were raised and lowered repeatedly. In some deposits the original bedding has not been disturbed, but in others the beds have been crumpled and broken and heaved up into mountain ranges.

CHARACTERISTICS OF LIMESTONE

Colour

Limestones range in colour from pure white through all shades of grey to black, and from blue through green, yellow, brown, and orange to red. Cream colours are also common and purple tints are sometimes present. These beautiful colours are due to the presence of small quantities of impurities of pigment-like nature. Limestones free from these impurities are white. Varying amounts of iron oxides are believed to cause the cream, buff, brown, yellow, orange, and red tints. The greys, blues, and blacks are due principally to very finely divided carbonaceous matter. In the weathered outcrop the colouring is never so vivid as on a polished or on a freshly broken surface, and some limestones change their surface colour completely when exposed to the weather, though this change seldom goes deep except with very impure stones. Black limestones rapidly become very light grey on the weathered surface, probably owing to a bleaching of the black carbonaceous pigment that colours them. This change is never more than skin deep and is accompanied by no decay in the stone. Some limestones, particularly dolomites, turn brown on the weathered surface and this change may extend to a considerable depth. It is seemingly due to the oxidation of small amounts of ferrous carbonate, iron present in dolomites being usually in the ferrous condition. The white and light blue colour of many highly altered limestones, such as some of the marbles, is due to organic pigments having been destroyed by heat or else segregated into flakes of graphite, and to the inorganic pigments having been segregated into crystalline masses.

Texture

The texture of limestone varies considerably. Some limestones are compact, others are porous and full of cavities, still others are composed of shells and fossil remains knit together with varying degrees of firmness. All limestones are crystalline. Even chalk, which appears amorphous, is actually composed of minute crystals of calcium carbonate visible only under a high-powered microscope. Thus the common usage of the term "crystalline limestone" to designate marble and all limestones that have been recrystallized through the agencies of heat or pressure, or both, is misleading in that it implies that some limestones are non-crystalline or amorphous. The term metamorphic limestone is preferable when referring to limestones that have been greatly altered or recrystallized through metamorphic agencies.

Intense metamorphism usually causes the limestone to become lighter in colour, obscures the original bedding planes, and causes segregation of inorganic impurities into larger crystals and masses.

The common sizes of individual crystals of calcite and dolomite composing limestones range from microscopic dimensions up to $\frac{1}{4}$ inch in diameter. In a few deposits crystals larger than $\frac{1}{2}$-inch diameter occur. Calcite crystals are rarely present in their true symmetrical forms, but usually as shapeless grains tightly interlocked. In contrast, dolomite crystals are generally well shaped. It is the size of glistening facets of the freshly broken crystals that gives a limestone the appearance of being either fine or coarse in grain. On a weathered surface the grain is not readily apparent. According to grain size, limestones may be classified as follows:—

Dense limestones—individual crystals not perceptible to the eye.

Fine-grained—crystals visible, but under $\frac{1}{32}$ inch in diameter.

Medium-grained—average crystal diameter between $\frac{1}{32}$ and $\frac{1}{16}$ inch.

Coarse-grained—average crystal diameter between $\frac{1}{16}$ and $\frac{1}{8}$ inch.

Very coarse-grained—average crystal diameter exceeding $\frac{1}{8}$ inch.

If a crystal or grain size is uniform a limestone is termed uniform-grained irrespective of the size of the crystals. In fact, wide variations in size of grain within a single stratum are uncommon (mottled limestone and partly dolomitized limestone excepted), but in a succession of beds the variation may be considerable. Complete fossils or fossil fragments thickly scattered throughout the stone may obscure the grain. When fossils are much in evidence and plainly visible the limestone is referred to as fossiliferous limestone, with distinctive names for the varieties depending on the characteristic fossil, as shell limestone, coral limestone, and crinoidal limestone. Many limestones are composed in part of little spherical and oval bodies called oolites. Usually the oolites are $\frac{1}{32}$ inch or less in diameter, although much larger ones also occur. When the oolites are sufficiently numerous to impart a characteristic texture the stone is called oolitic limestone.

Hardness

Limestones, even the very pure varieties, have a wide range in hardness. This may seem strange when it is considered that they are composed either of calcite with a hardness of 3, or of dolomite with a hardness of 3·5 to 4, but the amount and character of the cementing material and the degree of cementation have a great effect on the hardness. The common cementing materials in limestones are calcium carbonate and dolomite. Some limestones, such as certain of the oolitic and shell limestones that are cemented only at the points of contact of the particles, are very friable. Dense-textured, well-cemented limestones are usually harder than coarse-grained varieties. A limestone having a siliceous cement is invariably harder than one having a purely calcareous cement. The soft chalks and marls are examples of limestones that are only partly consolidated and cemented.

PRINCIPAL MINERALS AND IMPURITIES OF LIMESTONES

No limestone deposit is entirely free from impurities, the most common of which are silica, alumina, iron compounds, sulphur, alkalis, organic matter, and phosphorus. They may be present in such small quantities that their total amounts to less than 1 per cent, or at the other extreme some of them, particularly silica and alumina, may constitute a large percentage of the deposit.

Impurities are not always undesirable and, in fact, limestones containing appreciable quantities of certain impurities are preferred for some purposes. For instance, a siliceous limestone is preferred to a very pure limestone for road metal on account of its greater hardness and toughness. An argillaceous limestone low in magnesium carbonate is used in the manufacture of Portland cement, and an argillaceous dolomite is used in the manufacture of rock wool. However, for these and other uses demanding impure limestones the impurities must be uniformly distributed throughout the stone and not be present in streaks and nodules.

A description of the principal minerals and impurities of limestone generally reported in a chemical analysis follows.

Calcite

Calcite ($CaCO_3$) is an essential constituent of all limestones, excepting the dolomites. All dolomites contain calcium carbonate, but it is mostly in combination with magnesium carbonate in the form of the mineral dolomite and not as calcite, though minor amounts of calcite are commonly present. Calcite occurs in crystals of many shapes, all of which cleave to a rhombohedron of 105 degrees, but in most limestones the calcite is present as irregular grains instead of definite crystals. The hardness is 3, that is, it can be easily scratched with a knife. The specific gravity is 2·71 to 2·72. When pure it is colourless or white and has a vitreous lustre. Calcite can be readily distinguished from other minerals, excepting aragonite, by its vigorous effervescence when dilute acid is placed on it. Aragonite is of the same composition as calcite, but differs in crystal form, is heavier and slightly harder, and is not of known importance as a constituent of the older limestones.

Dolomite

Dolomite ($CaMg(CO_3)_2$), the double carbonate of calcium and magnesium, is named after the French geologist Dolomieu, who announced some of its characteristics in 1791. Like calcite it possesses perfect rhombohedral fracture and commonly occurs in rhombohedral crystals, but the faces of the dolomite crystals are often curved. Pure dolomite is white or yellowish white, has a hardness of 3·5 to 4, a specific gravity of 2·8 to 2·9, and a pearly to vitreous lustre. It can be distinguished from calcite by the very faint reaction or, in many cases, entire lack of effervescence when cold dilute acid is applied to a fragment of the mineral. If the cold acid is applied to the powdered mineral, however, or if hot acid is applied to a fragment, brisk effervescence will result. Dolomite itself forms large rock deposits and it is present to some extent in all limestones.

Silica

Silica (SiO_2) is present in all limestones in proportions varying from a trace to very large quantities. It may occur in visible form as sand grains, chert nodules, quartz veins, and silicified fossils, or be present as a constituent of microscopic silt, clay, and siliceous ooze deposited throughout the limestone. Where the limestone has been metamorphosed a great variety of silicate minerals may be developed, the most common of which are serpentine, diopside, tremolite, actinolite, hornblende, talc, sphene, and certain aluminium silicates, some of which are mentioned below.

Alumina

Alumina (Al_2O_3) is present in combination with silica in the form of shale or argillaceous matter. It may occur in mere traces disseminated throughout the stone, or in thin films along the bedding planes; or at the other extreme it may form a large proportion of the rock, in which case the limestone is referred to as "argillaceous". The argillaceous matter is always in an extremely fine state of division so that no characteristic crystals can be observed, but if much is present it may be detected by the characteristic odour given off when the stone is breathed on. In highly metamorphosed limestone, aluminium silicates such as garnet, tourmaline, epidote, and the several varieties of feldspar and mica are common.

Iron

Iron occurs in limestone principally in the form of oxides, sulphides, and carbonate, the last being particularly characteristic of dolomitic limestone. In chemical analyses, however, it is commonly recorded only as the ferric oxide (Fe_2O_3). Iron minerals are normally present only in small amounts, but some of the oxides are pigments to which, in large measure, is due the colour of the rock.

Hematite (Fe_2O_3) and turgite ($2Fe_2O_3 \cdot H_2O$), even if present in very small quantities, will impart a red colour, and limonite ($2Fe_2O_3 \cdot 3H_2O$) gives yellow and brown tints. Pyrite (FeS_2) in cubical, brassy-yellow crystals is common in limestones. It is often visible on joint planes and in cracks and is also scattered through the stone both in crystals sufficiently large to be readily seen and of microscopic size. Marcasite or white iron pyrites (FeS_2) is less common. It is paler in colour than pyrite and is present usually in nodular masses instead of distinct crystals. Iron carbonate, siderite ($FeCO_3$), is sometimes found in limestones. When fresh it is grey or brown but it oxidizes to the yellow limonite. In many metamorphosed limestones magnetite (Fe_3O_4) and specular hematite are present. Ferrous iron is particularly characteristic of dolomites, in which it is usually present in very small quantities.

Sulphur

Sulphur occurs in limestones principally in combination with iron as either pyrite or marcasite. It is also present in the sulphate form combined with calcium, barium, and strontium, and rarely with magnesium. Crystals of native sulphur have been observed occasionally in limestone associated with gypsum. The fetid smell given off by some limestones when struck with a hammer is attributed to the presence of hydrogen sulphide gas (H_2S) occluded in the stone. Sulphides of lead, zinc, and copper also occur.

Organic Matter

Organic matter, resulting from vegetable matter deposited in the limestone at the time it was formed, and from the soft parts of the creatures whose shells and skeletons compose a great part of the rock, is a common constituent of limestone. Carbonaceous matter even in very small amounts distributed through the stone acts as a pigment and to it most of the black and dark grey limestones owe their colour. In the form of liquid and solidified petroleum, it fills cavities in the stone. The partings, or thin films of shale between beds, often contain a high percentage of organic matter. Much of the organic matter is destroyed under the action of metamorphic agencies, but a portion of the carbon thereof may be converted into graphite which is commonly found in tiny flakes disseminated through metamorphosed limestones, to which it imparts bluish tints.

Other Impurities

Phosphorus in very small quantities is present in practically all Canadian limestones. The combination in which it occurs has not been determined, but it is probably present as calcium phosphate, in which hypothetical combination it is shown in the analyses in this report.

Alkalis. Many limestones, particularly the impure varieties, often contain soda (Na_2O) and potash (K_2O) compounds, chiefly the latter. The exact combination in which the alkalis occur in Canadian limestones has not been determined, but they are probably in the form of feldspars.

In addition to the more widely occurring impurities enumerated above, compounds of arsenic, manganese, titanium, fluorine, strontium, and barium are also found in limestone.

GENERAL STATEMENT ON THE LIMESTONES OF WESTERN CANADA

The limestones of Western Canada include practically all types from pure high-calcium limestone, through magnesian limestone to pure dolomite. The relatively rare brucitic limestone also occurs in at least one locality in British Columbia; and will probably be found in other places on Vancouver island and along the coastal mainland and adjacent islands, because conditions there are ideal for its occurrence.

The limestones range in age from Precambrian to Jurassic, with those of Ordovician, Silurian, Devonian, and Carboniferous age supplying most of the output.

In Manitoba, Ordovician, Silurian, and Devonian limestones, comprising both high-calcium and dolomitic varieties as well as magnesian limestones, occur in nearly flat beds over a wide belt of country from the vicinity of Winnipeg to north of The Pas and quarries are worked to supply stone for a variety of purposes, including the manufacture of cement and lime, for building stone, road metal, chemical and metallurgical uses, and for various minor uses. Many of the Manitoba limestones are highly coloured and have attracted attention as sources of marble.

In Saskatchewan, the only source of limestone near transportation is in the form of boulders in the glacial drift. These boulders have been utilized from time to time for various purposes, but are nowhere in sufficient quantity to afford a continuous supply of limestone of uniform composition to any industry requiring a considerable daily tonnage. The belt of Palæozoic limestone that crosses Manitoba continues on across northern Saskatchewan, but is not accessible at present.

The main limestone resources of Alberta are found in the Rocky mountains, where limestones of Cambrian to Triassic age occur in great quantity, generally in steeply dipping beds. High-calcium limestones, magnesian limestones, and dolomites are available, but all present production is from high-calcium deposits, the products being Portland cement, lime, stone for use in beet-sugar refineries, flux stone, and stone for a number of minor uses.

In British Columbia, limestone ranging from Precambrian to Jurassic in age is well distributed throughout the province, but the principal centres of production are, with one exception, along the west coast. High-calcium limestone, magnesian limestone, dolomite, and brucitic limestone are available, but all quarries at present worked are in high-calcium limestone. The main products are stone for use in sulphite-pulp mills, for making Portland cement and lime, for flux, and for agricultural use, as well as for a number of other products made in smaller quantities. Most of the production has come from Carboniferous and from Triassic or Jurassic limestones. The deposits are commonly steeply inclined and have been folded and faulted by mountain-building agencies and have been altered as well by igneous intrusions, so much so that much of the limestone has been converted into marble. A number of quarries have been worked for marble from time to time, but at present only stucco dash and similar marble products are obtained.

CHAPTER II

LIMESTONES OF MANITOBA

GENERAL DISTRIBUTION AND CHARACTERISTICS

There are two large areas of limestone in Manitoba, one in the northeast corner of the province bordering on Hudson bay, the other extending northwesterly across the province in a great belt 100 miles wide from near Winnipeg to The Pas. Most of the first-mentioned area is deeply covered by drift and little is known of the character of the limestones.

The great belt extending diagonally across the province includes the basins of Lakes Winnipegosis and Manitoba and the western half of Lake Winnipeg. The limestones lie in even beds having a slight prevailing dip to the southwest. On the eastern edge of the belt are mottled magnesian limestones of the Ordovician system, in the central portion are dolomites and shales of Silurian age, and on the western edge are high-calcium limestones and dolomites of the Devonian formations.

Overlying the limestones of this belt are Mesozoic shales and sandstones containing in places lenticular beds of impure limestone. Underlying the limestones are rocks of Precambrian age in which limestones are of rare occurrence.

TABLE I

Rock Systems and Formations of Manitoba Showing the Stratigraphic Position of the Limestones

System	Formation	Type of Rock
Quaternary		Unconsolidated deposits.
Tertiary		Sandstone.
Jurassic		Sandstone and shale.
Cretaceous		Shale, sandstone, and limestone.
Devonian	Manitoban	Calcium and high-calcium limestone.
	Winnipegosan	Dolomite.
	Elm Point	High-calcium limestone.
Silurian		Dolomite.
Ordovician	Stony Mountain	Shale and dolomite.
	Upper Mottled Limestone	Magnesian limestone.
	Cat Head	Magnesian limestone.
	Lower Mottled Limestone	Magnesian limestone.
	Winnipeg Sandstone	Sandstone.
Precambrian		Gneisses and schists with very little limestone.

Precambrian Limestones

Precambrian rocks are extensively exposed in eastern and northern Manitoba, but so far as is known they include little limestone and none that is of commercial value. No limestone has been reported from the Precambrian of the eastern part of the province, but Wright[1] reports the presence of thin beds

[1] Wright, J. F.: "Crystalline Limestone in the Kisseynew of Northern Manitoba", Can. Min. Jour., vol. LI, p. 762 (1930).

of crystalline limestone at several horizons within the quartz-mica-garnet gneiss (Kisseynew) of northern Manitoba, particularly in the vicinity of Sherridon where, on the southwest side of Found lake, are beds of medium-grained, impure, crystalline limestone 3 inches to 6 feet in thickness, and 200 to 300 feet northeast of the Sherritt-Gordon No. 2 shaft are beds from ½ inch to 6 inches thick. Wright states that the thicker limestone beds contain interbeds of quartzite.

Ordovician Limestones

These are the oldest of the limestones comprising the great limestone belt of Manitoba and occur along the eastern edge of the belt, with only a relatively thin formation of sandstone and shale between them and the ancient Precambrian floor. They dip southwest at a very low angle and in that direction are overlain by Silurian limestones. They are exposed at intervals from the vicinity of Winnipeg northwards along the west shore of Lake Winnipeg and on many of the islands thereof, to north of the Hudson Bay railway between Cormorant lake and Hargrave lake. The band then swings west and the northern edge of the Ordovician limestone area is marked by a prominent escarpment that extends due west from just north of Hargrave lake to the Saskatchewan boundary at Athapapuskow lake. Its southern boundary, which is not clearly defined, apparently runs due west from the southern part of Cormorant lake to near Wanless station on the Flin Flon railway and thence to the Saskatchewan boundary in the vicinity of the southern part of Namew lake. North of the Ordovician escarpment[1], which in places is 80 feet high, small outliers of Ordovician limestone are common within a distance of 5 miles or so, and one large outlier has been reported by Dowling[2] and Wright[3] as occurring on Limestone Point lake, 50 miles north of the main Ordovician escarpment at Reed lake. The outlier is described as being more than 2 miles long and ½ mile across at its widest point. It consists of fine-grained, buff, pinkish, and brownish dolomite similar to that found in the Ordovician escarpment to the south, and it is regarded by Wright as being probably of Trenton age.

Another large area of Ordovician rocks consisting in large part of limestone occurs in the northeastern part of the province at and near Hudson bay. This limestone area is crossed by the Hudson Bay railway beginning at about Mileage 353, but the limestone was seen only in the bottoms of deep river trenches, where it is not easily available and is very impure. Thus the limestone in this area was considered to be of little economic importance at present and was not further investigated.

The Ordovician rocks of the southern part of the province have been divided by Dowling[4] into the following formations:—

		Thickness, feet
5.	Stony Mountain	190
4.	Upper Mottled Limestone	130
3.	Cat Head	70
2.	Lower Mottled Limestone	70
1.	Winnipeg Sandstone	100

The thicknesses shown are only approximate and are of local rather than of general application. The Winnipeg Standstone formation, in particular, varies much in thickness from place to place as it was deposited on an uneven Precambrian floor. The unevenness of the floor may be inferred from the fact that

[1] Alcock, F. J.: Geol. Surv., Canada, Mem. 119, p. 28 (1920).
[2] Dowling, D. B.: Geol. Surv., Canada, Ann. Rept., vol. XIII, p. 23FF (1902).
[3] Wright, J. F.: Geol. Surv., Canada, Sum. Rept. 1930, p. 65C.
[4] Dowling D. B.: Geol. Surv., Canada, Ann. Rept., vol. XI, p. 37F (1898).

bosses of Precambrian rocks protrude through the Ordovician strata south of Sturgeon bay of Lake Winnipeg, and through Silurian strata around the northern part of Lake St. Martin, and also in townships 25, 26, and 27 of range 3, west of the Principal meridian, which is 10 miles west of Hodgson. The information regarding the first- and last-mentioned inliers of Precambrian rock was given in a personal communication by F. D. Shepherd of the Manitoba Mines Branch. The inliers at Lake St. Martin are mentioned by Tyrrell.[1]

The several Ordovician formations in Manitoba have been correlated with formations in Ontario. The Winnipeg Sandstone formation is considered the equivalent of the Black River formation in Ontario but, unlike the latter, which consists largely of limestone, the Winnipeg formation consists entirely of sandstone and shale.

The Lower Mottled, Cat Head, and Upper Mottled Limestone formations have been correlated with the Trenton, which in Ontario consists predominantly of high-calcium limestone in contrast to the highly magnesian character of the Manitoba Trenton. At Haileybury, Ontario, however, a magnesian, mottled, Trenton limestone occurs that is very similar to the Lower Mottled limestone of Manitoba in appearance and composition.

The Stony Mountain formation of dolomite and shale has been provisionally correlated with the Richmond formation of Ontario.

Lower Mottled Limestone Formation

This formation rests directly on the Winnipeg sandstone. It is a bluish grey or, where weathered, a drab-coloured limestone mottled with greenish brown and brownish grey magnesian material, and usually contains considerable pyrite. It is relatively thin-bedded. Because of an admixture of sand grains and clayey material, together with some nodules of chert, it is for the most part impure and of little or no interest from the standpoint of providing stone for chemical or metallurgical purposes or for lime. Many years ago, however, when impure lime was sought for building purposes because of its greater cementing qualities, some lime was made from this formation. It was also quarried for a time from the north end of Hecla island to supply crushed stone and rubble for the Winnipeg market. Nodules of chert, which are characteristic of much of the Upper Mottled Limestone formation, are less prevalent in the Lower Mottled.

Outcrops of the Lower Mottled limestone can be seen from Scanterbury at the south end of Lake Winnipeg and on various islands and headlands on the west shore of the lake to as far north as Berens island, which is north of the narrows. It has not been recognized north of this island.

Some of the principal exposures according to Dowling[2] are on Elk island, 12 feet; Hecla island, 12 feet; Deer island, 10 feet; Grindstone point, 8 feet; Bull head, 19 feet; Whiteway point (Dog head) to Snake island, 25 feet; Black Bear island, 30 feet; Little Tamarack island, 11 feet; Jack Head island, 15 feet; and on Little Black island, 14 feet.

A number of these outcrops were examined and sampled to obtain data on the chemical characteristics of the Lower Mottled limestone, even though it does not appear to be of economic importance at present. A study of the analyses reveals a progressive increase in the magnesium carbonate content of this formation as it is traced north from Scanterbury. This is due in part to an increase in the proportion of the mottlings of magnesian material and in part to an increase in the dolomite content of the matrix of the limestone. The purity of the Lower Mottled limestone also is greater in the upper beds as indicated by the analysis of the beds exposed on Jack Head island (page 46).

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. V, p. 203E (1889-90-91).
[2] Dowling, D. B.: Geol. Surv., Canada, Ann. Rept., vol. XI, pp. 63-73F (1898).

Cat Head Formation

Resting conformably on the Lower Mottled limestone is a fine-grained, yellowish, impure dolomitic limestone studded with nodules of chert and referred to as the Cat Head formation, from its type locality on Cat head, which is midway along the west shore of Lake Winnipeg. As here exposed it is in even, blocky beds which near the top of the cliff tend to cohere, giving apparently heavy beds. Chert nodules of all sizes are plentiful in the Cat Head limestone and this, coupled with a fairly high content of argillaceous matter, renders the limestone valueless for any chemical or metallurgical use. There is not sufficient argillaceous material present, however, to make it a suitable material for making rock wool. Dowling[1] allotted a thickness of about 70 feet to this formation and stated that other exposures occur on the north side of Outer Sturgeon island, on Inmost island, and at Howell and Robinson points. The formation apparently thins out to the north and has not been recognized north of Lake Winnipeg. No outcrops of Cat Head limestone are known to the south, but it has been identified in cuttings from wells drilled near Winnipeg.

Upper Mottled Limestone Formation

Overlying the cherty Cat Head limestone is the Upper Mottled Limestone formation which is the source of one of the finest building and ornamental stones in Canada. In addition it yields lime and stone for use in pulp-mill acid-tower systems.

The Upper Mottled limestone resembles the Lower Mottled as regards the nature of the mottling, but it is much more pleasing in appearance (Plate IA, page 20), is more heavily bedded, and much of it is comparatively pure except for nodules of chert at some horizons. In the southern part of the province the groundmass or matrix of the Upper Mottled limestone is fine-grained, bluish grey, high-calcium limestone, through which is a network of tubular masses of dark brown highly magnesian material. The top 8 to 12 feet of the stone in the outcrop, or near the surface, is much lighter in colour than that below, the matrix being light buff and the mottlings light brown. Stone of this type is quarried at Garson or Tyndall and has been quarried at Selkirk, East Selkirk, and Lower Fort Garry for use as building and ornamental stone. The production has come mostly from a band of stone 22 to 26 feet thick near the middle of the Upper Mottled formation. Beneath this horizon, nodules of hard, blue chert become increasingly numerous and spoil the limestone for use as cut stone. In the Tyndall district the Upper Mottled limestone contains from 1·5 to 2·5 per cent of silica, ferric oxide, and alumina and from 10 to 17 per cent of magnesium carbonate. Northwards, however, the limestone of this formation becomes harder and increasingly more magnesian until, where it is found in the vicinity of the Hudson Bay and Flin Flon railways, it is a true dolomite and the mottlings are merely colour mottlings. Coincident with the increase in magnesium carbonate the content of impurities such as silica, iron, and alumina has decreased, and the dolomite commonly contains less than 1 per cent of such impurities exclusive of cherty zones.

The Upper Mottled limestone is reported by Dowling[2] and Tyrrell to occur also along the west shore of Lake Winnipeg at Koostatak (mission on Fisher river), 2 feet; Clark point, 14 feet; Carscallen point, 2 feet; Dancing point, 4½ feet; Selkirk island, 10 feet; Robinson point, 20 feet; mouth of Sturgeon-gill river, 32 feet; and Howell point, 20 feet. According to Dowling this formation also thins out towards the north.

[1] Dowling, D. B.: Geol. Surv., Canada, Ann. Rept., vol. XI, p. 42 F (1898).
[2] Geol. Surv., Canada, Ann. Rept., vol. XI, pp. 83-88 F (1898).

Stony Mountain Formation

Overlying the Upper Mottled Limestone is a formation approximately 190 feet thick consisting of calcareous shale in the lower part and of dolomite in the upper part, known as the Stony Mountain formation. It is regarded as being the equivalent of the Richmond formation of the East. It is seemingly of limited extent, as the only known exposures are at Stony Mountain and between there and Winnipeg. Deep excavations made for buildings in Winnipeg have shown that it underlies the city. The full thickness of the dolomite member is not known, but it exceeds 20 feet. It is buff and light brown, cavernous in places, and for the most part is thin-bedded. The uppermost beds contain only about 2 per cent total impurities, but the impurities progressively increase towards the contact with the shale where the dolomite is siliceous and argillaceous and contains over 14 per cent total impurities. Between the dolomite and the red shale that forms the greater part of the formation is 15 feet of shaly dolomite.

The dolomite above the transition beds is being quarried at Stony Mountain by the City of Winnipeg for use as crushed stone, and is quarried and used at Stony Mountain penitentiary on a small scale for rough building stone. Formerly, it was quarried extensively for rubble for building purposes, for curbstones, and for making lime, in addition to its use as crushed stone. The lime from the upper beds is said to have been nearly white and that from the lower beds grey.

Silurian Limestones

The rocks of the Silurian system outcrop over a broad belt of country east of Lakes Winnipegosis and Manitoba that extends from Stonewall to The Pas. They consist of two dolomite formations separated in several localities by a thick belt of shales in which deposits of gypsum are found. The prevailing dip of the strata is southeast at a low angle.

The Lower Silurian dolomite, where examined at Stonewall and Gunton, is composed largely of buff-coloured, fine-grained, porous and cavernous (Plate IB, page 20), faintly mottled dolomite in beds of variable thickness. At both places the base of the formation is apparently exposed and the succession of beds is very similar. At Stonewall the top 10 to 12 feet of the dolomite has been used for many years for making lime. It is pure and yields a high-grade white lime. Beneath the quarry floors the dolomite is very impure and gradually passes into a shale. In the old quarries at Gunton, beds of the same horizon as at Stonewall are exposed, as are 20 to 25 feet of the beds higher up. The upper beds are mostly soft and argillaceous. The Gunton quarries, which have been idle for a number of years, were operated chiefly for crushed stone, but some lime was also made. In the district around Hodgson, farther north, the Silurian beds as exposed consist of interbedded pure buff dolomite and impure red dolomite. At Grand rapids on the Saskatchewan river, near where it empties into Lake Winnipeg, there is much shale interbedded with the dolomite. In the section of the lower part of the Silurian dolomite exposed on the Hudson Bay railway, only pure buff dolomite is visible, and there is no shale between the Silurian and the Ordovician unless it occupies a relatively narrow band of country in which no rock outcrops were observed.

The upper dolomite formation of the Silurian system differs from the lower largely in being finer in grain and less porous. At the top of this formation irregular areas of impure red dolomite occur. The pure, fine-grained dolomite can be seen at Inwood, Lundar, Ashern, Fairford, and at many points to the north. It has been burned for lime at a number of places and is being used for this purpose at Inwood. Small-scale operations to produce decorative stone from some of the attractively coloured beds of this formation were begun at Broad Valley and more recently at Hodgson, but there is only a small and occasional production from Hodgson.

Devonian Limestones

The Devonian system in Manitoba is represented by three formations, which Kindle[1] of the Geological Survey of Canada has named the Elm Point limestone, the Winnipegosan dolomite, and the Manitoban limestone. These formations are exposed in the basins of Lakes Manitoba and Winnipegosis. To the west they are overlain by the sandstones and shales of the prairies.

Elm Point Formation

The Elm Point formation is the present source of the limestone for cement and high-calcium lime in Manitoba. It is about 50 feet thick, and is composed of thin-bedded, mottled, grey, high-calcium stone. The mottling is not due to magnesian material as in the Ordovician limestones, but seemingly to a spotty distribution of iron oxide. This limestone is well exposed in the quarries at Oak Point, Steep Rock, and Spearhill, at several points on the shores of Lake Winnipegosis, and south of Ashern on the Gypsumville branch of the Canadian National railway.

At Steep Rock and Spearhill the stone is quite similar and contains on the average less than 1·5 per cent each of silica and of magnesium carbonate. At the former place a large quarry is worked to supply limestone for the manufacture of Portland cement. At Spearhill an outlier of Elm Point limestone is quarried for the making of chemical lime and to provide stone for chemical and metallurgical uses.

At Oak Point a quarry was once operated in the Elm Point limestone to supply a lime plant and a crushed stone plant. The formation here is more impure than in the other localities where it has been worked and contains a total of from 3 to 5 per cent silica and oxides of iron and alumina, and from 5 to 12 per cent magnesium carbonate. Along the shore of Lake Winnipegosis, at Brabant point, where this formation is again exposed, it is also impure.

Winnipegosan Formation

The Winnipegosan dolomite formation conformably overlies the Elm Point limestone. It is well exposed in low domes along the shore and islands of the northern part of Lake Winnipegosis, and on several islands and at Sifton narrows in Lake Manitoba. The Lake Winnipegosis outcrops are composed of interbedded magesian limestone and dolomite, much of which seems to be of indifferent quality. The stone is thin-bedded and fractured, and although it is porous and has many cavities, much of it is extremely hard. The colour ranges from grey to yellow, the latter tint being chiefly due to iron sulphide which is plentiful in some of the exposures.

The only exposure examined in the Lake Manitoba area was at Sifton narrows where a section of 9 feet of Winnipegosan dolomite is visible in a small quarry that was opened many years ago to supply dimension stone and lime to the prairie markets. The dolomite is very pure.

Manitoban Formation

The Manitoban limestone is the youngest of the Palæozoic limestones in Manitoba and succeeds the Winnipegosan dolomite. It is exposed along the western shore and islands of Lake Winnipegosis and on Swan lake and Red Deer lake. To the west it is overlain by the Cretaceous sandstones and shales. The exposures seen in Dawson bay at the north end of Lake Winnipegosis, and near Winnipegosis village and islands in the extreme south end of the lake, are in the

[1] Kindle, E. M.: Geol. Surv., Canada, Sum. Rept. 1912, p. 248.

form of low domes. The stone is fine-grained, soft, thin-bedded, grey or light brown, high-calcium limestone and most of it appears to be very pure. Occasional seams of soft shale and masses of earthy ferruginous stone occur in some of the exposures, and at Point Wilkins in Dawson bay a thickness of 30 feet of argillaceous limestone and an unknown thickness of shale underlie 40 feet of pure limestone.

The Manitoban limestone is quarried on a small scale 1½ miles west of Winnipegosis village, and has been quarried at Charlie point at the southwest end of Lake Winnipegosis. It is used to make whiting substitute.

Cretaceous Limestones

Cretaceous rocks in Manitoba consist chiefly of shales and sandstones with, particularly in the area south of the Assiniboine river, occasional beds of impure, soft, grey limestones. These impure limestones occur at several horizons near the top of what was formerly termed the Niobrara formation, which has since been subdivided into several formations. They do not apparently exceed 20 feet in thickness at any one horizon, and are exposed in flat-lying beds only in the banks of deep coulées in such positions that they can be worked only by underground mining methods. The magnesia content is uniformly low. Recorded exposures are at Leary's, Babcock, Arnold, and Windygates in the southern part of the province. Beds of similar limestone have also been reported north of Dauphin.

PRODUCTION AND UTILIZATION OF LIMESTONE IN MANITOBA

Statistics on the production of limestone, marble, and lime are given in Tables II and III and are shown graphically in Figures 1 and 2. Data prior to 1921 were obtained from the records of the Mines Branch, and for 1921 and subsequent years from the records of the Dominion Bureau of Statistics.

The chief products from the Manitoba quarries are stone for the manufacture of Portland cement and lime; building stone; crushed stone for road metal; flux; stone for use in pulp mills and sugar refineries; poultry grit; terrazzo; stucco dash; rubble; limestone flour for use in stock foods; and for whiting substitute. Limestone for a number of minor uses, chiefly chemical and metallurgical, is also produced. The limestones quarried include high-calcium limestone, magnesian limestone, and dolomite, with by far the greater part of the production being high-calcium limestone.

The best known of the Manitoba limestones is the mottled Tyndall limestone obtained in the vicinities of Tyndall and Garson. This stone is used as a building and as an ornamental stone and has been shipped to many parts of Canada, though its principal market is in the Prairie Provinces. For several years prior to 1931 this limestone accounted for a large part of the annual value of limestone produced in the province; but, owing to continued unfavourable conditions in the construction industry since then, its production now represents only a small part of the total output.

Building stone was at one time produced in small amounts at a number of other localities in Manitoba. In the early years of the present century, before Portland cement had become the dependable building material it is to-day, many quarries were producing rubble for walls, and also flagstones and curbstones. In fact the tonnages produced in those years have not been equalled since and the production of these various products now forms only a very small part of the total output. Quarries yielding such products were in operation at Stony Mountain, Little Stony Mountain, Stonewall, Gunton, Tyndall, and on Hecla island in Lake Winnipeg.

The colourful appearance of the Manitoba limestones, with their red, buff, yellow, brown, and purple tones, has directed attention to their possibilities of yielding marble and a number of deposits in various parts of the province, including some at Hodgson, Broad Valley, and along the Hudson Bay railway, have been investigated. Though some handsome and unique marble was produced, production at all the properties was discontinued for various reasons and except for a small quantity of terrazzo and stucco dash no marble has been produced in Manitoba since 1936.

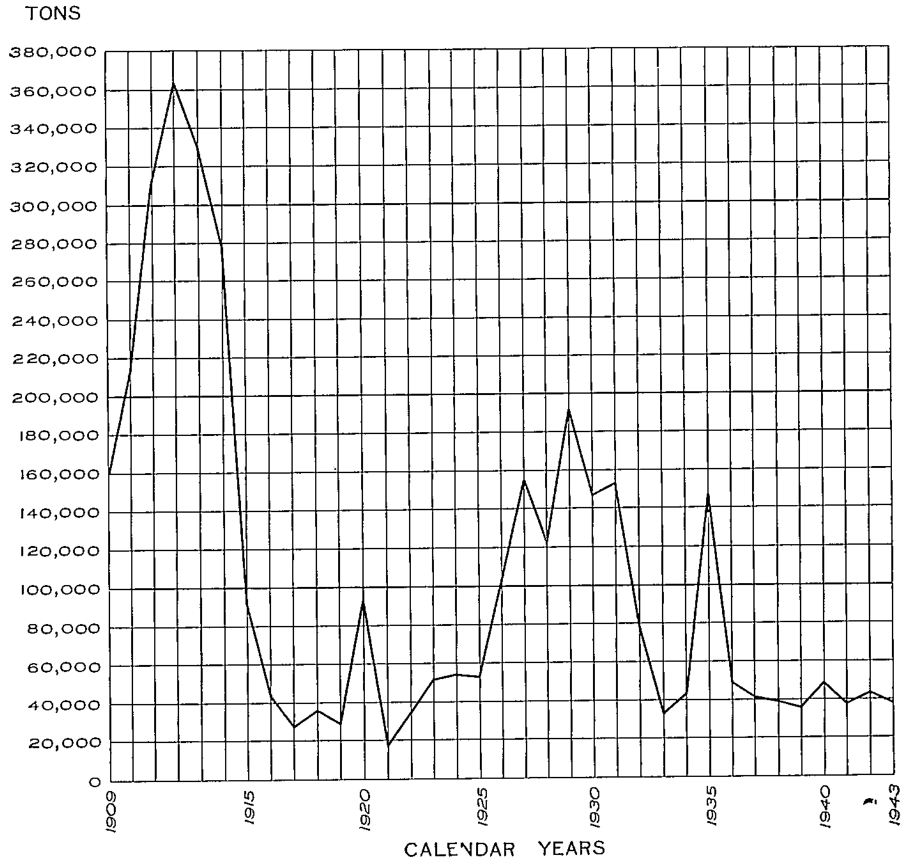


FIGURE 1. Production of limestone in Manitoba.

Limestone suitable for the manufacture of Portland cement is available at a number of places. It is being quarried extensively for this purpose at Steep Rock on Lake Manitoba, and is shipped to the cement plant south of Winnipeg.

Natural cement was made for a number of years from argillaceous limestones at Babcock and near Deerwood in the southern part of the province.

The lime industry was established in the early days of the settlement of the province and excellent grades of high-calcium and dolomitic lime are produced. Formerly, lime was made at a great number of localities, as the ruins of numerous kilns throughout the province testify, but, at present, production is centralized in modernized plants in relatively few localities. White high-calcium lime is made at Spearhill. White dolomitic lime is made at Stonewall and Inwood, and magnesian lime is made on occasion from the mottled Tyndall limestone at Garson.

TABLE II

Production of Limestone and Marble in Manitoba

Year	Limestone[1]		Marble	
	Tons	Value	Tons	Value
		$		$
1909	160,000*	328,554	....	....
1910	212,000*	328,029	....	....
1911	312,000*	315,782	....	....
1912	364,000*	381,572	....	....
1913	330,000*	382,984	....	....
1914	278,000*	346,258	....	....
1915	92,000*	153,113	....	....
1916	43,000*	372,894	....	....
1917	27,000*	301,968	....	....
1918	36,000*	238,251	....	....
1919	28,500*	89,067	....	....
1920	91,400*	374,286	....	....
1921	16,868	56,666	....	....
1922	34,356	106,638	....	....
1923	51,304	118,277	....	....
1924	54,065	93,876	....	....
1925	52,770	188,496	....	....
1926	101,571	357,884	....	....
1927	154,666	318,556	....	....
1928	121,864	494,217	....	....
1929	191,506	885,826	603	9,191
1930	146,316	1,075,485	762	9,994
1931	152,858	636,226	390	6,423
1932	78,405	299,050	....	....
1933	32,858	71,240	....	....
1934	42,914	50,843	....	....
1935	146,100	183,892	127	1,233
1936	49,261	69,837	60	90
1937	41,053	63,432	....	....
1938	39,049	95,497	....	....
1939	35,969	80,404	....	....
1940	48,488	74,116	....	....
1941	38,103	60,743	....	....
1942	43,355	69,514	....	....
1943	37,974	50,784	....	....

[1] These figures do not include the limestone used in the lime and cement industries.

*Estimated from incomplete data on file at the Bureau of Mines. The disparity between tonnage and value is due to the fact that the production in some years consisted largely of crushed stone and rubble having a low value per ton, and in other years consisted largely of dressed building stone having a high value per ton.

Crushed stone for road metal and concrete aggregate is produced at Stony Mountain, and small quantities for local use are produced at various other places as the demand arises. Gravel is available in many places throughout the area in which the limestones occur and it has been largely employed for highway construction, concrete aggregate, and railway ballast, thus limiting the demand for crushed stone.

Chemical limestone for use in chemical and metallurgical processes is available from many deposits in Manitoba and is being produced in quantity for use in sugar refineries, pulp and paper mills, for flux, and various minor uses. Spearhill is the chief centre of production. Dolomite for certain chemical and metallurgical uses is produced at Stonewall; and magnesian limestone from Garson is shipped for use in pulp mills.

Minor products made from Manitoba limestones include asphalt filler, calcium carbonate flour for incorporating into stock foods, stucco dash, and whiting substitute.

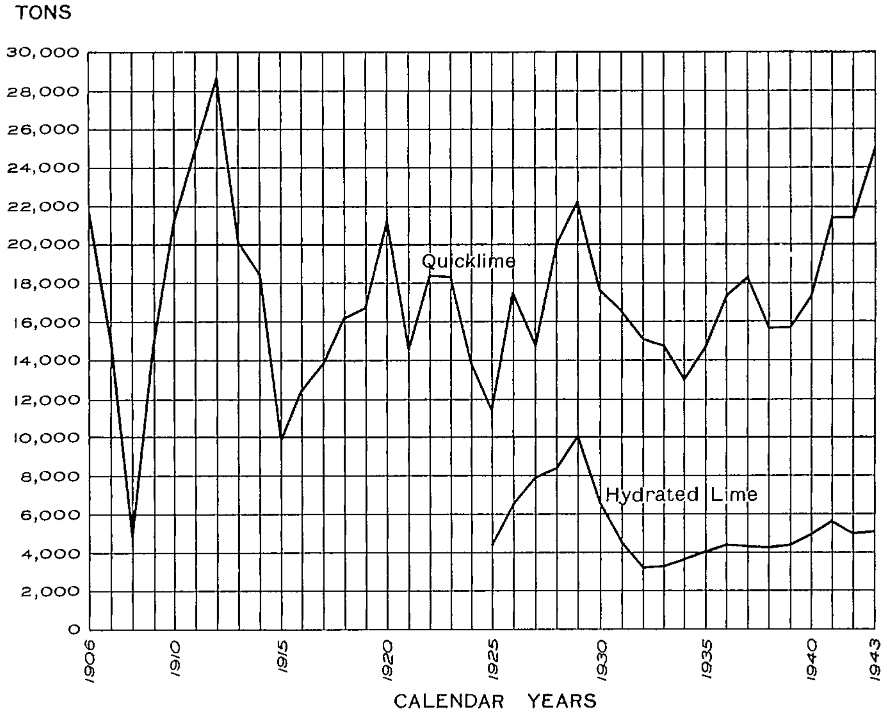


FIGURE 2. Production of lime in Manitoba.

TABLE III

Production of Lime in Manitoba

Year	Quicklime		Hydrated Lime		Total Lime	
	Tons	Value	Tons	Value	Tons	Value
		$		$		$
1906	21,707	119,792	....	....	....	119,792
1907	15,104	84,793	....	....	....	84,793
1908	4,858	24,192	....	....	....	24,192
1909	14,838	69,670	....	....	....	69,670
1910	21,234	100,808	....	....	....	100,808
1911	24,741	140,629	....	....	....	140,629
1912	28,638	168,257	....	....	....	168,257
1913	20,193	107,281	....	....	....	107,281
1914	18,416	92,898	....	....	....	92,898
1915	9,850	71,372	....	....	....	71,372
1916	12,436	83,754	....	....	....	83,754
1917	13,789	92,932	....	....	....	92,932
1918	16,189	134,725	....	....	....	134,725
1919	16,676	147,131	....	....	....	147,131
1920	21,189	210,984	....	....	....	210,984
1921	14,465	136,375	....	....	....	136,375
1922	18,381	163,799	....	....	....	163,799
1923	18,344	161,226	....	....	....	161,226

TABLE III—*Concluded*

Production of Lime in Manitoba

Year	Quicklime		Hydrated Lime		Total Lime	
	Tons	Value	Tons	Value	Tons	Value
		$		$		$
1924	13,798	121,518	....	....	....	121,518
1925	11,358	100,833	4,403	69,397	15,761	170,230
1926	17,461	147,401	6,528	103,868	23,989	251,269
1927	14,741	123,831	7,973	122,448	22,714	246,279
1928	20,006	173,127	8,331	146,572	28,337	319,699
1929	22,178	186,377	10,068	174,727	32,246	361,104
1930	17,587	143,955	6,511	116,370	24,098	260,325
1931	16,575	126,789	4,439	80,612	21,014	207,401
1932	15,047	116,369	3,188	55,741	18,235	172,110
1933	14,793	110,957	3,239	56,683	18,032	167,640
1934	12,988	100,958	3,580	62,650	16,568	163,608
1935	14,594	115,149	4,021	70,368	18,615	185,517
1936	17,314	133,227	4,446	77,808	21,760	211,035
1937	18,252	143,040	4,345	72,125	22,597	215,165
1938	15,600	124,763	4,224	73,922	19,824	198,685
1939	15,625	119,696	4,407	76,494	20,032	196,190
1940	17,261	135,326	4,906	82,221	22,167	217,547
1941	21,444	174,624	5,656	98,863	27,100	273,492
1942	21,443	181,052	4,981	84,027	26,424	265,079
1943	24,962	216,414	5,076	91,405	30,038	307,819

TABLE IV

Limestone and Marble Quarries in Manitoba

Operator	Location of Quarry	Product
Building Products and Coal Co., Limited, Christie St., Winnipeg.	Inwood	Quicklime.
Canada Cement Co., Limited, Box 290 Station B, Montreal.	Steep Rock	Portland cement.
Gillis Quarries, Limited, Richard and Spruce Sts., Winnipeg.	Garson	Building stone, quicklime.
	Stonewall	Quicklime.
McArdle's Quarry, Mafeking	Mafeking	Poultry grit, calcium carbonate flour.
Tyndall Quarry Co., Limited, 1591 Erin St., Winnipeg.	Garson	Building stone.
City of Winnipeg, Winnipeg	Stony Mountain	Crushed stone, asphalt filler.
The Winnipeg Supply and Fuel Co., Ltd., 812 Boyd Bldg., Winnipeg.	Stonewall	Quicklime.
	Spearhill	Quicklime, stone for chemical and metallurgical uses.
	Winnipegosis	Whiting substitute.
Winnitoba Marble Quarries, 1180 Wall St., Winnipeg.	Hodgson	Rubble, stucco dash, terrazzo.

MANITOBA MINING LAWS RELATING TO LIMESTONE

Regulations concerning the quarrying of granite, limestone, marble, slate, or any building stone, and clay, gravel, gypsum, marl, peat, sand, or volcanic ash may be summarized as follows:—

A licensee may obtain a "Quarrying Location" for the purpose of quarrying out, mining, or removing stone, or other material above-mentioned, by

(*a*) Staking out or having another licensee stake out on his behalf and in his name;

(*b*) Furnishing an application for a lease of the quarrying location accompanied by a declaration to the effect that the land comprised within the location contains in merchantable quantity the material of the claim applied for.

The fee for an application for a lease of a quarrying location is $5, and the annual rental is decided by the Minister, but must not be less than $1 an acre.

The location is limited to one quarrying location in any one year.

The lease conveys the rights only to the minerals covered by these regulations.

The lessee is limited to such surface rights as may from time to time be absolutely necessary for the removal of the material covered by the rights granted.

Permission to enter must be obtained when the surface rights of a location are covered by a timber licence, grazing lease, mineral claim, or other form of terminable grant.

In the case of the mineral rights having been disposed of by the Crown, no lease for quarrying purposes may be granted unless the application has been approved by the Minister and unless he is satisfied that such lease will not unduly interfere with mining operations.

The term of the lease is 10 years and is renewable.

An expenditure of not less than $2.50 an acre must be incurred in actual quarrying operations during the term of the lease.

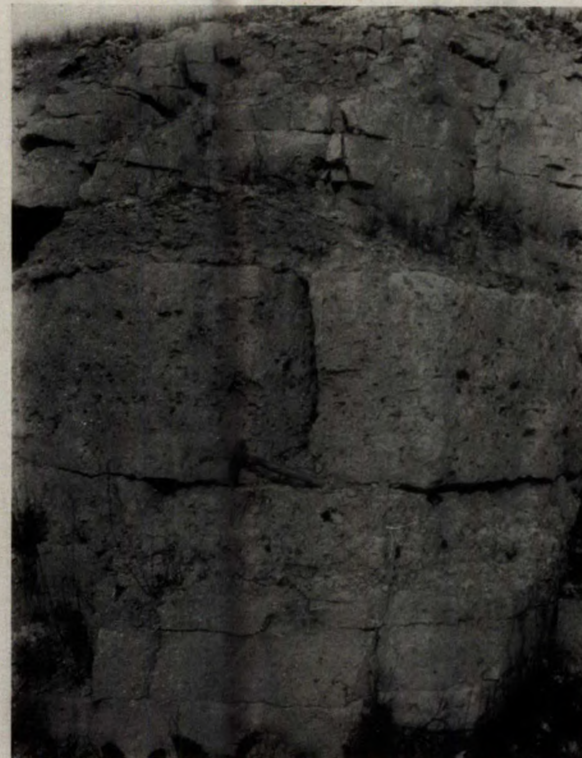
DISTRIBUTION OF LIMESTONE BY DISTRICTS

Tyndall-Garson-East Selkirk District

The quarries from which the well-known mottled building stone, variously known as Tyndall limestone, Manitoba limestone, Manitoba Tapestry limestone, and occasionally as Winnipeg limestone, is obtained are just south of the stations of Tyndall and Garson on the Canadian Pacific railway, 30 miles northeast of Winnipeg. Production began about 1896 and in the ensuing years the stone has been marketed across Canada. Although continuing unfavourable conditions in the construction industry in recent years have resulted in the demand for cut stone being so small that shipments could be supplied from stock, thus causing a virtual shutting down of the quarries, there is every reason to expect that quarrying will be resumed on a considerable scale after the war.

The desirable stone at Tyndall comprises a band 22 to 26 feet thick, stratigraphically situated about the middle of the Upper Mottled Limestone formation, which corresponds to the upper part of the Trenton formation of Ontario and Quebec. A deposit of Trenton limestone mottled similarly to the Tyndall limestone occurs at Haileybury, Ontario. The limestone at Tyndall and Garson lies nearly horizontally, with a slight prevailing dip southwest. The country in the vicinity of the quarries is flat, and the soil is deep. In places, however, the limestone strata have been pushed up into gentle domes and anticlines and it is on these structures where there is a minimum of soil cover that

A. Slab of Upper Mottled limestone showing mottling parallel to the bedding.



B. Cavernous Silurian dolomite as exposed in a quarry at Stonewall, Man.

the quarries have been opened. The present quarries are on the flanks of a low anticlinal ridge that strikes northwest-southeast across sections 3 and 9 of township 13, range 6, east of the Principal meridian and extends into section 35 of township 12. Other small quarries have been opened to the north and south on similar structures and prospecting would doubtless disclose a large area where high-grade building stone could be obtained without having to remove an undue amount of overburden.

Five large quarries have been opened in the Tyndall area but only two are now in operation. They are those of *Gillis Quarries, Limited, Spruce and Richard Sts., Winnipeg,* and *Tyndall Quarry Company, Limited, 1591 Erin St., Winnipeg.*

Two main varieties of stone are obtained, a buff mottled and a grey mottled. Both varieties are mottled exactly alike and differ only in colour. Only the top 8 to 12 feet of stone is buff, and immediately below this is a zone 2 to 4 feet thick that is part buff and part grey, and the stone from which is termed "variegated". Beneath this all is grey. The buff beds range from 12 to 26 inches in thickness and the grey from 12 to 36 inches. These measurements refer to thicknesses of stone free from distinct parting planes. Beds of buff up to 29 inches and of grey up to 40 inches can be obtained in which are only minor partings of a stylolitic nature. The difference in colour appears to be due to the action of downward percolating ground water on pyrite and organic matter present in the limestone. The change proceeds to unequal depths and follows joint planes, but usually stops at a bedding plane.

The groundmass of the mottled stone is dense, sub-crystalline calcium carbonate, containing many fossil fragments composed of calcite with an occasional one of silica. An analysis of the matrix is shown as No. 4D in the table on page 28. All through this matrix is a branching network of the finely granular, brown magnesian material that composes the mottling (Plate IA, page 20). An analysis is given as No. 4C in the table on page 28. The mottlings are not so highly fossiliferous as is the matrix but they do contain many fossil fragments composed of calcite. The main constituent, however, is dolomite in tiny rhombic crystals cemented by calcium carbonate. The mottlings are roughly tubular in shape and, as has been definitely proved by D. J. Birse[1], who dissolved away the matrix with acetic acid, they run through the stone in all directions, but are much more prominent and in prettier pattern parallel to the bedding than vertical to it. Some of the tubes are about a quarter of an inch in diameter and others are nearly an inch thick. In the centre of each is a tiny channel similar to a worm boring and immediately adjoining this channel the material is darker than the remainder. A sharp line of demarcation between the dark mottlings and the lighter coloured groundmass is typical of the stone in the Tyndall quarries. The mottling differs somewhat in degree in different beds though it is always similar in kind. In the buff stone the groundmass is a creamy buff and the magnesian mottlings are yellowish brown. In the grey stone the groundmass is light grey with a bluish tint in places, and the mottlings are grey-brown.

Small nodules of white and grey chert occur in some of the beds being quarried, particularly in the lower grey beds. They occur mostly in streaks parallel to the bedding, and in the stone that is quarried there is rarely more than one streak in any bed. They can thus be avoided in working the stone and therefore are not particularly objectionable. In the uppermost beds these chert nodules have decomposed to a soft chalky material. Many of the chert nodules and fossils are ringed with brown magnesian material similar to that composing the mottling.

All the quarries are of the pit type and are at the same geological horizon, apparently near the middle of the Upper Mottled Limestone formation. The band of limestone worked is 22 to 26 feet thick. Little is known of the charac-

[1] Birse, D. J.: Trans. Royal Soc. Canada, Sec. IV, pp. 215-221 (1928).

PLATE II

A. Quarry of Tyndall Quarry Company in Upper Mottled limestone, Garson, Man.

B. Quarry of Gillis Quarry Company in Upper Mottled limestone, Garson, Man.

teristics of the stone above this band, but it is seemingly very similar, judging by the poor exposures at St. Andrews locks, Lower Fort Garry, and East Selkirk. Beneath this band, however, the mottled limestone contains an increasingly large number of chert nodules which render it undesirable for building purposes. The most promising area, therefore, in which to search for more quarry locations is between Garson and East Selkirk.

Wells drilled in the vicinity of the Tyndall quarries show the thickness of the limestone to be approximately 200 feet, after which sandstone is encountered.

Waste from the building-stone operations is used in part for rubble, rustic walks, riprap, in sulphite-pulp mills, and for making lime. It is too soft to be used for crushed stone for railway ballast, road metal, and concrete aggregate.

Tyndall Quarry Company, Limited, 1591 Erin St., Winnipeg. The property of this company consists of 80 acres, comprising the north half of the northeast quarter of section 3, township 13, range 6, east of the Principal meridian. The quarry is in the centre of the property, is 1,000 feet long east and west, and has a maximum width of 350 feet. In the west end it has been worked to a maximum depth of 22 feet, exclusive of overburden, and the following section of strata dipping to the northwest at an angle of 1 or 2 degrees is exposed:

6 feet—Clay soil filled with pieces of limestone.
A bed, 23 inches—Buff bed, often cracked and in most places contains nodules of decomposed white chert. (Sample 1A.)
B bed, 23 inches—Buff bed (Sample 1B).
C bed, 28 inches—Buff bed (Sample 1C).
D bed, 29 inches—Buff bed (Sample 1D).
E bed, 28 inches—Buff bed, of which the top 6 inches is usually discarded owing to the presence of numerous parting planes (Sample 1E).
F bed, 24 inches—Buff bed (Sample 1F).
Prominent bedding plane containing clay.
G bed, 26 inches—Variegated bed.
H bed, 30 inches—Grey bed which in parts of the quarry is divided by a parting plane into two beds of equal thickness.
I bed, 36 inches—Grey bed with a distinct stylolitic parting 12 inches from the top.
J bed, 20 inches—Grey bed containing nodules of grey chert. (Sample 1G includes beds G, H, and I.)

The quarry (Plate IIA, page 22) is worked by means of channelling machines and the blocks of stone extracted are shipped either to the company's stone-dressing plant in Winnipeg for cutting and carving, or direct to stone-dressing plants in other cities. At one time the waste from this quarry was made into lime in a battery of stone kilns, now in ruins, in the east end of the quarry.

Adjoining the Tyndall Quarry Company's property on the west is No. 1 Quarry which was owned by *Western Stone Company,* no longer in existence. The property has been purchased by L. Jurovsky of Garson who is shipping rock from the waste piles for utilization in sulphite-pulp mills. This quarry is 300 feet wide, north and south, 480 long, and 30 feet deep. It is nearly full of water. The beds are at the same horizon as those in the Tyndall quarry, but the top buff beds are thinner and are much more broken. The quarry is almost on the axis of the ridge, which accounts for the fracturing that has taken place in the beds. It was abandoned by the Western Stone Company in favour of its No. 2 Quarry, 1 mile northwest, because the proportion of sound buff stone that could be extracted was small, and also because of the increasing prevalence of chert as the quarry was deepened. Sample 2 was taken from the lowest 8 feet of beds exposed when the quarry was in operation, but no chert nodules were included.

Gillis Quarries, Limited, Spruce and Richard Streets, Winnipeg. This company owns 290 acres in the east half of section 3, township 13, range 6, east of the Principal meridian. The quarry is just south of the highway that passes through the village of Garson and is about 400 feet square and 24 feet deep, exclusive of overburden. The strata dip at an angle of 1 or 2 degrees southwest. The following section of strata is exposed:

10 feet—Clay soil containing many fragments of limestone.
36 inches—Broken beds of buff limestone, 6 to 8 inches thick.
A bed, 18 inches—Buff bed containing some nodules of decomposed chert.
B bed, 17 inches—Buff bed, the top 3 inches of which shows several minor partings.
C bed, 28 inches—Buff bed with a stylolitic parting 10 inches down from the top which in places divides it into two beds.
D bed, 26 inches—Buff bed.
E bed, 30 inches—Part buff and part grey with partings, 3 inches and 9 inches down from the top.
F bed, 27 inches—Grey bed for the most part, but it is part buff in places.
G bed, 25 inches—Grey bed except bottom 3 inches, which is buff.
Prominent bedding plane containing clay.
H bed, 30 inches—Grey bed except for top 4½ inches, which is buff.
I bed, 27 inches—Grey bed.
J bed, 32 inches—Grey bed with an indistinct parting plane 6 inches down from the top.
K bed, 24 inches—Grey bed.

Samples taken in this quarry were: Sample 3A from A and B beds; Sample 3B from C, D, and E beds; and Sample 3C from F, G, H, and I beds.

As is seen, the section in this quarry and that in the Tyndall quarry do not exactly correspond. A thickening of some beds and a thinning of others is seen in tracing the beds along a face of any of the large quarries. It is claimed by the quarrymen that the B bed in the Gillis quarry is the same as the A bed in the Tyndall quarry.

The quarry (Plate II B, page 22) is worked by channelling machines and the quarried blocks are shipped either to the company's stone-dressing plant in Winnipeg for cutting and carving, or direct to stone-dressing plants in other cities.

Waste stone from this quarry is used in a lime plant beside the quarry. The plant originally consisted of four vertical draw-kilns, two built of stone and two with steel shells, but only one kiln is completely equipped for operating at present and it has not been used since 1942. When in operation, stone sized in 5- to 8-inch lumps is taken from the quarry in a truck and dumped directly into a side-dump steel car that is hauled by cable up an incline to the top of the kilns by a steam-operated hoist and there dumped by hand into the kiln. The capacity of the kiln is 10 tons of quicklime a day when poplar is used for fuel. The mottling of the stone carries through to the lime, as the magnesian material calcines to a brownish grey in contrast to the light grey of the high-calcium matrix. The lime is marketed as masons' lime.

Directly north of the Gillis quarry on the opposite side of the highway is a large quarry that was formerly worked by *Wallace Sandstone Quarries, Limited,* but which has been idle for many years. It is 1,200 feet long east and west and 600 feet wide at the west end, tapering to 100 feet at the east end where there is a battery of six old stone kilns. The quarry is 18 feet deep and the stone is essentially the same as that in the nearby quarries but the beds in general are thinner.

About 1 mile northwest of the above group of quarries, *Western Stone Company,* when operating in the Tyndall district, opened a quarry (No. 2 Quarry) on the northeast quarter of section 9, township 13, range 6, east of the Principal meridian. The quarry has not been worked since 1934 and is now owned by the municipality. It was served by a spur track, from which the rails have been removed, from Garson station on the Canadian Pacific railway, ¼ mile distant. Quarrying was done on both sides of the spur, the openings being about 300 feet square. The quarry on the west side is shallow, but that on the east reached a depth of 28 feet, exclusive of overburden, below which heavily bedded limestone containing much hard, black chert was encountered in a test pit. A section of the quarry face is as follows:

13 feet—Soil and loose blocks of buff limestone.
A bed, 27 inches—Buff bed, usually fractured.
B bed, 19 inches—Buff bed, usually fractured.
Well-defined parting plane.
C bed, 25 inches—Buff bed.
D bed, 24 inches—Buff bed.
E bed, 14 inches—Buff bed.
Well-defined parting containing clay.
F bed, 24 inches—Partly buff and partly grey, with many dries and some pockets of weathered chert.
G bed, 40 inches—Grey bed with a stylolitic parting which usually divides into an upper 25-inch and a lower 15-inch bed, the latter containing some chert.
H bed, 42 inches—Grey bed with an indistinct parting about 28 inches down. Grey chert in the lower 15 inches.
I bed, 22 inches—Grey bed containing white chert.
J bed, 34 inches—Grey bed with a zone in which nodules of chert are numerous.
K bed, 24 inches—Grey bed with some chert.
L bed, 36 inches—Grey bed with many chert nodules in the top and bottom 6 inches.
M bed, 48 inches—Grey bed exposed only in a small pit in the bottom of the quarry from which a few blocks were removed. It contains much black chert.

Sample 4A taken in this quarry includes beds A, B, C, D, and E, or all the buff beds. Sample 4B includes beds F, G, H, I, and J, exclusive of chert nodules. Sample 4C represents the magnesian material composing the mottlings, and Sample 4D the light-coloured matrix.

The stone in this vicinity has somewhat more of a yellowish tint than that at Garson and when this quarry was in operation the product from the buff beds was termed "ivory buff". Adjacent to some prominent joints the magnesian mottlings in the upper beds have become reddish brown and, in places, brick red in colour, though the high-calcium matrix has not been affected. A similar coloration is seen in stone wetted by the overflow of a flowing well drilled 205 feet to the contact between the mottled limestone and the underlying sandstone, and so the coloration is possibly due to the action of this ground water seeping upwards through some of the main joints. The highly coloured mottlings are noticeably softer than are the normal brown magnesian mottlings. This highly coloured stone, which was prized for interior decorative use, was not found below a depth of 14 feet and at that depth the zone was very narrow.

Many test pits have been put down to bedrock west and southwest of this quarry and they indicate that the same ivory-buff mottled limestone occurs over a wide area covered by from 10 to 18 feet of soil.

About 1½ miles northeast, in the northeast quarter of section 15, township 13, range 6, east of the Principal meridian, a small quarry known as the *Strindlund quarry* was opened many years ago to obtain stone for making lime. The quarry is on the south side of a slight rise on which there is about 4 feet of soil, and is 150 feet long and 75 feet wide. Three beds of yellow-buff mottled limestone each 22 inches thick are exposed. The beds are horizontal and rather badly fractured, owing possibly to the method of quarrying used. Sample 5 is representative of the 5½ feet of stone exposed.

A short distance north of the Strindlund quarry, and just across the road allowance from it in the northeast quarter of section 14, township 13, range 6, east of the Principal meridian is another pit, 100 feet in diameter and 15 feet deep, in which no solid rock is visible. This quarry, formerly worked for stone for making lime, is known as the *Sinclair quarry*.

Still farther north, on the southwest quarter of section 25, township 13, range 6, east of the Principal meridian, or 3 miles due north of Tyndall, a test pit was sunk in 1931 to find out the nature of the rock. This showed 7 feet of boulder clay and then a 20-inch bed, a 32-inch bed, and a 28-inch bed of mottled limestone. The 28-inch bed contained much chert and the stone in general had the appearance of that in the deeper parts of the Tyndall quarries, but the mottling is much less distinct and tends to merge gradually into the matrix instead of being sharply delineated. Sample 5A was taken here and the analysis shows that it is considerably higher in silica and alumina than is the stone at Tyndall.

South of the Tyndall quarries are several small quarries that were opened to obtain stone for making lime, but have not been in operation for many years. The largest of these, known as the *Hazel quarry,* is in the northwest quarter of section 34, township 12, range 6, east of the Principal meridian. The following section of limestone is seen in the quarry, which is 75 by 160 feet in area and is opened in the side of a low bush-covered rise:

4 to 6 feet—Soil
9-inch bed—Ivory-buff mottled limestone
17-inch bed—Ivory-buff mottled limestone
28-inch bed—Ivory-buff mottled limestone
Well-defined parting plane.
30-inch bed—Ivory-buff mottled limestone usually split into two 15-inch beds.
42-inch bed—Ivory-buff mottled limestone with a stylolitic parting 17 inches down from the top.
29-inch bed—Ivory-buff mottled limestone.

All the beds are much broken and cracked, owing probably to a slight doming that is apparent in the quarry floor. Otherwise the limestone is of excellent quality and is not marred by chert. It is said that this was one of the first quarries opened in the Tyndall district and that building stone as well as lime was produced. Sample 6 is representative of the 13 feet of beds in the quarry face.

Across the road allowance to the west, in the northeast quarter of section 33 in the same township and range, is the *Malmstrom quarry,* a very small quarry in which only loose blocks of mottled limestone are visible. The stone is similar to that in the Hazel quarry.

A mile east of the Hazel quarry is another small quarry in the northwest quarter of section 35 of the same township and range, known as the *Cutter quarry,* in which no bedded stone is visible owing possibly to the caving-in of the soil. It was operated to produce lime and rubble.

One and one-half miles south of the Cutter quarry, or 4 miles south of Tyndall station, a small quarry known as *Little's quarry* was opened in the side of a hill rising about 20 feet above the prairie level. Lime and rubble were produced for a short time. Wells[1] gives the following analysis of a single specimen from this quarry:

	Per cent
Insoluble matter	0·90
Alumina and iron oxides	0·34
Calcium carbonate	88·56
Magnesium carbonate	10·46
Sulphur trioxide	0·12
Moisture	0·13
Total	100·51

St. Andrews Locks

Four feet of Upper Mottled limestone containing much white chert is exposed at the water's edge beneath 30 feet of overburden on the east side of Red river, just below St. Andrews locks. In view of the prevailing dip of the

[1] Wells, J. W.: "Preliminary Report on the Limestones and the Lime Industry of Manitoba"; Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 42 (1905).

strata to the southwest these beds are much higher in the formation than those at Tyndall. The stone is very similar in general appearance to that at Tyndall but it is lighter in colour and softer. In places the magnesian mottlings are rusty brown. The beds are badly broken along the line of outcrop on the river bank but they are up to 14 inches in thickness. Although the depth of overburden would preclude quarrying in this vicinity, Sample 7 was taken from this outcrop to illustrate the chemical composition of the upper beds of the Upper Mottled Limestone formation. The limestone is somewhat more siliceous than at Garson.

Lower Fort Garry

Beds from near the top of the Upper Mottled Limestone formation are exposed in the west bank of the Red river at Lower Fort Garry, and it was from them that the stone for building the fort and the fort warehouses was quarried in 1832. Stone to supply a number of small lime kilns along the river also came from these outcrops. The limestone is similar in appearance to that at St. Andrews locks and apparently it is heavily bedded, though the beds were poorly exposed. An analysis, quoted by Dowling[1] as having been made from a sample obtained by D. D. Owen in 1848, is as follows:

	Per cent
Insoluble matter	1·0
Alumina, oxide of iron and manganese	1·4
Carbonate of lime	78·1
Carbonate of magnesia	17·8
Water and loss	1·7
Total	100·0

East Selkirk

A large quantity of buff mottled limestone for building purposes was obtained from quarries in the Upper Mottled limestone at East Selkirk prior to 1900, but the quarries have not been worked since then. The soil overlying the limestone has caved in to such an extent that no strata in place are visible, although numbers of loose blocks are seen. It is said that when the quarries were in operation a large part of the production came from loose blocks. Blocks lying around in the three quarries, which are south of the village in the vicinity of Cooks creek, show that beds at least 20 inches thick were obtained. The stone is lighter in colour and somewhat softer than that obtained at Tyndall. Analyses given by Wells[2] of samples taken from quarries in East Selkirk are as follows:

	1	2
	Per cent	Per cent
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
Moisture		0·07
Total	100·74	100·47

[1] Dowling, D. B.: Geol. Surv., Canada, Ann. Rept., vol. XI, pt. F, p. 78 (1898).
[2] Wells, J. W.: Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 42 (1905).

Analyses of Limestones at Tyndall and Vicinity

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
1A......	1·70	0·45	0·19	0·09	83·70	14·39	100·52	0·01	46·92	6·88	6·8 : 1
1B......	1·46	0·46	0·06	0·07	86·42	11·86	100·33	0·01	48·44	5·67	8·5 : 1
1C......	0·94	0·40	0·18	0·07	88·91	9·94	100·44	Tr.	49·83	4·75	10·5 : 1
1D......	0·84	0·35	0·51	0·09	87·82	11·33	100·94	Tr.	49·23	5·42	9·1 : 1
1E......	0·76	0·39	0·45	0·04	83·21	14·91	99·76	0·04	46·62	7·13	6·5 : 1
1F......	0·74	0·51	0·07	0·11	89·36	9·43	100·22	0·02	50·10	4·51	11·1 : 1
1G......	0·88	0·42	0·20	0·07	86·68	11·56	99·81	0·09	48·58	5·53	8·8 : 1
2........	0·92	0·44	0·36	0·07	83·95	14·37	100·11	0·12	47·05	6·87	6·8 : 1
3A......	1·38	0·29	0·29	0·09	81·80	16·67	100·52	Tr.	45·86	7·97	5·8 : 1
3B......	1·10	0·60	0·12	0·22	80·93	16·94	99·91	0·02	45·44	8·10	5·6 : 1
3C......	1·00	0·35	0·27	0·09	82·95	15·23	99·89	0·06	46·50	7·28	6·4 : 1
4A......	0·68	0·38	0·30	0·07	88·70	9·81	99·94	0·04	49·71	4·69	10·6 : 1
4B......	1·28	0·40	0·32	0·04	83·84	13·76	99·64	0·12	46·97	6·58	7·0 : 1
4C......	1·44	0·91	0·34	0·07	68·98	28·16	99·90	0·03	38·67	13·47	2·87 : 1
4D......	0·78	0·13	0·09	0·04	97·09	1·68	99·81	Tr.	54·40	0·80	68 : 1
5........	1·30	0·34	0·38	0·05	83·51	14·56	100·14	0·03	46·79	6·96	6·7 : 1
5A......	2·64	0·29	0·97	0·08	80·95	14·85	99·78	0·02	45·36	7·10	6·4 : 1
6........	1·10	0·36	0·34	0·07	80·31	16·96	99·14	Tr.	45·00	8·11	5·5 : 1
7........	2·14	0·46	0·20	0·07	86·11	10·60	99·58	Tr.	48·23	5·07	9·5 : 1

1A. Tyndall. A bed in quarry of Tyndall Quarry Co., Ltd.
1B. " B " " " "
1C. " C " " " "
1D. " D " " " "
1E. " E " " " "
1F. " F " " " "
1G. " G, H, and I beds in same quarry.
2. " Lowest 8 feet of beds worked in No. 1 Quarry formerly operated by Western Stone Company.
3A. " A and B beds in quarry of Gillis Quarries, Ltd.
3B. " C, D, and E beds in quarry of Gillis Quarries, Ltd.
3C. " F, G, H, and I beds in quarry of Gillis Quarries, Ltd.
4A. " A, B. C, D. and E beds in No. 2 Quarry formerly operated by Western Stone Company.
4B. " F, G, H, I, and J beds in same quarry.
4C. " Magnesian material composing the mottlings in the Tyndall limestone.
4D. " Light-coloured matrix of the Tyndall limestone.
5. " Five and one-half feet of mottled limestone in Strindlund quarry in NE¼ sec. 15, tp. 13, rg. 6E.
5A. " Six and one-half feet of mottled limestone in test pit 3 miles north of the village in SW¼ sec. 25, tp. 13, rg. 6E.
6. " Thirteen feet of mottled limestone in the Hazel quarry in NW¼ sec. 34, tp. 12, rg. 6E.
7. St. Andrews locks. Four and one-half feet of mottled limestone exposed in the east bank of the Red river.

Southern Manitoba

By "southern Manitoba" is meant the territory south of Winnipeg. Throughout this area the cover of soil is thick and rock exposures are confined to the sides of the deeper coulées. No outcrops of the Palæozoic limestones, so well exposed to the north, are known, but west of Red river and south of Assiniboine river, bands of impure, flat-lying Cretaceous limestone enclosed in shale are exposed in a number of coulées. These bands range from 2 to 20 feet in thickness. No use is being made of them, but a number of years ago two of the deposits having the proper composition were used to make natural cement.

Babcock

An 8-foot band of soft argillaceous limestone of Cretaceous age is exposed in the hillside immediately south of the Canadian National railway at Babcock station, where, between 1907 and 1924, it was mined by Commercial Cement Company for making natural cement. The limestone outcrops about 15 feet above the track level. It is light grey, faintly mottled, and lies in thin horizontal beds. It was mined by the room-and-pillar method and was conveyed over a trestle to the six vertical steel kilns on the opposite side of the track and 300 feet from the tunnel entrance. Sample 8 (page 31) is representative of the limestone exposed at the tunnel entrance. Subsequently, the following series of analyses of samples (taken while the mine was in operation) became available. They show the composition of the rock, foot by foot.

——	1	2	3	4	5	6	7	8	9
Silica (SiO_2)	13·50	19·70	20·08	15·70	17·51	17·12	18·00	16·53	16·00
Ferric oxide (Fe_2O_3)	3·84	2·56	3·20	3·20	3·20	3·52	3·20	3·20	2·56
Alumina (Al_2O_3)	6·56	5·44	7·36	5·60	6·40	6·88	6·68	7·60	7·04
Lime (CaO)	39·96	37·80	35·42	39·42	37·53	37·15	36·29	36·72	36·72
Magnesia (MgO)	0·12	0·13	0·11	0·11	0·14	1·52	0·15	1·50	1·44
Sulphur trioxide (SO_3)	4·08	3·94	4·08	4·22	4·62	5·03	5·57	4·76	5·44
Loss on ignition	31·40	30·20	29·60	31·00	30·10	28·40	29·20	29·40	30·50
Total	99·46	99·77	99·85	99·25	99·50	99·62	99·09	99·71	99·70

1. South chamber 1st foot
2. " " 2nd "
3. " " 3rd "
4. " " 4th "
5. " " 5th "
6. South chamber 6th foot
7. " " 7th "
8. East tunnel 1 to 4 feet
9. " " 5 to 7 "

Unlike the limestone used in Eastern Canada for making natural cement, this rock, in the main, is very low in magnesia.

Leary's Siding

Near Leary's siding on the Canadian National railway, 1½ miles west of Babcock, other outcrops of the argillaceous Cretaceous limestone are reported as occurring in the valley of the Boyne river. One of these is in section 13, township 6, range 8, west of the Principal meridian, 300 yards west of Leary's, and others are farther west in section 15 of the same township and range. Wells[1] gives the following analyses of samples from these deposits:—

	1	2	3	4	5
	Per cent	Per cent	Per cent	Per cent	Per cent
Silica	32·50	13·83	27·02	20·67	18·77
Ferric oxide	1·09	2·59	4·00	3·14 }	16·28
Alumina	14·80	5·99	9·32	8·70 }	
Lime (CaO)	40·00	40·97	35·28	37·00	44·47
Magnesia (MgO)	Tr.	0·38	0·50	0·50	Tr.
Alkalis	Tr.	0·66	1·38	1·20	....
Sulphur trioxide	0·40	0·88	0·82	0·49	3·26
Organic matter	11·00	7·36	0·41	0·63	....
Moisture	....	3·32	1·50	2·30	....
Carbon dioxide } Combined water }	Not det.	24·02	19·77	25·37	17·22
Total	99·79	100·00	100·00	100·00	100·00

1. Sandy calcareous shale, from Leary's pit No. 2, sec. 13, tp. 6, rg. 8 W.
2. Leary's cement rock deposit underlying C.N.R. track, sec. 15, tp. 6, rg. 8 W.
3. Leary's cement rock deposit outcropping on banks of Boyne river, beneath No. 2.
4. Same location as No. 1.
5. Yellow calcareous shale from a cliff in the Boyne valley near Leary's siding, C.N.R., in sec. 15, tp. 6, rg. 8 W.

[1] Wells, J. W.: "Preliminary Report on the Raw Materials, Manufacture and Uses of Hydraulic Cements in Manitoba", Mines Branch, Dept. of Mines, Canada, Rept. No. 9, p. 35 (1905).

Deerwood

A 20-foot band of thinly bedded, dark grey, faintly mottled, argillaceous limestone enclosed in Cretaceous shale is exposed at the base of a hill (section 16, township 5, range 7, west of the Principal meridian) at Arnold siding on the Canadian National railway, 2 miles east of Deerwood, and was used by Manitoba Union Mining Company some 40 years ago to make natural cement. The limestone was obtained by tunnelling into the hillside and was brought out to the kiln in wheelbarrows. The plant consisted of a vertical kiln and the necessary grinding equipment.

Other outcrops of similar argillaceous limestone were seen in the neighbourhood. The following analyses taken from Wells[1] report show the composition of the Cretaceous limestone in this vicinity.

—	1	2	3
	Per cent	Per cent	Per cent
Silica	18·13	20·10	16·16
Ferric oxide	2·93	3·41	2·45
Alumina	7·40	8·20	6·60
Calcium oxide	34·44	33·76	35·11
Magnesium oxide	0·61	0·78	Tr.
Alkalis	1·47	1·23	1·72
Sulphur trioxide	1·72	0·64	3·80
Carbon dioxide	26·62	17·21	26·04
Combined water and Organic matter	....	12·65	5·61
Moisture	1·97	1·84	2·11
Undetermined	4·71	....	....
Total	100·00	99·82	99·60

1. Calcareous shale, Arnold Cement Works.
2. Dark mottled shale with patches of soft chalk, from Pilling's cement property, Arnold.
3. Average sample of dark shale, Pilling's cement property, Arnold.

Windygates

Limestone beds characteristic of the upper part of the Cretaceous are reported to outcrop in the valley of the Pembina river in township 1, range 6, west of the Principal meridian, not far from the International Boundary. Concerning this locality Wells[2] states:

> Two test pits and several borings sunk by the Manitoba Cement Company showed 40 feet of horizontally bedded, fine-grained, uniform, slate-grey coloured shale free from sand but mottled by numerous white specks, the remains of foraminifera. A bed of cream-coloured, soft, dry chalk is in place at the top of the cliff and extends about 100 feet with an average thickness of 12 feet.

An analysis of the siliceous chalk as given by Wells[3] is as follows:—

	Per cent
Moisture	1·04
Insoluble matter	13·10
Oxides of iron and aluminium	10·09
Lime (CaO)	41·49
Magnesia (MgO)	0·63
Sulphur trioxide (SO_3)	0·15
Undetermined (CO_2 and organic matter)	33·50
Total	100·00

[1] Wells, J. W.: "Preliminary Report on the Raw Materials, Manufacture and Uses of Hydraulic Cements in Manitoba", Mines Branch, Dept. of Mines, Canada, Rept. No. 9, pp. 23 and 35 (1905).

[2] Wells, J. W.: "Preliminary Report on the Industrial Value of the Clays and Shales of Manitoba"; Mines Branch, Dept. of Mines, Canada, Rept. No. 8, p. 27 (1905).

[3] Wells, J. W.: "Preliminary Report on the Limestones and the Lime Industry of Manitoba"; Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 63 (1905).

Assiniboine River

Wells[1] reports a grey, rather soft Cretaceous limestone containing numerous white shells overlying a reddish, compact, soft, coarse-grained limestone in the banks of Assiniboine river in section 36, township 8, range 11, west of the Principal meridian. Each variety is about 2 feet thick and is seen at several places along the river banks in the vicinity. He gives the following analyses of each type:

	1	2
	Per cent	Per cent
Moisture	0·20	0·30
Insoluble matter	1·00	1·24
Oxides of iron and aluminium	0·72	1·16
Lime (CaO)	53·13	53·09
Magnesia (MgO)	1·27	1·07
Sulphur trioxide (SO_3)	0·13	0·14
Undetermined (CO_2 and organic)	43·55	43·00
Total	100·00	100·00

1. Grey limestone.
2. Red coarse-grained limestone.

This is the purest of any Cretaceous limestone sampled within the province.

Morden

Argillaceous limestone of Cretaceous age is reported to have been encountered in excavations in the town of Morden.

Analysis of Southern Manitoba Limestone

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
8........	16·56	3·21	7·42	n.d.	67·12	2·08	96·39	2·04	37·71	1·02	37 : 1

8. Babcock. Cretaceous limestone exposed at entrance to tunnel on property formerly worked by Commercial Cement Co.

Winnipeg District

Quarries and outcrops within 12 miles of the centre of the city are included under this heading. No quarries are operated within this area at present, but in past years the Stony Mountain dolomite, which underlies the entire area, was extensively quarried at Little Stony Mountain and a short distance north thereof for the production of crushed stone, rubble, building stone, and curbstones. Beneath the city the depth of soil is great and the only places where it is known to be sufficiently thin to permit quarrying are to the west and northwest.

St. James Municipality

In this municipality, which is directly west of Winnipeg, test pits have been sunk to the underlying limestone in several places in search of a suitable material for road metal. Most of them were dug near Victoria avenue near the western boundary of the municipality and showed depths of soil ranging from 8 to 10 feet in that locality. It is reported that much of the limestone encountered is shaly and not suitable for use as crushed stone. The only sample from this district that was seen by the writer consisted of a number of pieces of fine-

[1] Wells, J. W.: Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 63 (1905).

grained, buff, rather argillaceous dolomite. An analysis of this sample is shown as No. 9 in the table on page 33. Analyses of samples of individual limestone beds encountered in the test pits and supplied through the courtesy of the Municipal Engineer's office are as follows:—

	Per cent	Per cent
Insoluble material	2·9	1·7
Oxides of iron and alumina	2·3	1·4
Calcium carbonate	52·5	55·2
Magnesium carbonate	41·1	42·2
Total	98·8	100·5

These analyses are apparently of the better grade of limestone found in the test pits. They are similar to the analyses of some of the more impure beds of the Stony Mountain formation as exposed in the quarries at Little Stony Mountain to the north.

Little Stony Mountain

This is a slightly elevated area on the prairie, 6 miles northwest of the centre of Winnipeg, where the dolomite beds of the Stony Mountain formation are close to the surface. Formerly, a large quarry was worked here by the City of Winnipeg to obtain crushed stone, rubble, and curbstone, and a smaller quarry, known as the Egan quarry, was worked immediately south of it to obtain crushed stone and rubble. They are separated only by a road allowance and essentially the same strata are exposed in each. As quarrying proceeded away from the centre of the raised area where the original openings were made, the depth of soil increased and the thickness of desirable stone decreased and quarrying had to be discontinued. This is one of the few places, however, where the Stony Mountain formation is exposed and the stone was examined and sampled in order to get further data on the characteristics of the dolomite.

The City quarry covers a large area in the southwest quarter of section 34, township 11, range 2, east of the Principal meridian. In many places the working faces are largely hidden by soil that has caved in, but the following sections of strata are exposed at the north and south ends of the quarry, which are about 300 yards apart:—

South end of quarry:

6 to 10 feet —Soil.

6 feet —Pale, buff, faintly mottled, hard dolomite in beds 6 inches to 2 feet thick. Small cavities are numerous in all the beds and in places the dolomite is coloured red and deep purple. Sample 10 represents this stone.

10 to 16 inches—Soft red argillaceous bed at the quarry floor. Sample 10A.

North end of quarry:

7 to 10 feet —Gravelly soil.

26 inches —Light brown, fine-grained dolomite mottled with yellow. It is usually split into several beds but in places is one bed.

15 inches —Cavernous, mottled yellow and brown dolomite, usually in one bed.

14 inches —Light buff dolomite with a few cavities and only very faintly mottled.

39 inches —Mottled pinkish yellow dolomite containing many cavities and usually in one bed.

Sample 10B represents this 8 feet of dolomite.

Beneath these beds, as shown in a small water-filled excavation in the floor of the quarry, is 3 feet of soft, yellow, red, and greenish mottled argillaceous dolomite from which no sample was obtained.

Beds similar to those in the north face of the City quarry are visible in the smaller quarry immediately to the south in the northwest quarter of section 27 in the same township and range.

Five miles north and 2 miles west of the Arborg branch of the Canadian Pacific railway is the abandoned *Airdale* quarry that was worked in the dolomite of the Stony Mountain formation to obtain crushed stone and rubble. The quarry is neaı the centre of section 28, township 12, range 2, east of the Principal meridian. It is of irregular shape, approximately 700 feet square, and is opened on the crest of a low dome. The section of strata exposed is as follows:—

4 to 5 feet—Stony soil.
2 feet —Light brown, fine-grained dolomite usually in two beds but in places tightly joined. Many cavities are present in the top half.
10 inches —Fine-grained, red, rubbly, somewhat argillaceous dolomite similar in appearance to the red bed in the north face of the City quarry at Little Stony Mountain.
4 feet —Fine-grained, light brown, cavernous dolomite in beds averaging 10 inches in thickness.

Sample 11 is representative of the 6 feet of beds, exclusive of the red bed.

Analyses of Limestones in the Winnipeg District

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
9.......	3·24	0·53	1·91	n.d.	53·36	40·82	99·86	Nil	29·93	19·52	1·53 : 1
10.......	0·44	0·35	0·29	0·02	55·87	43·48	100·45	Nil	31·30	20·79	1·50 : 1
10A.....	1·64	0·56	1·26	0·04	53·96	42·85	100·31	Nil	30·24	20·49	1·48 : 1
10B.....	2·92	0·50	0·94	0·04	53·98	41·56	99·94	Nil	30·25	19·87	1·52 : 1
11.......	2·28	0·48	0·76	0·04	54·32	42·37	100·25	Nil	30·44	20·26	1·50 : 1

9.	St. James municipality.	Dolomite of the Stony Mountain formation from test pit on Victoria ave., near west boundary of the municipality.
10.	Little Stony Mountain.	Top 6 feet of Stony Mountain formation in old quarry formerly operated by the City of Winnipeg.
10A.	" " "	Red bed 10 to 16 inches thick in the quarry floor.
10B.	" " "	Eight feet of dolomite beneath the red bed.
11.	Airdale.	Seven feet of dolomite of Stony Mountain formation in old quarry on sec. 28, tp. 12, rg. 2 E.

Stony Mountain

Stony mountain is a hill of shale capped by 20 feet of dolomite that rises 50 or 60 feet above the surrounding flat prairie country. It is roughly a mile across on top and is intersected by a valley that cuts through the dolomite cap in a northwesterly direction making it virtually two hills. On the southwestern side is the village of Stony Mountain and the Federal penitentiary of the same name.

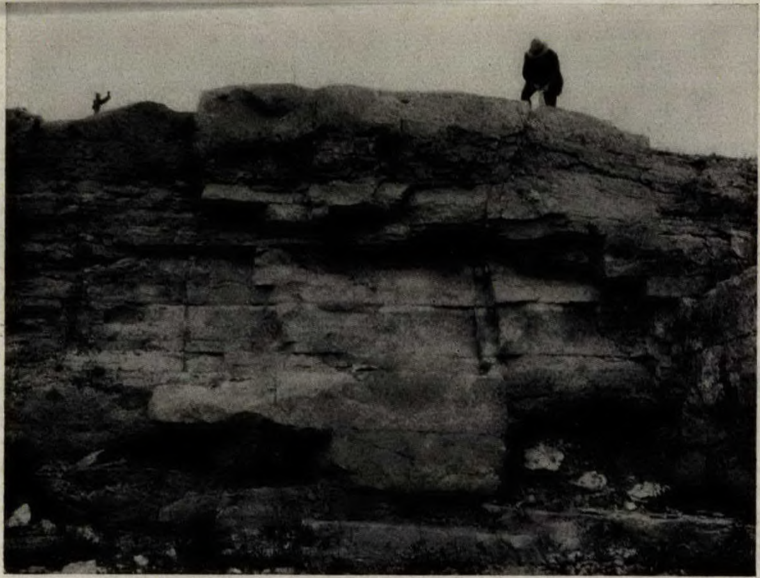
The north and west sides of Stony mountain are very steep and on them the dolomite and the underlying shale are exposed. The south and east slopes are gradual and no rock is visible. The City of Winnipeg operates a large quarry in the dolomite cap on the northwest side of Stony mountain for the production of crushed stone and asphalt filler. Formerly, other large quarries were worked for the production of building stone, curbstone, rubble, and stone for making lime and crushed stone.

The dolomite and shale are of Ordovician age. They have been grouped as a unit and named the Stony Mountain formation from this their best natural exposure in the province. The formation is apparently of limited extent as it has not been recognized to the north, and is seen to the south only in two other places between Stony Mountain and Winnipeg. It is encountered in deep excavations made for buildings in Winnipeg and apparently underlies the entire city.

Quarry Operated by the City of Winnipeg. This quarry (Plate IIIA, page 34) is in the southern part of the southwest quarter of section 14, township 13, range 2, east of the Principal meridian, and recently the large quarry to the

PLATE III

A. Quarry operated by the City of Winnipeg in Stony Mountain formation, Stony Mountain, Man.



B. Stony Mountain dolomite in the quarry of the City of Winnipeg, Stony Mountain, Man.

south which is separated only by a road allowance has been acquired, making a total area of quarry land of 100 acres, over much of which the dolomite has been removed. The original quarry is roughly triangular in shape with the southern face extending 500 yards easterly from the edge of the escarpment, the base along the west side being 300 yards long, and the north side converging towards the south side until they almost meet at the eastern extremity of the quarry. A maximum thickness of 20 feet of the dolomite is visible at one place in the quarry face, but the present working face does not exceed 14 feet, because the top beds have been removed in many places by glaciation. The strata exhibit a gentle folding, but there is no pronounced general dip in any direction except at the eastern end of the quarry where the dip is west. The succession of beds differs somewhat along the quarry face, but the following may be taken as an average of the south face. The north face is lower and the overburden is heavy.

1 to 10 feet—Soil. The greater depth is along the northern face of the quarry and in hollows in the rock. The average depth is less than 2 feet.

10 feet—Hard, very fine-grained, light brown, faintly mottled dolomite that weathers nearly white. Bedding is irregular and mostly thin, with some beds being 11 inches thick. The top beds contain many cavities. Down 6 feet from the top is a bed 10 inches to 2 feet thick of pink and yellow dolomite. This full thickness is seen only near the west end of the face and in most places in the quarry the top 6 feet of strata is missing.

5½ feet—Heavily bedded, light brown, fine-grained dolomite that is mottled with yellow and pink.

4 feet—Distinctly mottled, heavily bedded, pale buff dolomite that is softer and more argillaceous than that above. The mottlings are greenish in colour and the whole 4 feet has a greenish tint.

Beneath the quarry floor, as seen at the crushing plant at the west end of the quarry is

15 feet—Soft, yellow, shaly dolomite in beds up to 1 foot thick but which weathers like a shale.

14 feet—Purple and red shales with thin interbeds of coarse-grained, purple, high-calcium limestone, 2 to 4 inches thick.

Samples taken were as follows: Sample 12, top 10 feet of dolomite; Sample 12A, next 5½ feet of dolomite; Sample 12B, bottom 4 feet of dolomite exposed in the face; Sample 12C, 15 feet of shaly yellow dolomite beneath the quarry floor; Sample 12D, 14 feet of purple and red shale with interbeds of high-calcium limestone from below the shaly dolomite.

Drilling is done with jackhammers and the stone is loaded into 1½-yard, side-dump quarry cars by an electrically operated Northwest shovel mounted on caterpillar treads. The loaded cars are hauled singly by horse over a narrow-gauge track to a low hump, from which they run by gravity to a haulage system consisting of an endless cable to which the cars hook automatically by means of a clutch. At the crushing plant the cars are disengaged automatically. They are dumped from a tipple operated hydraulically and are then automatically attached to the cable and return to the working face where they disengage and are pulled by horse to be loaded. Twelve cars are thus kept in operation. The rope haulage is operated at a speed of 4 miles an hour.

The crushing plant has a capacity of 600 tons a day of stone crushed to ¾-inch and less. The chief product is crushed stone for concrete aggregate and mastic pavements. Asphalt filler is also produced, and material crushed to under ¼-inch is widely shipped for use as tennis court dressing. A spur track from the Arborg branch of the Canadian Pacific railway serves the quarry.

The City has recently acquired the Gunn quarry immediately south of the quarry being worked. This quarry was operated in recent years by the municipality of Rockwood for crushed stone for use on municipal roads. It is in the northern part of the northwest quarter of section 11 of the same township and range as is the City quarry, and has been worked due east for 300 yards from the east edge of Stony mountain. Twelve feet of dolomite is exposed in the face beneath 18 inches of soil. The beds are the same as those in the City quarry proper except that the highest 3 feet of beds seen in the latter are absent. Three samples were obtained from the eastern end of the quarry, which was 300 yards distant from where the samples were taken in the City quarry. Sample 13 represents the top 7 feet of strata; Sample 13A, the next 5 feet; and Sample 13B the impure dolomite comprising the quarry floor. The floor in this quarry is about 4 feet above that in the City quarry. It is proposed to quarry the stone in the road allowance now separating the two quarries and to extend the operations to the Gunn quarry.

On the face of the hill just below the Gunn quarry is an old vertical lime kiln in which rock from the quarry was at one time burned. It is stated that the stone from the top 7 feet of beds yielded a nearly white lime, whereas that from the lower beds was grey. The lime had the reputation of being very strong.

Four hundred yards due east of the Gunn quarry is the Kelly quarry, 250 feet in diameter and 12 feet deep, from which rubble for building purposes and crushed stone was once obtained. The top 7 feet is hard, buff dolomite mottled with purple, yellow, and red. The bottom 5 feet is softer and is mottled with green.

A small shallow quarry in the Stony Mountain dolomite is also operated in connection with Stony Mountain penitentiary to obtain stone for building purposes around the penitentiary.

Analyses of Limestones at Stony Mountain

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
12.......	1·08	0·35	0·37	0·02	54·66	43·21	99·69	Tr.	30·62	20·66	1·48 : 1
12A.....	3·00	0·38	1·10	0·09	53·36	41·81	99·74	Tr.	29·93	19·99	1·49 : 1
12B.....	9·22	0·69	2·63	0·09	50·50	36·62	99·75	Tr.	28·33	17·51	1·62 : 1
12C.....	11·46	1·06	2 88	0·09	48·06	36·35	99·90	0·04	26·93	17·38	1·55 : 1
12D*....	12·68	2·21	3·85	0·10	63·79	14·85	97·48	0·08	35·74	7·10	5 : 1
13.......	1·86	0·52	0·26	0·02	53·79	44·19	100·64	Tr.	30·13	21·13	1·42 : 1
13A.....	2·96	0·66	2·14	0·07	52·63	40·82	99·28	Tr.	29·51	19·52	1·51 : 1
13B.....	10·66	1·07	3·17	0·07	48·54	35·83	99·34	0·04	27·22	17·12	1·58 : 1

* Contains 2·39 per cent of alkalis.

12.	Stony	Mountain.	Top 10 feet in City of Winnipeg quarry.
12A.	"	"	Next 5½ feet of face.
12B.	"	"	Bottom 4 feet of face
12C.	"	"	Fifteen feet of shaly, yellow dolomite beneath the quarry floor.
12D.	"	"	Fourteen feet of purple and red shale below the shaly dolomite.
13.	"	"	Top 7 feet of strata in Gunn quarry recently acquired by the City of Winnipeg.
13A.	"	"	Next 5 feet in same quarry.
13B.	"	"	Four feet of impure dolomite comprising the quarry floor.

Stonewall-Gunton District

Stonewall

Stonewall has long been an important centre for the production of white dolomitic lime and to a lesser extent the quarries of this district have produced building stone, crushed stone, and dolomite for chemical use. Production is obtained from 8 to 12 feet of horizontally bedded Silurian dolomite (Plate IVB, page 37) that caps a low circular mound, nearly a mile in diameter, on which

PLATE IV

A. No. 1 quarry and lime plant of The Winnipeg Supply and Fuel Company, Stonewall, Man.

B. Silurian dolomite in quarry of The Winnipeg Supply and Fuel Company, Stonewall, Man.

the town is built. The boundaries of the town and of the mound nearly coincide, and thus much of the dolomite is unavailable. The mound is an erosion remnant left when the surrounding country was more deeply eroded by glacial action, and consequently the continuation of this particular 8 to 12 feet of strata that yields a white lime will not be found elsewhere in the immediate vicinity, but may possibly be found at some distance northwest.

About 30 years ago as many as five quarries were in operation around the north and east sides of the town of Stonewall, but present operations are carried on by one producer, *The Winnipeg Supply and Fuel Company, Limited,* which owns all of the relatively small amount of quarriable high-grade dolomite remaining on the outskirts of the town. East of Stonewall another company, *Gillis Quarries, Limited,* is also producing lime, but from different strata from those in the town.

Property of The Winnipeg Supply and Fuel Company, Limited, 812 Boyd Building, Winnipeg. This company owns 150 acres of land north and east of the town, including about 15 acres of high-grade dolomite yet unquarried. The present workings are on the north edge of the town. The quarry face is about 1,500 feet long and extends in an arc from Hickey avenue west to Jackson avenue. It is being worked to the north, in which direction its height is gradually lessening and the overburden of soil is increasing. The present face is 7 feet high and the rock is covered by 7 feet of clay soil. In the southeast corner of the quarry, near the junction of Hickey avenue and Lilly street, the greatest thickness of strata is exposed, and although quarrying cannot proceed farther south without encroaching on the town the full section as exposed here is described for purposes of record. It is as follows:

6 feet —Soil.
28 inches—Very fine-grained, creamy white dolomite with some rusty stains, in beds of variable thickness and separated from the stone below by a 2-inch seam of clay. The top bed is polished and striated. Sample 14 was taken from this 28 inches.
18 inches—Faintly mottled, light grey, very fine-grained dolomite in thin broken beds. Sample 14A.
5 feet —Faintly mottled, light grey, very fine-grained dolomite in beds up to 18 inches thick. There are many cavities in this stone. Sample 14B.
4 feet —Faintly mottled, light grey, very fine-grained dolomite in beds up to 2 feet thick. Sample 14C.

These are the beds being worked for stone to make lime. In the floor of the quarry is a pit exposing 33 inches of thinly bedded, rubbly, light grey dolomite, similar in appearance to that above, but it makes a grey lime in contrast to the white lime obtained from the upper beds. It has been quarried for crushed stone, but is not being worked. Sample 14D was taken from this 33 inches.

Another pit in the northeastern part of the quarry near No. 1 lime plant reveals additional strata beneath, as follows:—

14 inches—Rubbly, red, fine-grained dolomite.
3 feet —Very cavernous, grey, fine-grained dolomite that makes grey lime. Sample 14E.
3 feet —Grey, fine-grained dolomite in four beds. Sample 14F.
8 feet —Red, very fine-grained, shaly dolomite.
8 feet —Buff, sandy and shaly dolomite.

In 1944, when the quarry was last visited, this pit had been partly filled in and it was impossible to get a channel sample to determine its suitability as raw material for rock wool.

Until a few years ago two separate quarries with a lime plant at each were worked on this property. Quarry No. 1 and Plant No. 1 (Plate IV A, page 37) were west of, and Quarry No. 2 and Plant No. 2 were east of Hickey avenue. The quarries are now joined and are operated as a unit. Overburden is stripped by an electric shovel equipped with a $\frac{1}{2}$-yard dipper, and is loaded on trucks for disposal in a dump nearby. Jackhammers are used for drilling, and the rock, sized 5 to 8 inches, is loaded by hand on to 1-yard, steel skips set on trucks that are hauled by horse in trains of four over a narrow-gauge tramway to Plant No. 2, where the skips are lifted from the trucks by a derrick and are dumped into the kilns. Plant No. 1 receives its stone by truck. This plant consists of three vertical kilns built of the local stone, and Plant No. 2 consists of two kilns of the same type. Each has a capacity of 18 tons of lime a day when using poplar as fuel. Three kilns were in operation in 1944 and the products shipped were lump lime and crushed lime. A part of the lime was shipped to the plant of Gypsum Lime and Alabastine, Limited, in Winnipeg, to be converted into hydrated lime.

Adjoining Plant No. 2 is a small crushing plant in which stone too small for making lime is crushed and screened for use as flux and for fettling furnace bottoms. The Canadian Pacific railway serves these quarries.

On the east side of the town is the idle quarry formerly operated by Manitoba Quarries, Limited, but now owned by The Winnipeg Supply and Fuel Company, Limited. This quarry is separated only by a roadway from No. 2 quarry. It is 2,000 feet long and averages 400 feet in width. It was operated to obtain dimension stone for heavy construction and also stone for making lime. On the west side adjacent to the roadbed of the former spur track that served the quarry, the following section of strata is exposed:—

3½ feet —Soil.
27 inches—Bed of faintly mottled cream-coloured, fine-grained, porous dolomite containing many cavities and streaked horizontally. The surface is glaciated. Sample 15 was taken from this bed.
27 inches—Bed of dolomite similar in appearance to that above. Sample 15A represents this bed.
43 inches—Bed of faintly mottled, pale buff, porous dolomite with many cavities in the bottom part. Sample 15B was taken from this bed, which was the lowest bed used for making lime. Beneath it and composing the quarry floor is
3 feet —Thinly bedded, cream-coloured, hard and brittle, unmottled dolomite containing some pyrite and showing rust stains on the weathered surface.
14 inches—Rubbly and fine-grained dolomite, below which as seen in a pit is
5½ feet —Cavernous, mottled and streaked dolomite in beds 31 inches, 18 inches, 9 inches, and 9 inches thick.
16 inches—Greenish and reddish shale.
5 feet —Red argillaceous dolomite.

On the opposite side of the quarry, or toward the east, the top beds have been eroded and the quarry face is only 2 to 5 feet high. Immediately adjoining the quarry to the west is a strip of land 300 to 400 feet wide and 2,300 feet long still available for quarrying, where the beds shown in the above section are likely to occur beneath relatively light overburden. Two partly dismantled vertical draw-kilns and the ruins of a number of old pot kilns remain in this quarry.

Property of Gillis Quarries, Limited, Richard and Spruce Sts., Winnipeg. This company has a quarry and lime kiln, 5 miles by road northeast of Stonewall, on the southeast quarter of section 4, township 14, range 2, east of the Principal meridian, where a pure dolomite is available in flat beds beneath a light covering of soil. The quarry is 50 feet in diameter and 15 feet deep. The top bed is 10 to 12 inches thick and contains numerous cavities. The beds in the rest of the quarry face seldom exceed 3 inches. All the dolomite is pale buff in colour, very fine-grained, and is devoid of shale partings, but a film of greenish clay occurs between some of the upper beds. Sample 16 is representative of the 15 feet of strata.

The quarry is dry and requires no pumping in wet weather. Drilling is done with a jackhammer and the stone is loaded by hand into a skip that is raised by a stiff-leg derrick and dumped directly into the lime kiln that stands

PLATE V

A. Silurian dolomite in abandoned quarry at Gunton, Man.

B. Cliff of Lower Mottled limestone along the eastern shore of Hecla island, Lake Winnipeg.

at the edge of the quarry. The kiln is built of blocks obtained from the top 12-inch bed and is lined with firebrick. It has a capacity of 15 tons of lime a day with wood fuel. The lime produced is grey, but in common with most other grey limes it becomes almost white on being slaked. When visited in June 1944 the quarry and kiln were inactive.

Gunton

Just south of Gunton and adjacent to the Canadian Pacific railway are three large abandoned quarries in flat-lying Silurian dolomite (Plate V A, page 40) that formerly supplied rock for rubble, crushed stone, and lime. Outcrops near the quarries show that much similar dolomite is still readily available in the district. Two of these quarries are on opposite sides of the railway where it passes through section 28, township 15, range 2, east, 1 mile south of the village. The one on the east is known as the Gunn quarry and that on the west as the Williams quarry. Both quarries supplied building rubble and crushed stone, but have been idle since 1914. The following section of strata is exposed in the Gunn quarry, which extends for 600 feet north and south and is 200 feet wide:

2 feet to 3 feet	—Soil.
1 foot 9 inches	—Yellow, fine-grained dolomite in thin broken beds, of which the upper one is glaciated.
4 feet 2 inches	—Faintly mottled, very fine-grained, cavernous and porous, yellow dolomite in beds 2 to 6 inches thick with rough, rubbly parting planes.
3 feet	—Similar thin-bedded dolomite, most of which is not mottled. Sample 17 is representative of the top 9 feet of strata.
1 foot	—Rubbly, argillaceous, red dolomite that weathers buff. This bed is a horizon marker throughout the district.
4 feet 10 inches	—Faintly mottled, yellowish dolomite in beds 3 to 10 inches thick with rough uneven bedding planes and containing numerous small cavities.
2 feet 2 inches	—Single bed of yellow mottled dolomite. Sample 17A was taken from the 7 feet of beds below the red argillaceous bed.
9 inches	—Fine-grained, unmottled buff bed.
1 foot 1 inch	—Yellowish and reddish mottled, fine-grained bed.
9 inches	—Unmottled, yellow and reddish bed.
5 feet	—Mottled and unmottled, pink and yellow, fine-grained dolomite in beds from 4 inches to over 2 feet in thickness, and more evenly bedded than the stone above. Sample 17B is representative of this lower 7 feet 7 inches of beds.

In the crusher pit 18 feet of soft, shaly, fine-grained dolomite is exposed. Some of this is greenish, but most is of a mottled purple shade. Sample 17C was taken from this shaly dolomite but is not a channel sample. Similar beds are exposed in the Williams quarry on the opposite side of the track. This quarry is 900 feet long and 250 feet wide.

North of these two quarries and on the west side of the track is the third quarry, known locally as the Lime Quarry, where lime was made in set kilns now in ruins. This quarry is 400 feet long north and south and 200 feet wide. The same series of beds as in the other two quarries is exposed, with the exception that some of the top beds have been removed by glaciation. At the north end of the quarry they have been removed down to the red argillaceous bed referred to previously as a horizon marker, but at the south end there is nearly 3 feet of yellow dolomite above the red argillaceous bed. To check the uniformity of the rock, samples were taken in this quarry from the same series of strata as were the samples in the Gunn quarry. Sample 18 is from the 3 feet of beds above the red bed; Sample 18A from the 7 feet of beds immediately beneath the red bed, and Sample 18B from the 7 feet 6 inches of strata below that again. As the analyses show, the chemical composition of the same series of beds does not change appreciably within a distance of ½ mile.

Similar dolomite is exposed 2 miles south of these quarries.

Analyses of Stonewall and Gunton Limestones

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
14.......	0·24	0·32	0·18	0·02	54·96	44·86	100·58	Nil	30·79	21·45	1·43 : 1
14A.....	0·50	0·21	0·38	0·02	54·61	44·36	100·08	Nil	30·59	21·21	1·44 : 1
14B.....	0·28	0·22	0·08	0·02	54·82	44·65	100·07	Nil	30·71	21·35	1·43 : 1
14C.....	0·20	0·27	0·11	0·02	55·21	44·65	100·46	Nil	30·93	21·35	1·40 : 1
14D.....	0·53	0·26	0·08	0·04	55·39	43·96	100·26	Nil	31·04	21·02	1·47 : 1
14E.....	0·14	0·33	0·10	0·15	55·12	44·69	100·53	Nil	30·95	21·37	1·45 : 1
14F......	2·10	0·41	0·37	0·13	54·07	43·29	100·37	Nil	30·35	20·70	1·46 : 1
15.......	0·22	0·26	0·11	0·02	55·18	44·71	100·50	Tr.	30·91	21·38	1·44 : 1
15A.....	0·20	0·20	0·07	0·02	55·48	44·57	100·54	Nil	31·08	21·32	1·46 : 1
15B.....	0·16	0·26	0·07	0·02	55·45	44·37	100·33	Nil	31·06	21·21	1·46 : 1
16.......	0·26	0·28	0·10	0·02	55·25	44·19	100·10	Nil	30·96	21·13	1·46 : 1
17.......	1·00	0·36	0·30	0·04	54·73	44·48	100·91	Nil	30·66	21·27	1·44 : 1
17A.....	1·30	0·41	0·26	0·02	54·75	44·00	100·74	Nil	30·67	21·04	1·46 : 1
17B.....	2·38	0·38	0·73	0·07	52·95	43·27	99·68	Nil	29·69	20·69	1·43 : 1
17C.....	11·84	1·28	3·61	0·11	45·11	37·68	99·63	Tr.	25·32	18·02	1·40 : 1
18.......	1·02	0·30	0·11	0·02	55·21	44·01	100·67	Nil	30·93	21·04	1·47 : 1
18A.....	1·02	0·33	0·18	0·02	54·90	44·21	100·66	Nil	30·75	21·14	1·45 : 1
18B.....	3·18	0·47	1·08	0·02	52·52	43·52	100·79	Tr.	29·42	20·81	1·41 : 1

14.	Stonewall.	Top 28 inches of creamy white dolomite in quarry operated by The Winnipeg Supply and Fuel Company, Limited.
14A.	"	Next 18 inches of light grey dolomite in same quarry.
14B.	"	Next 5 feet in same quarry.
14C.	"	Next 4 feet in same quarry.
14D.	"	Thirty-three inches of rubbly, light grey dolomite in floor of quarry.
14E.	"	Three feet of cavernous, grey dolomite in pit.
14F.	"	Next 3 feet of grey dolomite in the pit.
15.	"	Top 27 inches of cream-coloured dolomite in old quarry formerly worked by Manitoba Quarries, Limited.
15A.	"	Next 27 inches of dolomite in the same quarry.
15B.	"	Next 43 inches of dolomite in the same quarry.
16.	"	Fifteen feet of dolomite in quarry operated by Gillis Quarries, Limited, 5 miles northeast of the town.
17.	Gunton.	Top 9 feet of dolomite in the Gunn quarry.
17A.	"	Seven feet of strata exposed in the face of the same quarry below the red bed.
17B.	"	Bottom 7 feet 7 inches of strata in the same quarry.
17C.	"	Shaly dolomite exposed in pit 18 feet deep in the floor of the quarry.
18.	"	Three feet of strata above the red bed in the Lime Quarry.
18A.	"	Seven feet 6 inches of strata below the red bed in the Lime Quarry.
18B.	"	Bottom 7 feet 6 inches of strata exposed in the quarry.

Lake Winnipeg

Lake Winnipeg, throughout its length of 260 miles, lies along the contact between the Ordovician and Precambrian rocks of Manitoba. The eastern shore, from the Winnipeg river northward, is composed of Precambrian rocks, chiefly granites, granite-gneisses, and schists, in which no limestone is known to occur, but the islands and the western shore are underlain by horizontally bedded sandstones, shales, and limestones of Ordovician age. The limestones are commonly exposed in cliffs and include the Lower Mottled, Cat Head, and Upper Mottled formations. Where exposed on Lake Winnipeg these limestones are relatively siliceous and contain from 7 to 36 per cent of magnesium carbonate, the higher content being found only in the Cat Head formation.

No quarries have been operated in the limestones along the shores of Lake Winnipeg in recent years, but 25 years ago a large quarry in the Lower Mottled limestone on Heclâ island was worked for the production of rubble for shipment to Winnipeg, and lime was at one time made from this formation at Hecla village and at Grindstone point.

Scanterbury

The most southerly exposure known of the Lower Mottled limestone occurs at Scanterbury at the south end of the lake. Here, in the bank of Brokenhead river, just above the railway bridge on the Victoria Beach–Pine Falls branch of the Canadian National railway, is a small outcrop of grey, impure, thinly bedded limestone mottled with yellow markings and containing much pyrite. Sample 19 was taken from the few beds exposed. Thinly bedded limestone of the same character is reported to be exposed in a small pit near the shore of Lake Winnipeg, due north of the village of Scanterbury.

Elk Island

Dowling[1] states that 12 feet of Lower Mottled limestone is exposed in a low cliff on the southwest end of Elk island which is just north of Victoria Beach. The following analysis is of a sample taken from this outcrop by F. D. Shepherd of the Manitoba Mines Branch and kindly supplied by personal communication:—

	Per cent
Insoluble	10·70
Oxides of iron and alumina	5·30
Calcium oxide	42·27
Magnesium oxide	3·14

Hecla Island

Hecla island, or Big island, is 16 miles long and 4 miles wide and lies in the southern part of the lake. The entire island is probably underlain by the Lower Mottled limestone, but most of the outcrops are in the northern part, where the limestone forms cliffs along the northern and eastern shores (Plate V B, page 40). On the northern tip of the island the underlying shales and sandstones are exposed, and thus the limestone seen comprises the lower part of the Lower Mottled formation. It is all rather siliceous and argillaceous, particularly the lowest beds, and because of the mottlings of dolomitic material it has a content of 8 to 12 per cent of magnesium carbonate. In appearance it resembles the Tyndall limestone (Upper Mottled formation), but the colouring is not so attractive and the bedding is much thinner. As at Tyndall, the upper beds have been weathered to a lighter colour than those beneath and where the rock has been long exposed the magnesian mottlings have weathered more rapidly than the matrix (Plate VI B, page 44). Thin seams of sand are present between some of the beds.

A good section of the limestone is exposed in a quarry that was worked for rubble by *Lake Winnipeg Shipping Company* on the northeastern tip of the island. The quarry is in section 28, township 25, range 6, east of the Principal meridian. The excavation is 75 feet wide, 15 feet deep, and parallels the shore in a southeasterly direction for more than 300 yards. The floor of the quarry is only slightly above the level of the lake. The beds are 3 to 8 inches thick and dip southeast at an angle of 2 or 3 degrees. Overburden of gravelly soil supporting a dense growth of poplar is 2 feet deep near the lake and 5 feet deep farther inland. The section of rock exposed (Plate VI A, page 44) is as follows:—

2 feet—Thinly bedded, drab, mottled limestone, all badly weathered and pitted owing to the disintegration of the material composing the mottlings.

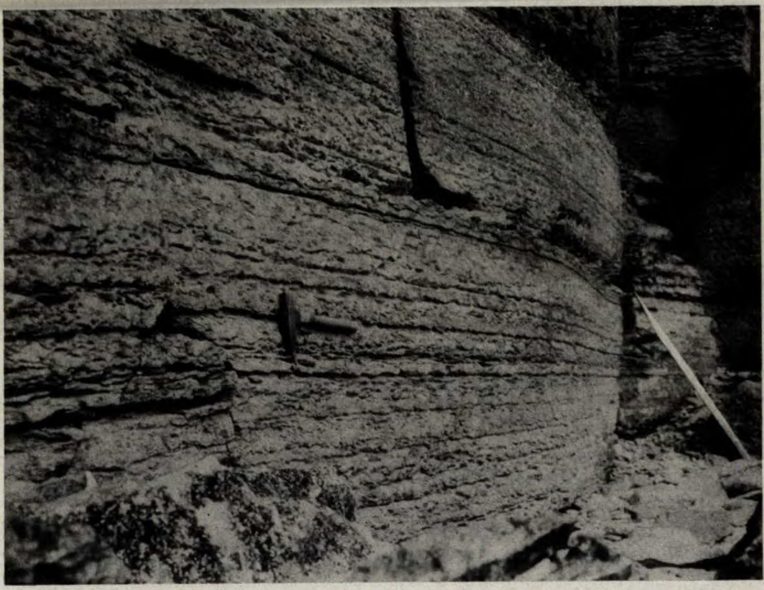
5 feet—Drab limestone with brownish grey mottlings, in beds up to 8 inches thick, some of which are separated by seams of loose sand.

5 feet—Somewhat shaly limestone of a bluish grey colour with greenish brown mottlings and containing some nodules of chert. Along joint planes the stone is drab-coloured for a short distance on either side of the joint. A seam of sand occurs near the top of this part of the section.

[1] Dowling, D. B.: Geol. Surv., Canada, Ann. Rept., vol. XI, p. 63F.

PLATE VI

A. Lower Mottled limestone in abandoned quarry on the northeastern tip of Hecla island, Lake Winnipeg.



B. Differential weathering in Lower Mottled limestone on Hecla island, Lake Winnipeg. The magnesian component stands out in relief.

3 feet—Unevenly bedded, bluish grey mottled limestone, with sand and a few chert nodules disseminated through it.

Pyrite is fairly abundant in this limestone and much of it has weathered to limonite, especially along joint and bedding planes in the top 12 feet.

Three samples were taken; Sample 20 from the top 7 feet; Sample 20A from the next 5 feet; and Sample 20B from the bottom 3 feet. As the analyses show, the limestone becomes progressively more impure at depth. Operations ceased in 1917, prior to which the stone was shipped on scows to Winnipeg for use chiefly as rubble.

On the north tip of Hecla island, west of Gull harbour, is a 30-foot cliff rising out of the lake, of which the top 15 feet is sandy and shaly mottled limestone containing a few nodules of chert, and the lower 15 feet is sandy shale and sandstone.

Cliffs of Lower Mottled limestone extend along the east side of Hecla island at intervals from Gull harbour to 1½ miles south of Hecla village. In places these cliffs rise to a height of 20 feet. Just south of the dock at Hecla village the cliff is 13 feet high. The top 10 feet of the limestone is drab in colour, with mottlings of brown, and the bottom 3 feet is bluish grey with greenish brown mottlings. The beds rarely exceed 3 inches in thickness and lie horizontally. Many of them contain a few nodules of chert. Seams of yellow sand occur between some of the beds. Sample 21 is representative of the top 10 feet and Sample 21A of the bottom 3 feet.

A number of years ago lime was made from the upper beds of the limestone at Hecla village.

Grindstone Point

Impure, thin-bedded and cherty Lower Mottled limestone lying on top of sandstone is exposed in a cliff at Grindstone point and for some distance south along the lake shore. It appears similar to the lowest beds seen on Hecla island, but is even more sandy and otherwise impure. On the southern side of the point the ruins of two pot kilns show that lime was at one time made from this limestone.

Punk Island

Thin-bedded, cherty, mottled, drab limestone of the Lower Mottled formation forms a low cliff on the shore of Punk island. An analysis of a sample of this stone as reported by Wells[1] is as follows:—

	Per cent
Moisture	0·19
Insoluble	10·62
Alumina and iron oxides	1·90
Lime carbonate	72·57
Magnesium carbonate	14·36
Sulphur trioxide	0·24
Total	99·88

Bull Head

Cliffs of Lower Mottled limestone and the underlying Winnipeg sandstone extend along the west shore of Lake Winnipeg from south of Bull head to Whiteway point, and in places rise to a height of 50 feet. The greater part of these cliffs consists of sandstone, but on the south side of Bull head the limestone has a thickness of 17 feet. It is thin-bedded, mottled, drab in colour, and sandy. Sample 22 was taken from this exposure.

[1] Wells, J. W.: Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 53 (1905).

Whiteway Point and Adjacent Islands

Low cliffs of Lower Mottled limestone occur along the shore west of Whiteway point; on the north shore of Snake island a short distance west; and on Black Bear island. The greatest thickness of limestone observed is at Whiteway point where there is a 12-foot cliff along the north side. All the limestone is thin-bedded and in places contains some chert, but the very sandy beds that immediately overlie the sandstone were not observed in these cliffs north of the narrows. The analyses of samples taken in this area by Wells[1] are as follows:—

—	1	2	3
	Per cent	Per cent	Per cent
Moisture	0·15	0·11	0·11
Insoluble	7·00	10·00	9·04
Alumina and iron oxides	1·68	1·70	1·70
Lime carbonate	82·23	75·97	77·61
Magnesium carbonate	8·99	11·48	10·46
Sulphur trioxide	0·09	0·09	0·09
Total	100·14	99·35	99·01

1. Whiteway point (Dog Head).
2. North end of Snake island.
3. Black Bear island.

Jack Head Island

Wells[2] gives the following analysis of 15 feet of Lower Mottled limestone exposed on Jack Head island, a very small island that was not visited by the present writer.

	Per cent
Moisture	0·12
Insoluble	2·15
Alumina and iron oxides	0·80
Lime carbonate	74·52
Magnesium carbonate	22·00
Sulphur trioxide	0·21
Total	99·80

This analysis shows the limestone to be of much greater purity and to have a much higher content of magnesium carbonate than any of the other outcrops of Lower Mottled limestone sampled along the shores of Lake Winnipeg. These beds are apparently in the upper part of the formation.

Cat Head

Cat head is the type locality for the Cat Head limestone formation, which is a cherty, dolomitic, unmottled limestone about 70 feet thick that occurs between the Lower and Upper Mottled formations. Outcrops of Cat Head limestone are few and this is the only place in connection with the present report where the Cat Head formation was examined and sampled. The section exposed on Cat head and westward along the headland towards Lynx bay and eastward to McBeth point is about 50 feet thick. The best section is at Cat head, where 45 feet is exposed. As seen here the Cat Head formation

[1] Wells, J. W.: Mines Branch, Dept. of Mines, Canada, Rept. No. 7, p. 53 (1905).
[2] Wells, J. W.: Op. cit., p. 53.

is a soft, fine-grained, yellow dolomitic limestone in thin, broken beds thickly studded with chert. In the lower half of the cliff the beds are particularly thin and broken and are full of chert. In the upper half the beds appear thicker owing to their tendency to cohere, and the chert occurs in zones, leaving some of the limestone relatively chert-free. Sample 23 was taken from as many beds of the cliff as could be reached, but only a few of the small chert nodules were included.

At Lynx bay the cliff of Cat Head limestone is about 25 feet high and the chert is noticeably in zones. Some of the chert nodules are very large.

At McBeth point, 12 feet of the cherty Cat Head limestone is exposed.

Exposures of Ordovician limestones, chiefly the Upper Mottled limestone, are reported by Tyrrell and Dowling[1] to occur on many of the headlands along the western shore of Lake Winnipeg north of Cat head. They are far removed from present transportation facilities, however, and were not examined in connection with the present report. The following brief summaries of information concerning them are taken from the above-mentioned report.

Clark point.	Fourteen feet of impure and shaly Upper Mottled limestone.
Carscallen point.	Fourteen feet of soft shaly Upper Mottled limestone.
Schiel point.	Six feet of yellow Upper Mottled limestone.
Dancing point.	Four and one-half feet of dolomitic Upper Mottled limestone.
Wicked point.	Thirteen feet of yellowish, cherty, mottled limestone. Probably the top of the Upper Mottled formation.
Selkirk island.	Twelve feet of hard, dolomitic, mottled limestone of the Upper Mottled formation.
Robinson point.	Twenty feet of Upper Mottled limestone.
Mouth of Sturgeon-gill river.	Thirty-two feet of dolomitic and argillaceous limestone of the Upper Mottled formation.
Howell point.	Twenty feet of cherty, dolomitic and argillaceous limestone of the Upper Mottled formation.

Two and one-half miles up the Saskatchewan river, from where it empties into Lake Winnipeg, Silurian dolomite is exposed along the Grand Rapids gorge. Kindle[2] terms this "the best section of the Silurian which is known in Manitoba," and gives the following measured section as combining all the beds exposed in the upper and lower part of the rapids.

	Thickness in feet
Hard light grey irregularly bedded dolomite (summit near tramway)	2
Buff dolomite (in tramway cuts) and covered	35 ±
Grey to pale buff thin-bedded, fine-textured dolomite, moderately hard and evenly bedded, weathering to innumerable small rectangular blocks. These beds are cut by joints 4 to 10 feet apart into rectangular pillars. Fossils scarce	22
Hard light buff dolomite with coarse texture and much more numerous fossils than above	4
Covered	10 ±
Light buff dolomite	3
Whitish thin-bedded dolomite	8
Hard compact buff limestone	1
Brecciated limestone	2
Total	87

[1] Geol. Surv., Canada, Ann. Rept., vol. XI, pt. F, pp. 77-88 (1898).
[2] Kindle, E. M.: Geol. Surv., Canada, Mus. Bull. No. 21, pp. 6 and 7 (1915).

An analysis by Leverin of a sample of dolomite taken by Parks[1] from the upper part of the section is as follows:—

	Per cent
Insoluble	0·30
Ferric oxide	Tr.
Ferrous oxide	0·37
Alumina	0·20
Calcium carbonate	54·20
Magnesium carbonate	43·89
Total	98·96

Parks states that this pure dolomite is overlain by argillaceous limestone and underlain by yellow calcium limestone.

South from the Saskatchewan river it is reported that many low ridges of pure dolomite occur in the woods at 4 to 7 miles west of the lake shore. A sample of fine-grained, cream-coloured dolomite, said to have come from this district, showed on partial analysis 0·4 per cent of insoluble matter and 43·5 per cent of magnesium carbonate. Another sample of yellow dolomite from the same general area contained 11·5 per cent of insoluble matter. Dolomite and magnesian limestone are reported to be exposed at Roche Rouge rapids in the Saskatchewan river, 2½ miles above Grand rapids, and at another rapid just below Cross lake.

Analyses of Limestones on the Shores and Islands of Lake Winnipeg

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
19	7·25	1·06	1·85	0·12	82·35	6·79	99·42	0·46	46·14	3·25	14 : 1
20	8·22	0·90	1·31	0·11	80·36	8·51	99·41	0·05	45·06	4·07	11 : 1
20A	10·88	1·64	1·60	0·22	76·52	8·57	99·43	0·63	42·97	4·10	10 : 1
20B	14·22	1·71	1·79	0·15	72·02	10·03	99·92	0·62	40·35	4·80	8·4 : 1
21	7·14	0·98	2·12	0·11	81·09	8·03	99·47	0·10	45·47	3·84	12 : 1
21A	9·56	1·80	1·68	0·13	73·52	12·42	99·11	0·54	41·24	5·94	7 : 1
22	8·56	1·50	1·60	0·12	74·82	13·29	99·89	0·32	41·92	6·36	6·6 : 1
23	9·74	0·65	1·31	0·09	51·83	35·93	99·55	0·16	28·04	17·18	1·63 : 1

19.	Scanterbury.	Lower Mottled limestone exposed in bank of Brokenhead river.
20.	Hecla island.	Top 7 feet of Lower Mottled limestone in old quarry at northeastern tip of the island.
20A.	" "	Next 5 feet of strata in same quarry.
20B.	" "	Bottom 3 feet of strata in same quarry.
21.	Hecla village.	Top 10 feet in cliff just south of the dock.
21A.	" "	Bottom 3 feet in same cliff.
22.	Bull head.	Seventeen feet of Lower Mottled limestone overlying sandstone.
23.	Cat head.	Forty-five feet of Cat Head limestone exposed in cliff.

Hodgson Branch of the Canadian National Railway

This line traverses country underlain entirely by Silurian dolomite, most of which is of a high degree of purity. Exposures of the dolomite are frequent from Inwood north, and quarries have been opened at various times at Inwood and Poplarfield to obtain stone for making lime, and at Broad Valley and near Hodgson for marble. At present (1944) only the quarry supplying the lime plant at Inwood is active, though small quantities of buff, red, and purple marble for use as terrazzo are obtained from the quarry near Hodgson.

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. No. 388, p. 103 (1916).

PLATE VII

A. Dense-textured Silurian dolomite at Inwood, Manitoba, illustrating the excessive fracturing that occurs on exposure to the weather.

B. Buff and red Silurian dolomite in quarry of Winnitoba Marble Quarries, Hodgson, Man.

Inwood

A short distance southwest of the village and ½ mile west of the railway the dolomite is exposed in a slightly raised area of considerable extent on the northwest quarter of section 34, township 17, range 1, west of the Principal meridian. Two feet of dolomite is exposed in each of three small pits from which stone was taken to supply a nearby pot kiln. The dolomite is thinly bedded, fine-grained, contains cavities throughout, and is cream-coloured on fresh fracture but weathers grey. A faint mottling and streaking parallel to the bedding is apparent. The lowest bed visible is dense-textured. Sample 24 was taken from the 2 feet of dolomite exposed.

Quarry of Building Products and Coal Company, Limited, Christie St., Winnipeg. This company is operating a quarry and lime plant on the south half of section 11, township 18, range 1, west of the Principal meridian, which is immediately adjacent to the Canadian National railway and 1 mile north of the village. The quarry was opened in 1942. In June 1944 it was 300 feet in diameter and 26 feet deep, exposing the following section of strata:—

6 inches to 2 feet	—Soil.
12 feet	—Dense-textured, creamy white dolomite in beds 2 to 3 inches thick with the exception of the top bed, which is 6 to 8 inches thick.
11 feet	—Very fine-grained, very light buff dolomite in irregular beds 3 inches to 8 inches thick and in places faintly mottled.
3 feet	—Buff dolomite composed largely of tiny shells and of very open texture.

The top 12 feet of dolomite has the texture of porcelain and is extremely brittle. On exposure to the air it becomes chalky on the surface and splits into small pieces in the manner of shale. This same tendency to split is exhibited in outcrops (Plate VII A, page 49), but is most pronounced in the quarry, where it has possibly been intensified by the shock of dynamite blasts. A seam of brown clay ¼ inch to 2 inches thick occurs all around the quarry at an average depth of 3 feet from the surface and to this depth encrustations of calcium carbonate occur between the beds and in joints.

The stone in the second 12 feet is not so brittle as that above, nor does it split so readily into small pieces on exposure, but it breaks very easily. It is in very uneven beds.

Sample 25 was taken from the top 12 feet and Sample 25A from the next 12 feet. As the analyses show, the rock is pure dolomite. At the time of the examination the lowest beds were under water and no sample could be obtained. The following analysis of the bottom beds supplied by the company shows that these beds are quite impure:—

	Per cent
Insoluble	7·80
Oxides of iron and alumina	1·31
Calcium oxide	28·85
Magnesium oxide	18·21
Loss on ignition	44·72
Total	100·89

The quarry is worked in benches, and jackhammers are used for drilling. The stone is loaded on trucks by a dragline scraper and conveyed to the crushing plant 200 yards distant. In this plant, which is of the semi-portable type with a gyratory as a primary, the rock is crushed and screened to minus 1½ inch plus ¾ inch for use as crushed stone; minus ¾ inch plus ¼ inch for burning to lime; and minus ¼ inch, at present stock-piled but not used. The quarry and crushing plant are operated only for a short time each summer and sufficient material is stock-piled to last for the remainder of the year.

The lime plant consists of two Ellernan kilns designed to calcine small-size limestone and the first of their type put into commercial operation. Each has a capacity of 4½ tons of lime per day and though designed to burn oil they have been adapted to burn wood. The stone, carefully screened to minus ¾ inch plus ¼ inch, is fed to a hopper above the kiln and passes through it by gravity, the rate being fixed by the rate of discharge of the finished lime. The lime is sold on the Winnipeg market as pebble lime.

One and one-half miles north of Inwood and 1 mile west of the Canadian National railway, Silurian dolomite is exposed in a small quarry that was formerly worked to obtain stone for making lime. This is about the centre of section 10, township 18, range 1, west of the Principal meridian. Eleven feet of horizontally bedded dolomite is exposed beneath 1½ feet of black stony loam that supports a dense growth of small poplars. The top 7 feet is buff in colour with a faint mottling of brown, and is fine-grained and porous. It has no well-defined bedding. Crusts of calcareous tufa occur in the cracks. Many cavities are present in the top 2½ feet and in the 7th foot, but the remainder is nearly free of them. The bottom 4 feet is lighter in colour, extremely fine-grained, and is in thin broken beds. Sample 25B was taken from the top 7 feet, and Sample 25C from the bottom 4 feet. There is little difference in composition between the two sections sampled.

Sandridge

Outcrops of pale buff Silurian dolomite similar to that described above occur east, west, and south of Sandridge station.

Narcisse

Extremely fossiliferous, buff Silurian dolomite in flat beds is exposed along the road and railway in section 15, township 19, range 1, west of the Principal meridian. Sample 26 was taken from exposures along the road on the southern edge of the southwest quarter of section 15. The exposures along the railway are where the railway crosses the northern boundary of section 15.

Poplarfield

In 1935, Sun Lime Products, Limited of Winnipeg built and operated a small lime kiln of the pot-kiln type 1 mile north of Poplarfield and near the Canadian National railway. Stone for burning was obtained from a small quarry 8 feet deep that was sunk in the buff Silurian dolomite adjacent to the kiln. Sample 27 was obtained from the quarry. The top 2 feet of strata made a white lime, and the remainder, a grey lime. Operations were discontinued after a few months.

Broad Valley

The Silurian dolomite exposed north of the village was investigated as a source of marble and building stone in 1914 by Manitobite Stone Works, Limited. Operations were interrupted by World War I and were not resumed. Except for one or two beds the dolomite exposed is too thinly bedded to yield large blocks of sound stone. The attractive yellow colour of some of the stone, however, makes it of interest as a source of yellow terrazzo.

A small amount of quarrying was done in the southeast quarter of section 22, township 23, range 2, west of the Principal meridian, which is 1 mile north of the village and on the east side of the Canadian National railway. The dolomite forms a low escarpment facing north and there is little or no soil covering. The top bed of this escarpment is 3 feet 6 inches thick in places, but in other places it is split by uneven partings into three beds and it has several cavities. The top stone has been removed over a small area by a channelling machine. It is fine-grained, yellow, and faintly mottled. In the top 11 inches some faint pinkish tints are observable. Sample 28 represents this stone. Beneath this rather heavily bedded stone 5 feet of thinly bedded, extremely fine-grained, cream-coloured dolomite is exposed in a small pit. Sample 28A was taken from this 5 feet. At the foot of the escarpment is another pit in which 4 feet of fine-grained, yellow dolomite similar to the top bed of the escarpment is exposed. Sample 28B is representative of this 4 feet. Beneath it is extremely fine-grained, cream-coloured dolomite similar to that beneath the top bed.

The Winnipeg Supply and Fuel Company, Limited, 812 Boyd Bldg., Winnipeg, the present owner of this property, sunk a test pit about 500 feet south of the escarpment and exposed the following section of strata:—

1 foot—Fine-grained, yellow dolomite.
2 feet—Buff, fine-grained dolomite in beds 1 to 2 inches thick.
2 feet 6 inches—Faintly mottled, yellow, fine-grained dolomite.
1 foot 6 inches—Dove-grey, very fine-grained dolomite containing spheres, $\frac{1}{8}$ inch in diameter, of white dolomite.
8 feet—Extremely fine-grained, cream-coloured dolomite in beds of variable thickness.
3 feet—Yellow, fine-grained, faintly mottled dolomite in three beds.
2 feet—Red clay.
6 feet—Yellow, fine-grained dolomite containing a number of cavities. Beneath this, at the bottom of the pit, is another seam filled with red clay.

The company kindly supplied the following analyses of samples taken at the depths indicated.

—	5 ft.	12 ft.	16 ft.	19 ft.	23 ft.
	Per cent	Per cent	Per cent	Per cent	Per cent
Insoluble	1·2	0·2	0·36	0·3	0·2
Oxides of iron and alumina	2·2	0·6	0·30	0·2	0·15
Calcium carbonate	56·2	58·75	55·90	54·8	53·9
Magnesium carbonate	40·4	40·3	43·40	44·6	45·7
Total	100·0	99·85	99·96	99·9	99·95

Fisher Branch

Red and buff Silurian dolomite in thin, flat beds is exposed along the road and along the Canadian National railway 3 miles north of Fisher Branch, and extensive exposures of similar dolomite are reported to occur to the northeast, particularly in section 24, township 24, range 1, west of the Principal meridian. Still farther north, red, purple, and buff dolomite is quarried for rubble and for use as terrazzo (*see* below).

Hodgson

South of this village, which is at the end of the Hodgson branch of the Canadian National railway, buff, red, and purple Silurian dolomite is exposed in many places, and on section 18, township 25, range 1, west, it has been quarried for marble by *Winnitoba Marble Quarries, Limited, 1180 Wall St., Winnipeg.* This company's property consists of 160 acres, mainly in the northeast quarter of section 18, township 25, range 1, west of the Principal meridian. The dolomite is exposed in flat-lying beds in an escarpment 18 to 20 feet high (Plate VII B, page 49) in which the original quarry was opened, at approximately 700 yards east of the railway. The section exposed in the quarry is as follows:—

1 foot—Soil.
2 feet—Buff, fine-grained dolomite.
1 foot 6 inches—Red, fine-grained dolomite.
2 feet 4 inches—Buff dolomite.

1 foot 8 inches—Red dolomite streaked with buff and containing some small nodules of chert.
2 feet 2 inches—Buff dolomite.
1 foot 8 inches—Dark red dolomite.
3 feet—Buff dolomite.
—Red dolomite.

All the dolomite is fine-grained and the main partings usually occur between the beds of different colour, though some beds are part red and part buff. Incipient parting planes within the beds cause them to split horizontally. The red dolomite tends to weather more rapidly than does the buff. Sample 29 was taken from the buff beds and Sample 29A from the red. The red dolomite is impure and deposits containing it are unsuitable for chemical and metallurgical use and for making lime. Both red and buff stone take an excellent polish and make very attractive marble, some being especially rich in colouring, with purple and red colours set off by a golden buff background.

Two other pits have been sunk on the property to find beds without incipient partings. The first is 700 yards due south of the original quarry, and the second 500 yards southwest of it. In the first pit, which is 9 feet deep, a succession of beds is exposed similar in thickness and colour to that in the quarry. The second pit is 19 feet 6 inches deep and exposes more of the buff and less of the red dolomite. One purple bed 6 inches thick occurs here. The thicknesses of the variously coloured strata are as follows:—

2 feet —Gravelly soil.
1 foot —Buff, fine-grained dolomite.
2 feet —Red and buff dolomite.
2 feet —Red dolomite.
4 feet —Buff dolomite.
6 inches—Purple dolomite.
8 feet —Buff dolomite.

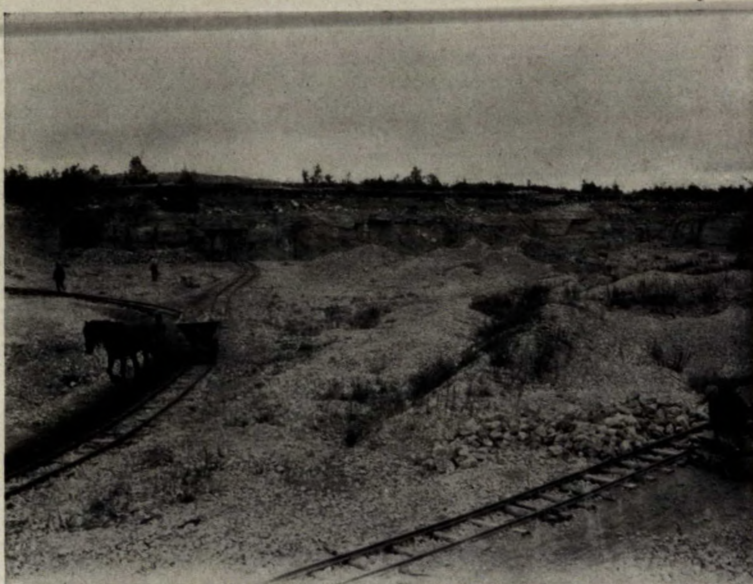
It is seen that the buff dolomite greatly predominates over the red. The thicknesses given, however, are not those of individual beds. Jointing is such that large blocks can be obtained, but the beds have a strong tendency to split horizontally along almost invisible parting planes, and there is much waste material in the production of slab marble from this property. The stone makes excellent rubble, however, and yields attractively coloured terrazzo. It is being used on a small scale for these purposes.

Three miles east of the quarry property, pale buff dolomite, mottled and streaked with pink and red, is exposed in a high ridge east of the east branch of Fisher river. This is on sections 10 and 15 of township 25, range 1, west. Because of the attractive colouring of the dolomite the name Marble Ridge has been given to the locality. The beds as seen in the outcrops are thin and it is doubtful if large blocks of marble could be obtained therefrom.

A short distance southeast of Hodgson, principally in section 28, township 25, range 1, west, pale buff and red dolomite is exposed.

PLATE VIII

A. Thinly bedded Devonian limestone (Elm Point formation) in old quarry at Oak Point, Man.



B. Quarry of Moosehorn Lime Company in Devonian limestone (Elm Point formation) at Spearhill, Man.

Analyses of Limestones Along the Hodgson Branch of the Canadian National Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
24.......	0·30	0·33	0·12	0·02	55·25	44·58	100·60	Tr.	30·95	21·32	1·45 : 1
25.......	0·24	0·21	0·05	0·02	54·49	45·07	100·08	0·01	30·53	21·55	1·42 : 1
25A.....	0·36	0·14	0·18	0·04	54·59	44·84	100·15	0·01	30·59	21·44	1·42 : 1
25B.....	0·22	0·30	0·06	0·02	55·25	44·67	100·52	Tr.	30·95	21·36	1·44 : 1
25C.....	0·22	0·28	0·08	0·02	55·77	44·28	100·85	Tr.	31·24	21·27	1·46 : 1
26.......	0·14	0·35	0·03	0·02	55·46	44·98	100·98	Tr.	31·07	21·51	1·44 : 1
27.......	0·25	0·40	0·10	0·02	55·30	44·18	100·25	Tr.	30·98	21·13	1·46 : 1
28.......	0·27	0·20	0·10	0·02	55·50	44·73	100·82	Tr.	31·10	21·39	1·45 : 1
28A.....	0·20	0·15	0·15	0·02	55·96	43·94	100·42	Tr.	31·35	21·01	1·49 : 1
28B.....	0·22	0·23	0·18	0·02	55·50	44·52	100·74	Tr.	31·09	21·29	1·46 : 1
29.......	1·54	0·32	0·26	0·02	53·84	44·30	100·28	Tr.	30·16	21·18	1·42 : 1
29A.....	5·30	0·64	1·00	0·02	51·37	42·02	100·35	Tr.	28·78	20·09	1·43 : 1

24.	Inwood.	Silurian dolomite to depth of 2 feet in small pits on sec. 34, tp. 17, rg. 1 W.
25.	"	Top 12 feet of Silurian dolomite in quarry of Building Products and Coal Co., Ltd.
25A.	"	Next 12 feet in same quarry.
25B.	"	Top 7 feet of Silurian dolomite in old quarry on sec. 10, tp 18, rg. 1 W.
25C.	"	Bottom 4 feet in same quarry.
26.	Narcisse.	Silurian dolomite exposed on road in sec. 15, tp. 19, rg. 1 W.
27.	Poplarfield.	Silurian dolomite in quarry formerly worked by Sun Lime Products, Ltd.
28.	Broad Valley.	Top 3½ feet of Silurian dolomite in escarpment on SE¼ sec. 22, tp. 23, rg. 2W.
28A.	" "	Next 5 feet of thinly bedded strata.
28B.	" "	Four feet of dolomite in pit at base of the same escarpment.
29.	Hodgson.	Buff Silurian dolomite in quarry of Winnitoba Marble Quarries, Limited.
29A.	"	Red Silurian dolomite in same quarry.

Gypsumville Branch of the Canadian National Railway

The Canadian National railway from Winnipeg to Gypsumville, throughout the greater part of its length, runs near the line of contact between the Silurian dolomite to the east and the high-calcium limestone of the Devonian system to the west, and thus both types of limestone are available within a short distance. The high-calcium limestone is being quarried for the manufacture of Portland cement at Steep Rock on Lake Manitoba, and is hauled over this railway to the cement plant at Fort Whyte, south of Winnipeg. At Spearhill the high-calcium limestone is quarried for making lime and for chemical and metallurgical uses. Crushed stone for road metal and for use in concrete has been produced at Oak Point and Lundar.

Oak Point

Two and one-half miles north of Oak Point station and 2 miles back from the shore of Lake Manitoba, high-calcium limestone of the Elm Point formation was formerly quarried for making lime and for crushed stone by David Bowman of Winnipeg. The 40-acre property, which was last worked in 1924, is now owned by The Winnipeg Supply and Fuel Company. The quarry is triangular in shape, with two sides 250 feet long and the other 400 feet long. It is 12 feet deep, exclusive of the soil, but is filled with water to within 4 feet of the top. The limestone exposed above the water is very fine-grained, tough, brown, fossiliferous, and mottled, and lies in horizontal, wavy beds 2 to 3 inches thick (Plate VIII A, page 54). The top bed is glaciated and is covered by 1½ to 3 feet of stony soil. A calcareous crust has been deposited from circulating ground waters between the upper beds. The mottlings, which are darker brown than the remainder of the stone, consist of pure calcium carbonate. Such magnesium carbonate as is present occurs in the matrix. Some of the beds contain a considerable quantity of sand grains. Sample 30 is from the 4 feet of strata above the water in the quarry.

The following series of analyses, made by the Canada Cement Company and representative of each individual foot of stone in the quarry, was supplied through the courtesy of Mr. Bowman.

Sample	SiO_2	Fe_2O_3 Al_2O_3	CaO	MgO	Loss on ignition	Total
1st foot	3·00	0·72	50·76	3·06	41·00	99·08
2nd "	1·92	0·92	50·68	3·06	41·10	98·22
3rd "	4·00	0·74	49·34	4·39	41·00	99·47
4th "	3·09	0·94	49·94	3·74	40·86	99·38
5th "	4·06	0·96	47·01	6·48	40·37	99·42
6th "	4·00	1·00	50·91	4·24	39·18	99·33
7th "	2·94	1·04	51·81	3·60	39·93	99·68
8th "	3·00	1·00	51·81	2·88	40·97	99·66
9th "	1·96	0·96	52·19	2·52	42·00	99·63
10th "	1·80	0·72	52·79	2·43	42·22	99·96
11th "	1·84	0·94	52·41	2·88	41·90	99·97

A crushing plant and a lime plant consisting of two Keystone draw-kilns stood at the edge of the quarry and were supplied with stone from skips raised by a derrick. Products were shipped over the Canadian National railway.

Similar limestone is available beneath light overburden over a considerable area in this vicinity.

Lily Bay

See page 62.

Lundar

East of Lundar on the Gypsumville branch of the Canadian National railway is an area where the soil is thin, and outcrops of flat-lying beds of dolomite of the uppermost division of the Silurian are common. The dolomite is very fine-grained, cream-coloured, and is in beds ranging from a few inches to 1 foot in thickness, between which are no shale partings. In a small clearing in the northwest corner of lot 6, township 20, range 4, west of the Principal meridian, is a pit in which 4 feet of the cream-coloured dolomite is exposed. Sample 31 was taken here. Farther east along the highway, glaciated beds of creamy grey, somewhat porous dolomite up to 8 inches thick are exposed. In these beds are a number of vugs, some of which have a brick-red coating, and others are filled with red clay. Sample 31A was taken at this place and possibly represents a thickness of 5 feet of strata that occur above those sampled in the pit nearer the village. The dolomite at both places is similar in composition. That to the east along the road, however, contains more vugs and red streaks than that just east of the village. After field work in this district was completed a small quarry for road material was opened ½ mile east of Lundar.

One and one-half miles north of Lundar, glaciated beds of buff, fine-grained dolomite are exposed on a slight rise on the west side of the railway track. Sample 32 was taken here. The land in the vicinity is thickly wooded with small poplar.

Eriksdale

In this vicinity the bedrock is covered by from 2 to 15 feet of clay soil and no outcrops are reported. The following information on the character of rock encountered in drilling wells on the farm of Mr. G. Warren on the northeast quarter of section 20, township 21, range 5, west of the Principal meridian, was kindly supplied by Mr. F. V. Seibert, Industrial Commissioner, Canadian National Railways, Winnipeg. The log of Well No. 1 shows 12 feet of clay overburden followed by 2 feet of interbedded red and buff dolomite overlying 22 feet of buff dolomite. That of Well No. 2, 50 feet southeast, shows 7 feet of clay soil and then 38 feet of red dolomite. In Well No. 3, 25 feet farther southeast, the soil was 12 feet deep and beneath was 2 feet of interbedded red and buff dolomite underlain by 20 feet of buff. The notable feature is the extreme variation in thickness of the red dolomite within such a short distance. An analysis, made by Milton Hersey Company, Winnipeg, of the red dolomite is as follows:—

	Per cent
Silica	12·40
Iron oxide	2·18
Alumina	7·02
Calcium carbonate	41·94
Magnesium carbonate	36·11
Total	99·65

Mulvihill

Mulvihill is near the line of contact between the Devonian and Silurian rocks, but the only outcrops observed were of Silurian age. One mile due east of Mulvihill is a large area where the soil is thin and exposures of finely granular, somewhat cavernous, brownish buff Silurian dolomite are plentiful. The beds are broken and have a slight dip east from the crest of a low ridge. Sample 33 is representative of the beds exposed.

One mile northwest of Mulvihill, on the southeast quarter of section 10, township 23, range 6, west, similar, yellowish brown, porous, finely granular dolomite is exposed in uneven, broken beds in a small quarry formerly worked by John Strindlund for making lime in two pot kilns. The property is owned by Mr. F. Olsen. The quarry is opened in a low ridge that extends in a northeast-southwest direction across the southeast corner of the lot. Sample 34 represents the 3½ feet of dolomite exposed.

South and west of Mulvihill, along the boundary between townships 22 and 23, an impure red dolomite, which in this district is characteristic of the uppermost beds of the Silurian system, is exposed along the southern boundaries of sections 3 and 6. A sample representative of only the top bed had the following analysis:—

	Per cent
Insoluble	5·21
Oxides of iron and alumina	2·72
Calcium carbonate	53·01
Magnesium carbonate	39·45
Total	100·39

Ashern

Like Mulvihill, Ashern is almost on the boundary between the Silurian formation to the east and the Devonian to the west, but only Silurian dolomite including a pure, buff variety and an impure, red variety is exposed in the neighbourhood of the village. The buff dolomite seen along the railway 2 miles south of Ashern on the west side of the road 1 mile south of the village, and again ¾ mile east of the village, is apparently pure. No good section of the rock was visible and Sample 34A taken from the several outcrops is representative, possibly, of only one bed.

The red dolomite is exposed 1 mile west of Ashern in section 27, township 25, range 7, west of the Principal meridian, and 3 miles south of Ashern, in the ditch along that part of the road running east and west between sections 3 and 10 of the same township and range. In the latter locality the rock is mottled red and buff, not solid red.

Spearhill

An outlier, or isolated mass, of Devonian high-calcium limestone (Elm Point formation) resting on and surrounded by Silurian dolomite occurs at Spearhill, 3 miles northeast of Moosehorn, and is being quarried for chemical limestone and for making chemical lime by Moosehorn Lime Company, a subsidiary of Winnipeg Supply and Fuel Company, Limited, Winnipeg. The high-calcium limestone covers an area of possibly 150 acres, of which 80 acres is in a mound that is readily quarriable. This is in the southeast quarter of section 22, township 27, range 7, west of the Principal meridian.

Quarry of Moosehorn Lime Company, Limited, Head Office, 812 Boyd Bldg., Winnipeg. The quarry (Plate VIII B, page 54) has been opened in the northeastern side of the outlier to take advantage of a dip of 2 or 3 degrees in that direction for drainage. By 1944 the high-calcium limestone had been removed over an area of 19 acres. The overburden of gravelly soil, supporting a thick growth of small trees, varies from 1 to 10 feet in thickness, largely because of the uneven nature of the limestone surface. The working face, which is 1,200 feet long, exposes 14 to 16 feet of very fine-grained, rather soft, light brown limestone in thin, uneven beds that in places are joined tightly together, giving a semblance of heavy bedding (Plate IX A, page 59). No shale is present in the bedding planes. Much of the stone is faintly mottled with two shades of brown, and in some places it contains a number of small cavities and appears to be a breccia. When allowance is made for the dip the thickness of strata exposed is about 22 feet. The quarry floor is uneven and consists for the most part of a rusty yellow, siliceous, magnesian rock from which arise occasional reefs and mounds of various heights, some extending to the top of the face. This type of rock is discarded in the quarry operations. The parts of these reefs and mounds of yellow rock that extend above the quarry floor may not have a much greater content of magnesium carbonate than has the pure high-calcium limestone, but they are always siliceous and argillaceous. Occasional patches of gnarled cavernous stone containing pockets of clay are also encountered. Sample 35 is representative of the quarry face. Sample 35A was taken from the yellow stone just beneath the quarry floor, and Sample 35B is yellow mottled stone from near the top of one of the reef-like masses.

In working the quarry the overburden is loaded on trucks by a gasoline-driven power shovel having a $\frac{1}{3}$-yard dipper and mounted on caterpillar treads. Drilling is done with air drills mounted on tripods, and the rock is blasted with 40 per cent dynamite. Hand-sledging is employed to break up any large masses remaining after blasting. All the rock is hand-loaded into steel side-dump cars of 1-yard capacity, which are hauled in trains of seven by horse over a narrow-gauge track to the kilns or to a loading platform for shipment by rail. Stone for the kilns is sized from 2 to 6 inches, that for shipment to sugar factories is 2 to 5 inches, and for shipment to pulp mills is 6 to 15 inches. Spalls less than 2 inches in diameter are at present discarded.

The lime plant (Plate IX B, page 59) has a capacity of 100 tons of lime a day and consists of four vertical steel-shell kilns 70 feet high and 11 feet in outside diameter, two of which are fired with gas produced from coal in a standard gas producer, and two with gas obtained from wood burned in semi-gas producers of the company's design. The gas is introduced into the kilns through

PLATE IX

A. Elm Point limestone quarried for making lime and for chemical use by Moosehorn Lime Company, Spearhill, Man.

B. Lime plant of Moosehorn Lime Company, Spearhill, Man.

small ports in a central arch and this permits the burning of smaller size stone than can usually be burned in a shaft kiln. The stone in the quarry cars is hauled by electric hoist up an incline to the top of the kilns and is dumped into the kilns through openings that at all other times are kept tightly closed. Gases from the kilns are drawn off by a fan. Electric power for the plant is provided by two General Electric generators driven by Crossley diesel oil engines. The products include lump lime, pebble lime, and pulverized lime. Hydrated lime made from quicklime produced at this plant is prepared at the plant of Gypsum, Lime and Alabastine, Canada, Limited, in Winnipeg.

Two hundred yards southwest of the lime plant, along the railway to Mooschorn, cavernous, brown dolomite is seen underlying the mottled high-calcium limestone. The contact between the two is sharp and apparently unconformable. Sample 35C was taken from the dolomite.

One and one-half miles west of Spearhill, the Silurian dolomite upon which the Spearhill outlier of high-calcium limestone rests, is exposed in a quarry 60 feet square and 15 feet deep that was opened to obtain dolomite for making lime by Manitoba Gypsum Company, Limited, the former owners of the Spearhill plant. The quarry is opened in a low ridge at about the dividing line between sections 28 and 29 of township 27, range 7, west of the Principal meridian. The section exposed is as follows:—

1 foot—Soil.
2 feet—Breccia consisting of angular fragments of very fine-grained, pale buff, white weathering dolomite in a salmon-coloured to red-brown groundmass; all of which is devoid of bedding.
2 feet—Drab dolomite split into very thin beds and weathering to a red colour.
4 inches to 2 feet—Drusy, fine-grained, cavernous dolomite having a columnar structure and weathering to a red colour with yellow ochreous matter in the numerous vugs. The thickness is variable, and where it thickens out it is at the expense of the beds above.
1 foot—Cavernous, brown dolomite weathering pink.
9 feet—Fine-grained, porous, cream-coloured dolomite in thin blocky beds.

Sample 36 is representative of the top 5 feet of dolomite in this quarry, and Sample 36A of the bottom 9 feet.

Steep Rock

See page 64.

Fairford

Two miles due south of Fairford, pale buff, fine-grained, cavernous dolomite is exposed in a low, broad ridge along the northern edge of section 8, township 30, range 9, west of the Principal meridian. Sample 37 taken here consisted of fragments from exposures over a considerable area but probably representing not more than a foot or two of strata. This locality is 1½ miles west of the Canadian National railway.

Pure dolomite of Silurian age is exposed on land belonging to the Church of England Mission at Fairford village, a short distance east of where the Canadian National railway crosses the Fairford river. The land is flat and rises only about 15 feet above the river. The dolomite is in flat beds and is seen either in flat outcrops or in shallow pits from which the rock has been taken for making lime for local use. About 4 feet of thinly bedded, very pale yellow, fine-grained, porous dolomite is exposed, and this is available over a fairly large area where the soil is thin. Sample 38 is representative of a thickness of 4 feet of this pure dolomite.

Similar dolomite is seen at intervals in low knolls for about a mile east of Fairford, and also south of the village along the road to Steep Rock where, however, it is mixed with magnesian limestone. It is also visible at the water's edge on the south bank of the Fairford river where the latter leaves Lake Manitoba.

Five miles north of Fairford, dolomite and magnesian limestone constitute a low ridge trending northwest-southeast, in which a small amount of quarrying was done at one time. The limestone is variable in appearance and composition and no sample was taken.

On the northeast corner of section 24, township 31, range 10, west of the Principal meridian, a finely granular buff dolomite is exposed adjacent to the new highway to Gypsumville, according to information received from Mr. F. V. Seibert, Industrial Commissioner, Canadian National Railways, Winnipeg, who also supplied the following analysis:—

	Per cent
Silica	0·51
Oxide of iron and alumina	0·45
Calcium oxide	28·45
Magnesium oxide	21·80

Analyses of Limestones Along the Gypsumville Branch of the Canadian National Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
30	1·86	0·31	0·41	0·09	91·05	5·67	99·89	0·01	51·32	2·72	18·8 : 1
31	0·30	0·33	0·03	Tr.	54·64	45·38	100·68	Nil	30·60	21·70	1·41 : 1
31A	0·34	0·24	0·19	0·02	55·09	44·71	100·59	Nil	30·86	21·38	1·44 : 1
32	0·26	0·39	0·11	0·04	55·18	44·52	100·50	Nil	30·92	21·29	1·45 : 1
33	0·30	0·35	0·10	0·02	54·95	44·64	100·36	Nil	30·78	21·35	1·44 : 1
34	0·20	0·19	0·10	0·02	54·84	45·08	100·43	Nil	30·72	21·55	1·42 : 1
34A	0·38	0·29	0·20	0·02	54·89	45·00	100·78	Nil	30·75	21·52	1·43 : 1
35	1·18	0·20	0·25	0·04	97·71	0·40	99·78	Nil	54·74	0·19	288 : 1
35A	2·86	2·81	0·79	0·09	59·29	33·86	99·70	0·03	33·25	16·19	2·05 : 1
35B	5·26	0·70	0·42	0·05	91·60	1·96	99·99	0·01	51·32	0·94	55 : 1
35C	0·84	0·87	0·59	0·07	54·70	43·35	100·42	0·01	30·67	20·73	1·48 : 1
36	1·28	0·33	0·47	0·02	54·16	43·65	99·91	Nil	30·34	20·87	1·45 : 1
36A	0·22	0·33	0·21	0·01	55·37	44·00	100·14	Nil	31·01	21·04	1·47 : 1
37	0·23	0·30	0·12	0·02	54·70	45·17	100·54	Nil	30·67	21·60	1·42 : 1
38	0·14	0·34	Tr.	0·02	55·23	44·69	100·42	Nil	30·94	21·37	1·45 : 1

30.	Oak Point.	Top 4 feet of Elm Point limestone in old quarry 2½ miles north of the railway station.
31.	Lundar.	Four feet of Upper Silurian dolomite in pit on sec. 6, tp. 20, rg. 4W.
31A.	"	Glaciated Silurian dolomite beds on highway to east of where Sample 31 was taken.
32.	"	Glaciated Silurian dolomite 1½ miles north of Lundar and on west side of railway.
33.	Mulvihill.	Silurian dolomite 1 mile due east of the village.
34.	"	Silurian dolomite on property of F. Olsen 1 mile northwest of the village.
34A.	Ashern.	Buff Silurian dolomite outcropping southeast of the village.
35.	Spearhill.	Fifteen feet of Elm Point limestone in face of quarry of Moosehorn Lime Company.
35A.	"	Yellow magnesian limestone beneath the quarry floor.
35B.	"	Yellow mottled limestone from a reef-like mass in the quarry.
35C.	"	Silurian dolomite exposed 200 yards southwest of the lime plant.
36.	"	Top 5 feet of Silurian dolomite in old quarry 1½ miles west of Spearhill.
36A.	"	Bottom 9 feet in same quarry.
37.	Fairford.	Dolomite in low ridge along northwestern edge of sec. 8, tp. 30, rg. 9 W.
38.	"	Silurian dolomite in old quarry in the village.

Lake Manitoba

High-calcium limestone and dolomite of a high degree of purity are exposed in a number of places on the shores and islands of Lake Manitoba. At Steep Rock point on the east shore, pure high-calcium limestone of the Elm Point formation (Devonian) is quarried on a large scale for the manufacture of Portland cement. High-calcium limestone was formerly quarried for crushed stone and for making lime at Oak Point and is available on the west shore of the lake at Kinosota. Pure dolomite was quarried in the past at The Narrows and at Fairford. The lake is shallow and is navigable only for boats of light draught. Railways, however, serve some localities on the east and west shores.

Lily Bay

Mottled high-calcium limestone of the Elm Point formation is reported to be exposed east of Lily bay and near the highway in or about section 34, township 20, range 6, west of the Principal meridian. It is said to approximate in chemical composition that at Steep Rock farther north.

The Narrows

Pure Devonian dolomite, probably of the Winnipegosan formation, is available beneath a light covering of soil over a considerable area on the east side of Lake Manitoba at The Narrows, formerly known as Sifton Narrows. It is exposed in a quarry about 30 feet square and 8 feet deep, 200 yards east of the shore. The dolomite is pale buff in colour, soft, fine-grained and very cavernous. (Plate X B, page 63). It lies in even horizontal beds 13 to 19 inches thick that have no shale partings. Sample 39 was taken from the 8 feet of strata exposed in the quarry.

Across The Narrows, on the west shore of the lake, a small exposure of pinkish magnesian limestone is visible on the shore opposite Manitoba island.

Manitoba Island

Tyrrell[1] states that at the north end of this small island, which is at the northern entrance to The Narrows of Lake Manitoba,

> ......is a cliff 200 paces in length and twelve feet high, composed of horizontal strata of hard, compact, brittle, thin-bedded limestone, very irregularly jointed and fractured. The general colour is cream, but in some places this runs into a bright buff or dull pink. A rather softer buff-coloured band runs along the face of the cliff five feet down from the top. Some of the more compact layers contain little masses and vugs of crystalline calcite, and occasional little pits are seen from which crystals of pyrite have weathered out.
>
> The rock breaks into very irregular flattened fragments. From the foot of the cliff, a beach fifty feet wide of these flattened pebbles, which ring like a bell when struck with a hammer, with occasional boulders of gneiss, extends to the edge of the water. When the wind blows from the north and the waves roll on this shingle beach, carrying with them, both advancing and retiring, these resonant pebbles and dashing them against one another, a roaring noise is made which Indian superstition has attributed to the Manito beating a drum, or otherwise similarly disporting himself. Thus this part of the lake was called "Manito-bà", or the "Narrows of the Spirit", a name that was afterwards applied to the whole lake and then to the province.

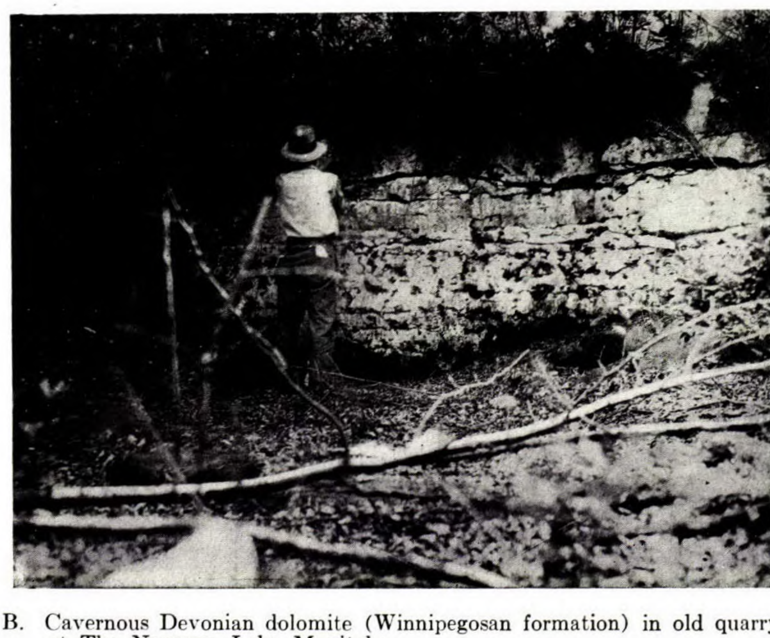
On the east and west sides of the island, argillaceous limestone is exposed near the lake level.

Point Richard

On the west side of Point Richard, which is on the east side of Lake Manitoba, just north of The Narrows, 10 feet of heavily bedded, buff dolomite forms a steep cliff rising directly out of the lake. Sample 40 was taken here.

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept. vol. V, pt. E, p. 192 (1892).

A. Thinly bedded, mottled Elm Point limestone in quarry of Canada Cement Company, Steep Rock, Man.



B. Cavernous Devonian dolomite (Winnipegosan formation) in old quarry at The Narrows, Lake Manitoba.

Steep Rock

Pure high-calcium limestone of the Elm Point formation (Devonian) is well exposed at Steep Rock village, in cliffs 20 feet high along the shore of Lake Manitoba, and in the quarry (Plate XI A, page 67), of Canada Cement Company, where a thickness of nearly 50 feet has been proved and the base of the formation has not been reached. This is nearly double the thickness previously allotted to the Elm Point formation. South and east of the village, along the road to Mooschorn, soil covering is thin and the Elm Point limestone is exposed in a number of places for a distance of 4 miles, but because of the prevailing southwest dip of the strata a lessening in the thickness of the limestone is to be expected towards the east.

Quarry of Canada Cement Company, Limited, Head Office, Canada Cement Company Building, Phillips Square, Montreal. High-calcium limestone for use in the Portland cement plant at Fort Whyte (near Winnipeg) is obtained from the Elm Point formation at the village of Steep Rock. The quarry is on the east shore of Lake Manitoba, just north of the village, and extends over 70 acres of a quarry property of 780 acres. The major part of the quarry has been worked to a depth of only 18 feet, to allow for natural drainage into a small lake to the east, but present operations are being carried on between Lake Manitoba and the former quarry, and a face 3,400 feet long with a maximum height of 26 feet is being worked and the quarry is now drained into Lake Manitoba. The land is flat and boulder clay soil covers the rock to an average depth of 2 feet, except at the eastern end of the quarry where the rock ends abruptly and the clay soil is 20 feet thick.

The limestone (Plate X A, page 63) is in thin, broken beds without shale partings. It is light grey and is distinctly mottled with nearly circular, light brown patches from $\frac{1}{4}$ inch to 2 inches in diameter. The mottlings are fine-grained and consist of pure calcite, the magnesia content of the rock being due to tiny crystals of dolomite in the groundmass. This groundmass is soft, fine-grained, and in places has an oolitic texture. Fossil fragments of calcite are plentiful. On weathering, the groundmass assumes a yellowish tint. Pockets of blue and of red clay are present in a few places and there are occasional reef-like masses of yellowish limestone of approximately the same composition as the rest, that extend upwards from the quarry floor, but these are not numerous. An occasional patch was observed where the mottlings are red. The limestone is uniformly pure throughout the large quarry and as shown by analyses is of a good grade. Sample 41 was taken from the top 13 feet of face, and Sample 41A from the bottom 13 feet.

In working the quarry, the soil is removed with a $\frac{3}{4}$-yard, gasoline shovel and loaded into trucks for disposal. Drilling is done with two gasoline-driven churn drills, the holes being 6 inches in diameter. The limestone is loaded by a $2\frac{1}{2}$-yard steam-driven shovel into 8-ton side-dump cars, which are hauled in trains of ten cars to the crushing plant by a Whitcombe gasoline locomotive. The crushing plant has a capacity of 140 tons an hour and is electrically operated from power generated by a 360 H.P. Fairbanks Morse diesel engine. A Fairmount roll primary crusher reduces the quarry run of rock to 8 inches, and this material is further reduced in a Pennsylvania hammer mill to $1\frac{1}{2}$ inches and under, and is taken to bins having a live storage capacity of 1,500 tons. The crushed stone is loaded into stone cars and hauled over the Canadian National railway 150 miles to the cement plant at Fort Whyte, south of Winnipeg.

In 1940 the company put down a series of 20-foot holes in the quarry floor over an area 1,700 feet long (east and west) by 650 feet wide. The cuttings from these holes were sampled at intervals of 2 feet and 4 feet and were analysed. Through the courtesy of the company these analyses were made available to the Bureau of Mines. The analyses of samples from Holes 1, 4, 7, 10, and 13, which are representative of the entire area drilled, are as follows:

Hole	Depth	SiO_2	R_2O_3	CaO	MgO	Loss on ignition	Na_2O	K_2O	Total
	feet	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
1	0–2	1·70	0·24	53·97	0·29	42·91	....	....	99·11
	2–4	2·72	0·60	53·15	0·43	42·95	....	....	99·38
	4–6	1·06	0·22	54·71	0·34	43·24	....	....	99·57
	6–8	1·12	0·22	54·57	0·33	43·15	....	....	99·39
	8–10	1·38	0·38	53·38	1·07	43·05	....	....	99·26
	10–12	1·54	0·40	53·38	1·02	42·85	....	....	99·19
	12–14	2·26	0·44	53·68	0·47	42·70	....	....	99·55
	14–16	1·92	0·38	53·60	0·60	42·26	....	....	98·76
	16–18	1·36	0·38	54·20	0·47	43·04	....	....	99·45
	18–20	1·12	0·36	54·64	0·07	43·30	....	....	99·49
4	0–2	1·32	0·22	54·58	0·44	43·26	....	....	99·82
	2–4	2·20	0·30	54·12	0·37	42·89	....	....	99·88
	4–6	1·90	0·20	54·12	0·40	42·95	....	....	99·57
	6–8	2·44	0·20	54·05	0·43	42·80	....	....	99·92
	8–10	3·16	0·26	53·31	0·45	42·39	....	....	99·57
	10–12	3·90	0·26	52·64	0·53	42·27	....	....	99·60
	12–14	3·12	0·22	53·31	0·34	42·56	....	....	99·55
	14–16	2·40	0·18	53·79	0·33	42·80	....	....	99·50
	16–18	1·60	0·18	54·17	0·34	43·25	....	....	99·54
	18–20	1·46	0·20	54·24	0·35	43·23	....	....	99·48
7	0–2	2·00	0·28	54·02	0·24	42·50	....	....	99·04
	2–4	1·44	0·34	54·62	0·30	43·12	....	....	99·82
	4–6	1·64	0·28	54·39	0·33	43·48	....	....	100·12
	6–8	2·10	0·30	54·09	0·42	43·17	....	....	100·08
	8–10	2·92	0·54	53·34	0·48	42·55	....	....	99·83
	10–12	2·98	0·30	53·34	0·39	41·89	....	....	98·90
	12–14	3·00	0·44	53·34	0·40	41·77	....	....	98·95
	14–16	2·12	0·28	53·79	0·38	42·04	....	....	98·61
	16–18	2·74	0·28	53·49	0·28	41·84	....	....	98·63
	18–20	2·48	0·60	49·12	3·85	42·85	....	....	98·90
10	0–2	1·42	0·30	54·32	0·37	43·31	0·04	0·12	99·88
	2–4	1·60	0·20	53·80	0·43	43·56	....	....	99·59
	4–6	2·60	0·50	53·05	0·68	42·95	....	....	99·78
	6–8	2·24	0·60	51·70	1·86	42·43	....	....	98·83
	8–10	3·00	0·62	51·10	1·62	42·04	....	....	98·38
	10–12	3·20	0·54	52·00	1·24	41·75	....	....	98·73
	12–14	3·10	0·40	52·98	0·62	41·92	....	....	99·02
	14–16	1·90	0·28	53·72	0·43	42·43	....	....	98·76
	16–18	1·14	0·30	54·55	0·33	42·54	....	....	98·86
	18–20	0·94	0·24	54·47	0·36	42·39	....	....	98·40
13	0–2	1·40	0·22	54·47	0·34	42·52	....	....	98·95
	2–4	1·46	0·26	54·47	0·34	42·62	....	....	98·15
	4–6	1·72	0·26	53·95	0·41	42·33	....	....	98·67
	6–8	2·52	0·52	51·63	1·79	42·63	....	....	99·09
	8–10	2·12	0·32	52·30	1·62	42·83	....	....	99·19
	10–12	2·10	0·42	52·15	1·70	42·60	....	....	98·97
	12–14	2·48	0·42	52·15	1·76	42·20	....	....	99·01
	14–16	3·10	0·56	51·85	1·55	42·25	....	....	99·31
	16–18	1·76	0·52	53·57	0·86	42·63	....	....	99·34
	18–20	1·02	0·28	54·56	0·36	42·93	....	....	99·15

As the analyses show, the limestone to a depth of 20 feet below the present quarry floor is substantially of the same composition throughout, although the last sample obtained from Hole 7 had a much higher magnesia content than the remainder. This is possibly due to the presence of a "reef" of dolomitic limestone similar to those seen in the Elm Point limestone at Spearhill (page 58). In any case the results of this drilling show that the thickness of the Elm Point formation is at least 50 feet instead of about 25 feet as was previously believed.

North of Steep Rock the soil is thin and exposures of the mottled high-calcium limestone of the Elm Point formation are seen for several miles along the road to Fairford.

About halfway between Steep Rock and Fairford a brick-red, very impure argillaceous dolomite is exposed along the side of the road (southeast corner of township 30, range 10, west of the Principal meridian). A pit in the red dolomite shows that it is underlain at a depth of 6 feet by buff dolomite. Sample 41X is representative of the 6 feet of red dolomite.

Davis Point

Thinly bedded, pale yellow, fine-grained Silurian dolomite and coarser grained magnesian limestone are exposed on the shore of Lake Manitoba a short distance south of Davis Point.

Crane River

Tyrrell[1] states that at Monroe point on the west side of the lake just west of the mouth of Crane river and north of the settlement of the same name, Devonian dolomite (Winnipegosan formation) forms

> ....three minor points at which are little cliffs, showing respectively nine, and six feet of a tough white compact or vesicular and entirely uncrystalline dolomitic limestone. In some of the compact bands, where no vesicles are present, a smooth, newly fractured or polished surface of the rock shows a kind of oolitic structure, the round or irregularly shaped oolitic grains being more opaque than the surrounding matrix. The bedding is heavy and horizontal.

Pentamerus Point

Also according to Tyrrell[2], Winnipegosan dolomite like that at Monroe point is exposed at lake level at Pentamerus point, 3½ miles north of Monroe point.

Kinosota

At Kinosota, formerly known as Manitoba House, on the west side of Lake Manitoba, flat-lying beds of very fine-grained, buff calcium limestone are exposed at the shore of the lake near the Mission south of the village. Some of the beds are spotted with purple. Sample 42 was taken here.

The nearest railway shipping point is Alonsa on the Canadian National railway, 14 miles by road to the south.

Embury

Just east of Embury on the Canadian National railway, 5 feet of buff dolomite is exposed in a ditch by the railway station. No other exposures were noticed in the vicinity.

Analyses of Limestones on the Shores of Lake Manitoba

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
39.......	0·36	0·27	Tr.	0·02	55·05	44·53	100·23	Tr.	30·84	21·29	1·45 : 1
40.......	0·85	0·24	0·34	0·03	54·47	44·01	99·94	Tr.	30·52	21·04	1·45 : 1
41.......	1·10	0·22	0·36	0·04	95·34	2·68	99·74	Tr.	53·41	1·28	41 : 1
41A.....	1·20	0·22	0·24	0·07	95·64	2·49	99·86	0·01	53·60	1·19	45 : 1
41X.....	15·28	2·06	4·24	0·04	44·00	34·02	99·64	n.d.	24·65	16·27	1·5 : 1
42.......	2·20	0·66	0·82	0·C3	95·70	0·94	100·35	0·01	53·62	0·45	119 : 1

39.	The Narrows.	Winnipegosan (?) dolomite in small quarry on east side of the lake.
40.	Point Richard.	Ten feet of Devonian dolomite in cliff rising out of the lake.
41.	Steep Rock.	Top 13 feet of Elm Point limestone in quarry of Canada Cement Company.
41A.	" "	Next 13 feet of strata in quarry face.
41X.	" "	Red, impure dolomite in pit on roadside halfway between Steep Rock and Fairford.
42.	Kinosota.	Outcrop of calcium limestone at lake shore south of the village.

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. V, p. 197 (1892).
[2] Tyrrell, J. B.: Op. cit., p. 197.

A. Thinly bedded Devonian limestone (Elm Point formation) in quarry of Canada Cement Company, Steep Rock, Man.

B. Cliff of Devonian limestone (Manitoban formation) on Snake island, Lake Winnipegosis, Man.

Lake Winnipegosis

Lake Winnipegosis is underlain mostly by Devonian limestones that are exposed in a number of places along its northern, western, and southern shores. The eastern shore of the northern half of the lake is underlain by Silurian dolomite which, however, is exposed only in a few localities. Much of the limestone, both the high-calcium and the dolomitic varieties, is of a high degree of purity. Most of the lake is less than 17 feet deep and the shores are low. A branch of the Canadian National railway runs to Winnipegosis village at the southwest end of the lake, and the new highway to The Pas passes close to Dawson bay at the northwestern end. At Winnipegosis village small quantities of light grey high-calcium limestone are quarried occasionally and shipped to Winnipeg for the making of whiting substitute. The large deposits of this same type of limestone at Dawson bay have attracted attention as raw material for the making of Portland cement. A small quantity of high-calcium limestone exposed near the mouth of Red Deer river, which empties into Dawson bay, is being quarried and processed by L. K. McArdle, for use as poultry grit and as an ingredient of stock food.

Winnipegosis Village

Pure high-calcium limestone of the Manitoban formation is exposed 1½ miles west of the village and on the banks of Mossy river, ½ mile south. At the first-mentioned locality *The Winnipeg Supply and Fuel Company, Limited, 812 Boyd Building, Winnipeg,* owns a property from which the limestone is quarried from time to time for use in making whiting substitute. The quarry is on the northern part of section 9, township 31, range 18, west of the Principal meridian. It is opened in a low ridge of limestone that extends southerly from the road going west from the village. It is 100 feet in diameter and exposes 6 feet of cream-coloured, extremely fine-grained, rather soft, white-weathering limestone in thin uneven beds that dip south at a low angle. On weathering it turns nearly white. In the deepest part of the quarry some small masses of soft, yellowish magnesian material occur in the cream-coloured high-calcium rock. This yellow limestone is discarded in quarry operations. Sample 43 was taken from the rock in the quarry exclusive of the yellow patches. When the quarry is in operation the broken rock is loaded by hand into a truck and taken to Winnipegosis, from where it is shipped by rail to the plant of Manitoba Gypsum Company at Winnipeg, where it is made into whiting substitute.

The exposures ½ mile south of the village are on the northwest bank of Mossy river, where they extend for 300 feet downstream from the road bridge. A maximum of 8 feet of extremely fine-grained, cream-coloured high-calcium limestone of the Manitoban formation is here exposed. The beds have been pushed up into a low anticline that pitches away from the river. In the immediate vicinity of the river the limestone is covered by only a few inches of soil, but the soil cover deepens to the northwest. The limestone is slightly darker than that west of the village and it contains some patches of reddish and yellowish, soft, magnesian material. Seams of calcareous clay occur in some badly fractured parts of the deposit. Sample 43A represents the 8 feet of strata, exclusive of the reddish and yellowish patches, and Sample 43B was taken from the reddish and yellowish patches.

Six hundred yards farther down the river similar limestone is exposed on both banks, but only 4 feet of strata are visible.

Snake Island

This island is about 4 miles due east of Winnipegosis village. It is about $1\frac{1}{4}$ miles long, very narrow, and rises about 25 feet above the lake level. It is composed entirely of Manitoban high-calcium limestone, which is well exposed in low cliffs along the west shore. These cliffs are the truncated ends of gentle anticlinal folds the axes of which are at right angles to the shore. The first cliff begins at the northern end of the island and extends for 500 feet southward along the beach. It has a maximum height of 8 feet. After an interval of 500 feet the second cliff begins and extends for 600 feet. It has a maximum height of 19 feet along the shore, but inland the ground is much lower. Overburden consists of a few inches of pebbly soil. A vertical section at the highest part of the cliff is as follows:—

13 feet—Very fine-grained, very light brown, thinly bedded high-calcium limestone containing some small crystals of secondary calcite and occasional crystals of pyrite. A faint mottling is discernible in places and fossil shells are very numerous especially along bedding planes. Some of the beds are ripple marked.
1 inch—Brown, calcareous shale.
2 feet—Somewhat lighter-coloured and finer-grained high-calcium limestone in beds about 2 inches thick and which are fractured into blocks.
4 feet—Cream-coloured, dense-textured calcium limestone in laminated beds up to 7 inches thick, in which fossils are not so numerous. As shown by chemical analysis these bottom beds contain much argillaceous matter and more magnesium carbonate than those above.

Sample 44 was taken from the top 15 feet of the cliff and Sample 44A from the bottom 4 feet. The general appearance of the limestone is shown in Plate XI B, page 67.

Charlie Point

At Charlie point at the south end of Lake Winnipegosis and 2 miles south of Snake island the Manitoban high-calcium limestone is exposed in a number of domed structures 400 yards in diameter and rising to a height of 25 or 30 feet above the lake. The log[1] of a well drilled in one of these domes shows that calcium limestone, presumably the Manitoban formation, has a depth of 70 feet at this place, below which dolomite was encountered. The limestone at the surface is soft, fine-grained, light brownish grey, and is in thin uneven beds. Sample 45 represents 6 feet of strata exposed along the beach, and Sample 45A was taken from outcrops farther inland. The limestone can be easily quarried at this place and the overburden is thin.

About three-quarters of a mile south of Charlie point similar limestone, dipping easterly at an angle of 5 degrees, is exposed along the beach. Other outcrops are reported farther south and also on a long point at the extreme south end of the lake.

Charlie Island

Charlie island, $1\frac{1}{2}$ miles east of Charlie point, is composed of soft, thinly bedded, light brown, Manitoban high-calcium limestone, and exposures occur on the east and west shores and near the centre of the island. The island is about $1\frac{1}{2}$ miles long and $\frac{1}{2}$ mile wide. Very little of it is more than 15 feet above the lake level. Sample 46 was taken from 5 feet of strata composing the cliff on the west shore.

Meadow Portage

Winnipegosan dolomite, which underlies the Manitoban high-calcium limestone, is exposed in a low domed structure for 150 feet along the beach on the

[1] Wickenden, R. T. D.: Geol. Surv., Canada, Sum. Rept. 1933, pt. B, p. 165.

west side of and near the tip of the point at the southeast end of Lake Winnipegosis, 1½ miles west of the Meadow portage to Lake Manitoba. Four feet of hard, cavernous, fine-grained dolomite is visible. When freshly broken it is bluish grey, but it weathers to a yellow-brown. Sample 47 is representative of this outcrop. The dolomite is pure, but because of the low land on which it ocurs it would be difficult to quarry.

Farther south along the west side of this same point are small outcrops of thinly bedded, soft, brownish limestone, possibly the basal beds of the Manitoban formation.

Weston Point

Tyrrell[1] states that the lower beds of the Manitoban formation are exposed on a small island in Lake Winnipegosis, just north of Weston point. His description of this outcrop is as follows:—

> . . . . Along the eastern side of the island is a cliff ten feet in height of white, thick-bedded limestone, the upper six feet being very compact and massive, while the four 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 eight feet abruptly out of the lake, the beds dipping S.40°W. at an angle of 10°.

The same author states that the Winnipegosan dolomite is visible on the shore a short distance south of Weston point.

Net Point

Three feet of hard, fine-grained buff dolomite of the Winnipegosan formation is exposed on Net point on the east side of the lake opposite Weston point. It dips north at an angle of 10 degrees.

Brabant Point

The largest exposure of limestone on the east side of Lake Winnipegosis is at Brabant point, where argillaceous magnesian limestone and dolomite form a cliff for 1,000 yards along the shore. In places the cliff attains a height of 26 feet. This limestone is of Devonian age, but the formation to which it belongs has not been ascertained. Near the north end of the cliff the following succession of strata is visible:—

4 feet —Weathered shale and clay soil supporting a thick growth of birch and poplar.

6 feet —Soft, fine-grained, drab, argillaceous magnesian limestone in thick beds that are badly fractured. The topmost bed has a greenish tint. This stone weathers deeply to a yellowish shade.

10 feet —Buff-grey magnesian limestone faintly mottled with yellow, and of medium hardness. It is in thick, broken beds that are apparently variable in chemical composition, some seeming to be more dolomitic than others. The mottling is similar to that of the Tyndall limestone and is most pronounced in the bottom 2 feet. Secondary calcite is present in isolated crystals and in thin seams, and occasional vugs are lined with colourless crystals of calcite.

3 inches—Shale bed.

12 feet —Fine-grained, hard, tough, cream-coloured dolomite having a conchoidal fracture, and in beds up to 1 foot thick. Shale partings are present between the upper beds of this part of the section. The 18-inch bed just beneath the 3-inch shale seam is more of a magnesian limestone than a dolomite.

Sample 48 was taken from the top 6 feet of limestone; Sample 48A from the next 10 feet; and Sample 48B from the bottom 10½ feet exposed, the 18-inch bed at the top of this part of the section not being included.

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. V, p. 167E (1890-91).

Where this section was measured the strata are nearly horizontal, but farther south they dip in a southerly direction; and in this direction beds of red and greenish grey shale overlying the limestone are exposed. Several small faults with a downthrow to the south were also observed.

South Manitou Island

This small island is nearly opposite Brabant point and about 4 miles distant. It is composed mostly of brownish grey, high-calcium Devonian limestone that is overlain in places by a purplish, argillaceous calcium limestone.

Birch Island

This large island is about midway up the lake. On its northeastern tip 10 feet of pale buff, finely granular, porous, argillaceous dolomite is exposed in nearly flat beds for over 300 yards. According to Tyrrell[1] this outcrop is the lowest series of strata in Manitoba that has been definitely determined to be of Devonian age. No sample for analysis was taken.

Devils Point

Along the west side of Devils point, which is on the west side of Lake Winnipegosis some 20 miles north of Birch island, an ancient wave-worn cliff of dolomite lies in the forest at a distance of 100 yards from the present shore. The cliff begins at an elevation of about 15 feet above the present lake level and in places is over 12 feet high. The dolomite composing it is light yellow, finely granular, very porous, and comparatively pure. Near the shore it is underlain by a red shale. Sample 49 is representative of 12 feet of this dolomite. The water is shallow along the shore. On Grand island nearby, similar dolomite composes an ancient cliff over 40 feet high, but little of the rock can be seen.

Ami Island

Hard, dense-textured, buff, Silurian magnesian limestone containing large nodules of grey chert is exposed on the north side of Ami island and in several places along the eastern shore of the lake south of the island. All outcrops seen are small. No samples for analysis were taken because of the cherty nature of the limestone.

Whiteaves Point

High-calcium limestone and dolomite of Devonian age are exposed on Whiteaves point on east side of Dawson bay, at the north end of Lake Winnipegosis. The rock is exposed for over one-half mile along the face of an old cliff on the west side of the point, 100 feet in from the beach. This cliff rises in places to a height of 30 feet, but debris hides the base and rarely is there more than 15 feet of bedded limestone visible at one place. Beginning at the north end of the cliff, the first limestone seen is brown, very fine-grained, fossiliferous high-calcium limestone similar to that in the vicinity of Winnipegosis village and probably belonging to the Manitoban formation. A 10-foot thickness of this rock is visible. The top 8 feet is fractured into blocks and has no definite bedding. The bottom 2 feet is stratified and is in even beds up to 6 inches in thickness. The dip is northwest at a low angle. Sample 50 is representative of this 10 feet of limestone.

Seven hundred feet southeast, pure, thinly bedded, fine-grained, brown-grey dolomite, largely composed of small shells, and lying nearly horizontally, is

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol V, p. 169E (1890-91).

exposed for 10 feet along the top of the cliff. In the intervening space the cliff is low and no rock in place is visible. Sample 50A is representative of the 10 feet of dolomite, which is probably part of the Winnipegosan formation.

Six hundred feet farther southeast, 8 feet of very hard, dense-textured, brownish, pure dolomite in rather thin uneven beds composes the top of the cliff. This dolomite apparently underlies that to the north. It is not nearly so fossiliferous and contains some small cavities. Sample 50B was taken here. Similarly pure dolomite composes a 40-foot cliff on the west side of an island, near Whiteaves point.

Salt Point

Salt point lies on the opposite side of Dawson bay from Whiteaves point. Along the north shore of this point, at a place 2½ miles from the tip is a cliff of pure, fine-grained, extremely hard, grey dolomite that at one place attains a height of 30 feet. The strata dip away fanwise from the centre of the cliff, and within a radius of 400 feet, along the shore and inland, the ground is low. The beds are mostly thin and are of uneven thickness. The lowest 10 feet exposed (Plate XII A, page 73) is more porous and more heavily bedded than the top 20 feet and contains a few small crystals of pyrite, but in general this dolomite closely resembles that on Whiteaves point and on the small island near that point. Sample 51 was taken from the top 20 feet of this exposure, and Sample 51A from the bottom 10 feet. There is little difference in composition between the dolomite in the two parts of the cliff.

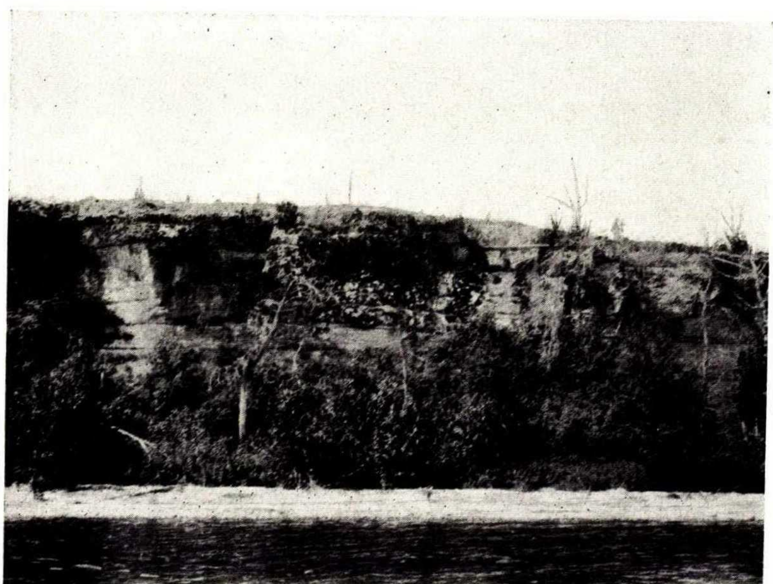
Two miles westward from where Sample 51 was taken, the same type of dolomite is exposed along the beach in a cliff 25 feet high. The top 7 feet of strata consists of interbedded magnesian limestone and dolomite, but the lower 18 feet consists of very hard, fine-grained, rather porous, light yellow dolomite in which are numerous small crystals of pyrite. The bedding is heavier and more regular than in most of the other outcrops and in places beds 4 feet in thickness occur. Sample 52 is representative of the lower 18 feet of limestone exposed in this cliff.

Point Wilkins

Calcium and high-calcium limestones of the Manitoban formation form a cliff 80 feet high along the north and east sides of Point Wilkins (Plate XII B, page 73) on the west side of Dawson bay between the Red Deer and Steep Rock rivers. On the north side of the point the limestone cliff extends for nearly a mile, but gradually decreases in height in this direction until it disappears. Along the east side of the point the cliff maintains its height for a greater distance, and beyond it to the south are several other high cliffs of the same types of limestone. Inland from the point the land is equally as high as, and in places higher than the cliffs. A very large tonnage of limestone is therefore available. The forest on top of the point has been burned and only a few inches of soil covers a large area of limestone.

At the highest part of the cliff, which is near the tip of Point Wilkins, the top 40 feet of rock is a very fine-grained, light brownish grey, soft, high-calcium limestone in thick broken beds. Fossils, crystals, and veinlets of secondary calcite are numerous. Sample 53 is representative of this upper limestone. Underlying the high-calcium limestone is 30 feet of soft, dull-lustred, argillaceous, calcium limestone in regular beds 3 to 5 inches thick, separated by partings of soft shale. Sample 53A was taken from this 30 feet of strata. Beneath the soft, argillaceous limestone a few beds of hard, siliceous, dense-textured, fossiliferous limestone are seen, and beneath this is red calcareous

A. Devonian dolomite at Salt point, Lake Winnipegosis, Man.



B. Cliff of Devonian limestone (Manitoban formation) 80 feet high, Point Wilkins, Lake Winnipegosis, Man.

shale. The bedding is horizontal and irregularities in the height of the cliff are caused by erosion. At both ends of the cliff the top pure limestone is missing, and the centre cliff is composed of the argillaceous variety.

As noted by Tyrrell,[1] at certain places along the cliff the limestone has the character of a breccia and is associated with sand and sandstone. Tyrrell's explanation of this is that the brecciated areas are formed by the falling-in of overlying rock to fill a cave or fissure.

About 2 miles south of Point Wilkins the pure high-calcium limestone of the Manitoban formation is again exposed in a 40-foot cliff that represents a cross-section of an anticlinal fold trending at right angles to the shore. The limestone is exposed for 600 yards along the beach. It is soft, fine-grained, buff in colour, and contains many fossils and secondary calcite. Bedding appears heavy from a distance, but the limestone is split into beds rarely over 2 inches thick. The strata dip away in both directions from the centre of the cliff at low angles, but to the west, or inland, the land maintains its height, thus indicating a large available tonnage of limestone. Sample 54 was taken from the top 20 feet, and Sample 54A from the bottom 20 feet of the cliff. There is little difference in composition.

Tyrrell describes other exposures of limestone south of Point Wilkins and along the shores and on the islands of Dawson bay. Many of these exposures are in the form of small domes.

Mafeking

The building of the highway to The Pas has made accessible much limestone north of Mafeking and around the head of Lake Winnipegosis. On the southeast quarter of section 21, township 5, range 25, west of the Principal meridian, L. K. McArdle is quarrying high-calcium limestone and processing it for poultry and hog feed, the latter being ground to minus 150 mesh. The plant has a capacity of 10 tons a day.

Through the courtesy of the Manitoba Mines Branch the following series of analyses of limestone along the highway north of Mafeking were made available for this report. The samples were collected by Dr. J. H. Morgan.

—	1	2	3	4	5	6	7
Silica	2·02	2·30	0·43	0·93	2·02	1·01	0·73
Iron and alumina	1·14	1·04	0·35	0·49	0·81	0·65	0·41
Calcium carbonate	96·18	95·94	97·91	97·83	96·12	97·62	98·37
Magnesium carbonate	0·62	1·00	1·43	0·81	0·77	0·67	0·21
Total	99·96	100·28	100·12	100·06	99·72	99·95	99·72

1. Eleven and three-quarter miles north of Mafeking.
2. Twelve and one-half miles north of Mafeking.
3. Twenty feet of flat-lying strata, 13 miles north of Mafeking.
4. Twelve feet of strata, 14 miles north of Mafeking.
5. Twelve feet of strata, 100 yards west of the highway bridge over Red Deer river.
6. Five feet of nearly white limestone, 2¼ miles in on the road to Dawson Bay from where it leaves the highway 9½ miles from Mafeking.
7. Five feet of lower beds at the same locality as Sample 6.

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol V, p. 183E (1890-91).

Analyses of Limestones on Shores of Lake Winnipegosis

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
43.......	0·96	0·07	0·39	0·02	98·00	0·38	99·82	Nil	54·89	0·18	305 : 1
43A.....	1·30	0·33	0·65	0·11	96·59	0·80	99·78	0·03	54·11	0·38	145 : 1
43B.....	2·02	1·98	0·90	0·04	81·59	13·32	99·85	0·02	45·71	6·37	7 : 1
44.......	1·58	0·18	0·48	0·22	95·18	2·17	99·81	Tr.	53·42	1·04	51 : 1
44A.....	3·92	0·49	1·47	0·07	85·93	7·01	98·89	0·10	48·16	3·35	14 : 1
45.......	1·52	0·12	0·36	0·07	96·45	0·86	99·38	Nil	54·05	0·41	132 : 1
45A.....	1·78	0·23	0·77	0·11	95·52	0·61	99·02	Nil	53·55	0·29	185 : 1
46.......	1·30	0·33	0·14	0·07	96·52	1·18	99·27	Nil	54·08	0·56	96 : 1
47.......	0·38	0·71	0·38	0·02	54·86	44·73	101·08	Nil	30·73	21·39	1·43 : 1
48.......	6·94	0·73	2·13	0·22	74·68	15·02	99·72	Tr.	41·94	7·18	6 : 1
48A.....	2·06	0·43	0·47	0·13	83·84	14·41	101·34	0·01	47·02	6·89	7 : 1
48B.....	4·56	1·08	1·51	0·20	54·25	37·68	99·28	0·01	30·49	18·02	1·69 : 1
49.......	1·34	0·29	0·62	0·11	54·43	44·26	101·05	Tr.	30·54	21·16	1·44 : 1
50.......	1·66	0·16	0·43	0·11	96·37	0·78	99·51	Nil	54·03	0·37	146 : 1
50A.....	0·60	0·50	0·31	0·20	54·91	44·60	101·12	Nil	30·86	21·33	1·44 : 1
50B.....	0·26	0·33	0·15	0·13	55·25	44·88	101·00	Nil	30·96	21·46	1·44 : 1
51.......	0·20	0·40	0·18	0·04	55·16	44·11	100·09	Tr.	30·91	21·09	1·41 : 1
51A.....	0·34	0·39	0·13	0·13	55·25	44·77	101·01	0·03	31·00	21·41	1·45 : 1
52.......	0·22	1·25	0·27	0·09	54·79	44·26	100·88	0·12	30·70	21·16	1·45 : 1
53.......	1·00	0·17	0·25	0·09	97·30	0·53	99·34	Tr.	54·54	0·25	218 : 1
53A.....	9·42	0·43	2·08	0·11	85·88	1·50	99·42	0·01	47·22	0·72	66 : 1
54.......	1·87	0·12	0·58	0·07	95·59	0·86	99·09	Nil	53·57	0·41	131 : 1
54A.....	1·76	0·19	0·55	0·04	95·96	0·69	99·19	0·01	53·76	0·33	163 : 1

43.	Winnipegosis.	Six feet of Manitoban limestone in quarry of Winnipeg Supply and Fuel Co., Ltd.
43A.	"	Eight feet of Manitoban limestone from bank of Mossy river.
43B.	"	Reddish and yellowish magnesian patches in Manitoban limestone at Mossy river.
44.	Snake island.	Top 15 feet of Manitoban limestone in cliff.
44A.	" "	Bottom 4 feet in same cliff.
45.	Charlie point.	Six feet of Manitoban limestone, along the beach.
45A.	" "	Outcrops inland from the shore.
46.	Charlie island.	Five feet of Manitoban limestone in cliff on west shore.
47.	Meadow portage.	Four feet of Winnipegosan dolomite, on the beach 1½ miles west of the portage.
48.	Brabant point.	Top 6 feet of Devonian limestone in cliff.
48A.	" "	Next 10 feet in same cliff.
48B.	" "	Bottom 10½ feet in same cliff.
49.	Devils point.	Twelve feet of Devonian dolomite forming cliff 100 yards inshore.
50.	Whiteaves point.	Ten feet of Manitoban (?) limestone at north end of cliff.
50A.	" "	Ten feet of Winnipegosan (?) dolomite forming cliff 700 feet to southeast of where Sample 50 was taken.
50B.	" "	Eight feet of Devonian dolomite 600 feet still farther to the southeast.
51	Salt point.	Top 20 feet of Devonian dolomite in cliff on north side of the point.
51A.	" "	Bottom 10 feet.
52	" "	Lower 18 feet of dolomite in cliff 2 miles to the west of where Sample 51 was taken.
53.	Point Wilkins.	Top 40 feet of cliff.
53A.	" "	Next 30 feet of argillaceous limestone in same cliff.
54.	" "	Top 20 feet of Manitoban limestone in cliff on shore 2 miles south of Point Wilkins.
54A.	" "	Bottom 20 feet of same cliff.

Swan Lake

Swan lake, a shallow lake with low shores, lies between Lake Winnipegosis and the Canadian National railway, the nearest stations on the latter being Novra and Bellsite, each of which is 9 miles distant.

Tyrrell[1] states that Devonian limestone occurs on the islands in the northern part of the lake and on the eastern side of the delta of Swan river. The exposure on Rose island consists of a cliff rising 10 feet above the water and composed of strata dipping south at an angle of 8 degrees. The rock is fine-grained,

[1] Tyrrell J. B.: Geol. Surv., Canada, Ann. Rept. vol. V, pp. 189-190 E(1890-91).

compact limestone of the upper part of the Manitoban series. In places it is brecciated, and has a clayey matrix. Three adjoining islands consist of the same limestone.

On the eastern side of the delta of Swan river are two outcrops of limestone. The northern one consists of "light-grey, stratified, slightly argillaceous limestone belonging to the lower portion of the Manitoban series" and rises only 2 feet above the water. Two miles south a rocky point 8 feet in height consists of "thick-bedded grey limestone breaking readily into small polygonal fragments," and generally similar to that composing Rose island. It appears to be raised in a low anticline, striking southeast and northwest.

Some of the limestone at Swan lake is of a good degree of purity, as shown by the following analyses published by Wells:[1]

—	1	2	3
	Per cent	Per cent	Per cent
Insoluble	3·25	0·65	1·40
Alumina and iron oxide	0·74	0·22	0·42
Lime carbonate	95·01	97·90	96·30
Magnesium carbonate	1·20	0·90	0·85
Sulphur trioxide	Tr.	0·04	0·08
Moisture	0·03	0·03	0·05
Total	100·23	99·74	99·10

1. Fine-grained, compact, rather soft, fossiliferous Upper Devonian limestone, collected by J. B. Tyrrell, 1889, from Hog island, Swan lake.

2. Grey, compact, rather soft, fossiliferous Upper Devonian limestone, collected by J. B. Tyrrell, 1889, from Rosebush island, Swan lake.

3. Fossiliferous, similar to No. 2, collected by J. B. Tyrrell, 1889, from Station 89, Swan lake.

Cross Lake

At Cross lake, on the Saskatchewan river between Cedar lake and Lake Winnipeg and 100 feet higher than the latter, Silurian dolomite and magnesian limestone are exposed in several places, according to Tyrrell,[2] Kindle,[3] and Parks.[4]

Parks gives the following description of 12 feet of horizontally bedded limestone exposed on the south shore of the lake near the outlet.

> 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, 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.

Other exposures mentioned are on the south shore, the west shore, on Burnt island, and at Demi-charge rapids, where the Saskatchewan river enters the lake. None of the sections reported consists of more than 4 feet of strata. An analysis

[1] Wells, J. W.: Mines Branch, Canada, Rept. No. 7, p. 67 (1905).
[2] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept., vol. V, p. 150E (1890-91).
[3] Kindle, E. M.: Geol. Surv., Canada, Mus. Bull. No. 21, p. 9 (1915).
[4] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. No. 388, p. 100 (1916).

made at the Bureau of Mines of a sample of limestone reported to have come from Cross lake was as follows:—

	Per cent
Insoluble	0·89
Ferric oxide	0·76
Alumina	0·69
Calcium carbonate	61·23
Magnesium carbonate	36·46
Total	100·03

On the south side of the broad expansion of the Saskatchewan river above Demi-charge rapids, cliffs of dolomite rising 35 to 40 feet above the river, are mentioned by Kindle.

Cedar Lake

Many outcrops of Silurian dolomite and magnesian limestone are reported as occurring on Cedar lake, which closely adjoins Cross lake on the Saskatchewan river and is 16 feet higher. Tyrrell[1] states that at the discharge of the lake low cliffs of thin-bedded dolomitic limestone extend along the shore for several hundred feet below the rapids, and Kindle[2] says that "low cliffs of light-grey dolomite 5 to 25 feet high in horizontal beds occur at frequent intervals along the southeast shore of Cedar lake as far west as Collins island. The most westerly of these exposures is located about 5 miles southwest of Collins island." Dolomite also composes many of the islands in the eastern part of the lake.

In the western part of the lake, also, dolomite in flat beds is exposed at numerous places, notably near Chemahawin, the Hudson's Bay Company's post near where the Saskatchewan river enters the lake. Parks[3] obtained a sample from a 10-foot cliff of fine-grained, light bluish-grey, cavernous dolomite in this vicinity, which analysed:—

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

Other outcrops of dolomite are reported to occur on islands and in places along the shores in the northwestern part of the lake.

Moose Lake

Dolomite of Silurian age is reported to occur at a number of places along the southern shores of Moose lake, which is directly north of Cedar lake. One such exposure is on the southwest part of the lake near the former post of the Hudson's Bay Company. In the more northerly parts of the lake and in its eastern part, Ordovician limestones are exposed.

Flin Flon Branch, Canadian National Railway

The Flin Flon subdivision of the Hudson Bay railway was not completed when the limestones along the main line of the Hudson Bay railway were examined in 1928, and no information was at that time obtained on the lime-

[1] Tyrrell, J. B.: Geol. Surv., Canada, Ann. Rept. vol. V, p. 151E (1890-91).
[2] Kindle, E. M.: Geol. Surv., Canada, Mus. Bull. No. 21, p. 10 (1915).
[3] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. No. 388, p. 98 (1916).

stone exposed adjacent to the right of way. Through the courtesy of Mr. F. V. Seibert, however, arrangements were made whereby samples were obtained from the various rock-cuts for examination and analysis in connection with the present report. The following description of the limestones is taken in part from notes supplied by Mr. Seibert and in part from an examination of the samples.

The Flin Flon subdivision branches off from the main line of the Hudson Bay railway at a point 4·2 miles north of The Pas and continues almost due north across country underlain by Silurian and Ordovician limestones for 50 miles to Athapapuskow lake, beyond which it traverses Precambrian rocks to Flin Flon. The limestone over which the railway passes is the northern end of the great limestone belt that extends diagonally across the province. It is essentially the same as that underlying the Hudson Bay railway and like the latter is all dolomite and is comparatively pure. Other than for the first exposure, which is of Silurian age, all the limestone exposed along this line is Ordovician.

Mile 0

The first exposure is about 500 yards north of the junction and consists of fine-grained, buff dolomite that has numerous cavities. Sample 55 was obtained from this exposure.

Mile 18

One hundred yards south of Mile 18, brownish grey, fine-grained, earthy-looking dolomite containing some white chert is exposed. The rock is composed of rounded fragments of brown dolomite that have been cemented together. It has no definite lines of cleavage but breaks in all directions. Sample 56 was taken here. All visible chert was removed before the sample was analysed.

Mile 19

Thinly bedded, pale buff, fine-grained dolomite is exposed in two places within 700 yards north of Mile 19. Sample 57 is a composite from both outcrops.

Mile 38

Three hundred yards north of Mile 38 heavily bedded, fine-grained, hard, brown dolomite exhibiting a faint mottling is exposed in an escarpment 15 feet high facing north, which is crossed at right angles by the railway. This stone takes a good polish, but it contains small white fossils that show rather prominently on the polished surface. Sample 58 was taken at this place.

Mile 65

Seven hundred yards west of Mile 65 on the north side of Athapapuskow lake the railway cuts through an exposure of rather soft, porous, fine-grained dolomite. In the eastern end of the cut the dolomite is buff in colour and faintly mottled, but in the western end it is dark red, faintly mottled with brown. Sample 59 represents the buff dolomite.

Analyses* of the Limestones Along the Flin Flon Branch of the Canadian National Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
55.......	0·20	0·33	0·15	0·01	53·47	45·09	99·25	0·01	29·96	21·56	1·39 : 1
56.......	0·78	0·21	0·49	0·02	54·98	44·04	100·52	0·02	30·81	21·06	1·46 : 1
57.......	0·52	0·33	0·17	0·01	53·47	44·55	99·05	0·02	29·96	21·30	1·46 : 1
58.......	1·02	0·33	0·39	0·03	52·72	44·51	99·00	0·01	29·54	21·28	1·39 : 1
59.......	1·08	1·17	0·51	0·04	51·11	43·17	97·08	0·03	28·64	20·64	1·39 : 1

* Analyses by A. Sadler, Bureau of Mines.

55. Mile 0. Buff dolomite exposed 500 yards north of the junction.
56. Mile 18. Brownish grey dolomite 100 yards south of Mile 18.
57. Mile 19. Pale buff dolomite in two places 700 yards north of Mile 19.
58. Mile 38. Brown dolomite in escarpment 300 yards north of Mile 38.
59. Mile 65. Buff dolomite in cut 700 yards west of Mile 65.

Hudson Bay Railway

From The Pas northeastward this railway passes over flat beds of Palæozoic dolomite for the first 110 miles, then over Precambrian rocks devoid of limestones for another 225 miles, and from Limestone rapids on the Nelson river to Churchill it again passes over flat beds of Ordovician limestone. In this last area, however, the limestone is everywhere deeply buried beneath clay soil and is visible only in a few places in the deep cuts made by rivers where it is not commercially available. Furthermore, such limestone as was seen is cherty and otherwise impure.

The dolomite available along the railway, for 100 miles northeastward from The Pas, is of a high degree of purity, except for certain cherty bands in the vicinities of Mile 65 and Mile 82. This dolomite is the northern extension of the great limestone belt that crosses the province in a northwesterly direction from its southeast corner. It is all very similar in composition from The Pas to the last outcrop sampled at Mile 87½. That from The Pas to the vicinity of Mile 29 has been determined as being of Silurian age and is the continuation of the belt of predominantly dolomitic rock that occupies the territory between the lakes. That from Mile 29 to Mile 110 is of Ordovician age and is the continuation of the great band of mottled magnesian limestone that underlies much of Lake Winnipeg and supplies the well-known building and ornamental stone at Tyndall. In its northern extension, however, though it still has a mottled appearance it is all dolomite and is much more highly coloured than farther south. The attractive colouring and the ability of the dolomite to take and retain a polish led to the opening of several marble quarries along the Hudson Bay railway between Mile 39½ and Mile 69½, but for various reasons the quarries were in operation for only a short time.

The belt of Devonian limestone that occupies the basins of Lake Manitoba and Lake Winnipegosis, and which in those areas furnishes high-calcium limestone, apparently pinches out northwest of Lake Winnipegosis and has not been recognized in the vicinity of The Pas.

Throughout most of the area between The Pas and Mile 110 the dolomite has only a light covering of soil and is commonly exposed in low ridges that represent gentle flexures in the otherwise nearly flat beds. The prevailing dip of the limestone strata is southwest at a very low angle and the gentle folding has occurred normal to the dip, leaving ridges and in places low escarpments trending northwest-southeast.

The following notes refer to the limestone exposed immediately adjacent to the railway and describe in effect a complete cross-section of the limestone belt.

PLATE XIII

A. Thinly bedded Silurian dolomite at Mile 9¼, Hudson Bay railway.

B. Concretions in Silurian dolomite in floor of small quarry at Mile 19¼, Hudson Bay railway.

Mile 6

The first exposures of limestone observed along the Hudson Bay railway were in the vicinity of Mile $4\frac{1}{4}$ where the Flin Flon subdivision branches off to the north, but the first good section of beds is exposed at Mile 6 in a cutting 200 yards long, where 7 feet of yellowish buff Silurian dolomite in thin, broken beds is seen beneath a light covering of soil. The dolomite is fine-grained to dense-textured and there are many cavities in some of the beds. Sample 60 represents the 7 feet of strata.

Mile $9\frac{1}{4}$

Six feet of light brown, dense-textured Silurian dolomite, somewhat softer than that previously seen, is exposed in thin broken beds (Plate XIII A, page 80) in a cutting at Mile $9\frac{1}{4}$. Much of the dolomite is badly iron-stained and the bottom beds particularly contain many cavities. Sample 61 was taken from the 6 feet of beds.

Mile $13\frac{1}{4}$

Hard, brittle, pale brown dolomite in very uneven beds is exposed to a depth of 5 feet in a cutting that begins at Mile $13\frac{1}{4}$ and extends north for 300 yards. There is little soil on top of the rock. The beds range from $\frac{1}{2}$ inch to 1 foot in thickness and a pillow-like structure is common. They are devoid of shale partings. Sample 62 is representative of the 5 feet of rock exposed.

Mile 14 and Mile $16\frac{3}{4}$

At Mile 14 and Mile $16\frac{3}{4}$ are small cuttings in rusty yellow, cavernous, very fine-grained Silurian dolomite that has no distinct bedding. The covering of soil is thin. Sample 63 is representative of a 3-foot thickness of this cavernous dolomite.

Mile $19\frac{1}{4}$

A small quarry to obtain rock for fill was opened at Mile $19\frac{1}{4}$ during construction of the railway. In it 6 feet of yellow-buff, dense-textured, brittle Silurian dolomite is exposed in indistinct and uneven beds. Peculiar, egg-shaped concretions (Plate XIII B, page 80) are seen in the bed that forms the floor of this quarry. They are of the same chemical composition as the beds in which they occur. Sample 64 was taken from the 6 feet of dolomite exposed in the quarry. Similar dolomite is seen in a small rock-cut at Mile $18\frac{1}{2}$.

From Mile $19\frac{1}{4}$ to Mile 28 the soil is thin and the flat beds of dolomite are exposed in many places near the track. The dolomite is pale buff in colour but weathers nearly white. Much of it is highly fossiliferous, some beds being almost entirely composed of tiny shells. Between Mile 23 and Mile 25 a 15- to 25-foot escarpment of dolomite, similar to that described above is seen at a distance of $\frac{1}{4}$ to $\frac{1}{2}$ mile southeast of the tracks.

Mile $29\frac{1}{4}$

From Mile 13 to Mile $29\frac{1}{4}$ there are several outcrops of pure Silurian dolomite along the railway, but for the next 7 miles there is none. At Mile $29\frac{1}{4}$ the track crosses at right angles a 4-foot ledge of light grey, white-weathering yellowish brown dolomite conglomerate that is possibly close to the base of the Silurian system. In any case the line of contact between the Silurian and Ordovician dolomites appears to be near here. Sample 65 taken from a 4-foot thickness of the conglomerate shows it to contain more silica than any of the outcrops sampled between here and The Pas.

PLATE XIV

A. Evenly bedded Ordovician dolomite, Mile 39, Hudson Bay railway.

B. Low escarpment of Ordovician dolomite, Mile 63¼, Hudson Bay railway.

Mile 39

Beginning at Mile 37, exposures of buff and pink, very fine-grained Ordovician dolomite are common, and at Mile 39 an escarpment (Plate XIV A, page 82) of this dolomite 20 feet in height extends along the northwest side of the track for some distance. On the opposite side of the track near Mile 39 a quarry for marble was opened in this escarpment by Manitoba Marble Quarries, Limited. It was worked at intervals from 1929 to 1936. The quarry extends for 200 feet along the escarpment, 100 feet back into it, and has a face 12 feet high. A section of the quarry face showing the thickness of the main beds is as follows:—

1 foot 6 inches—Soil.
1 foot —Fractured buff dolomite.
2 feet 6 inches—Buff dolomite.
2 feet 6 inches—Buff dolomite.
1 foot 8 inches—Pink and buff dolomite.
2 feet 10 inches—Pink and buff dolomite.
1 foot 8 inches—Pink and buff dolomite.

From the quarry floor down to the lake level another 8 feet of reddish pink is exposed. Sample 66 is representative of the top 6 feet of buff dolomite, and Sample 66A of the bottom 13 feet of pinkish dolomite. As the analyses show, there is little difference chemically between the buff and the pink.

The quarry was worked by means of jackhammers and a broaching tool mounted on a quarry bar, and the top buff beds have been more extensively quarried than the pink. Jointing is wide-spaced, permitting the extraction of blocks with a large superficial area. The dolomite is hard and takes a brilliant and lasting polish, but it has a tendency to pluck along wavy parting planes during the sawing and polishing processes.

Mile 41½

On the north side of the narrows of Cormorant lake a small quarry has been opened in which 7 feet of yellowish brown and pink dolomite is exposed in beds up to 30 inches thick. Extremely thin films of reddish shale form a network through much of the rock, which is very fine-grained to dense in texture. On weathering, the dolomite turns to light grey. Another small quarry in similar rock has been opened on the east side of the track a short distance north of the narrows. Sample 67 is representative of the rock exposed. The beds are horizontal and the overburden is thin. At the most there is about 15 feet of rock above the water level. Exposures of dolomite are seen in outcrops and rock-cuts until Mile 43, after which no outcrops occur until Mile 52.

Mile 52

Beginning at Mile 52 the railway passes over three low ledges of buff-grey Ordovician dolomite within a distance of three-quarters of a mile. The dolomite is rather unevenly bedded and has no shale partings. It is fine-grained, but most of the beds contain many small cavities. Sample 68 is representative of about 12 feet of strata exposed in the three ledges.

Mile 63

Eight feet of fine-grained Ordovician dolomite in horizontal beds is exposed in a cutting 200 yards in length at Mile 63. The outcrops end abruptly in a low escarpment (Plate XIV B, page 82) at right angles to the railroad at Mile 63¼. The top 5 feet of strata is almost in one heavy bed, but it is divided by incipient parting planes. In colour the top 5 feet is mottled pink and buff with the pinkish tones prevailing. The bottom 3 feet is brick-red and is in thin beds. Sample 69 was taken from the top 5 feet of beds and Sample 69A from the bottom 3 feet. This dolomite is exceptionally pure. Hudson Bay Marble and Granite Quarries, Limited held a lease on the dolomite at this place.

Between Mile 65 and Mile 67½ are flat beds of cherty, pink dolomite in a number of places adjacent to the track. No sample was taken. At Mile 68 is a low escarpment of pink limestone.

Mile 69½

Mottled red and buff Ordovician dolomite in beds up to 30 inches thick is well exposed in an escarpment over 15 feet high at this mileage, and was quarried for marble by Hudson Bay Marble and Granite Quarries, Limited in the years 1930 and 1931. Overburden is thin and the dolomite is exposed at frequent intervals over a large area. Jointing is widely spaced and large blocks are obtainable. The dolomite is extremely fine-grained and is mottled in a manner much like that of the Tyndall limestone, except that the mottling is not so distinct. It takes an excellent polish and makes a handsome marble, but exhibits a tendency to pluck on sawing and polishing because of the presence of extremely thin films of red shaly material throughout much of the stone. Sample 70 was taken from 15 feet of strata. Examples of this marble are seen in the Arts Building at the University of Manitoba.

Mile 78¾

Thin, irregular beds of very fine-grained, tan and purplish Ordovician dolomite, dipping northeast at an angle of 2 degrees, are exposed to a depth of 7 feet in a cutting at Mile 78¾. The dolomite is hard and brittle. It weathers to a rubbly state because of a network of films of reddish purple shale that occurs in all the beds. There is about 1 foot of soil on top that supports a heavy growth of jackpine. Sample 71 is representative of the 7 feet of strata exposed.

From Mile 81½ to Mile 83 flat exposures of pink dolomite containing nodules of chert and films of deep red shale are numerous.

Mile 87

A 20-foot thickness of mottled purplish red and tan Ordovician dolomite in heavy beds forms an escarpment along the northwest shore of Woody lake and extends for about one-half mile on each side of Mile 87. The dolomite is fine-grained, hard, and brittle, and contains many fossil fragments, principally crinoid stems. Jointing is widely spaced. Sample 72 is representative of the entire thickness of the dolomite exposed. This is the last exposure of limestone seen along the right of way of the Hudson Bay railway northwards from The Pas.

Mile 353

Impure, cherty, grey mottled magnesian limestone and dolomite are seen at Upper and Lower Limestone rapids on the Nelson river in the vicinity of Mile 353. The river banks here, however, are upwards of 100 feet high and are composed of clay. The limestone, in thin broken beds, is seen for only a few feet above the high-water level, where it is not commercially available. Sample 73 representing only a few beds was taken to show the impure nature of the limestone of this area.

Small exposures of limestone are reported to occur along the lower Nelson river.

Analyses of Limestones along the Hudson Bay Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
60.......	0·52	0·48	0·34	0·02	55·00	44·40	100·76	Tr.	30·82	21·23	1·45 : 1
61.......	0·50	0·26	0·38	0·04	55·45	44·40	101·03	Tr.	31·07	21·23	1·46 : 1
62.......	0·64	0·54	0·22	0·02	54·73	44·17	100·32	Tr.	30·66	21·12	1·45 : 1
63.......	0·34	0·78	0·30	0·04	55·30	43·65	100·41	Tr.	30·98	20·87	1·48 : 1
64.......	0·24	0·43	0·11	0·02	55·36	44·38	100·54	Tr.	31·01	21·22	1·46 : 1
65.......	1·10	0·34	0·12	0·02	54·42	44·45	100·85	Tr.	30·49	21·25	1·44 : 1
66.......	0·50	0·27	0·23	0·02	55·05	44·69	100·76	Tr.	30·84	21·37	1·44 : 1
66A.....	0·60	0·21	0·23	0·02	55·04	44·44	100·54	Tr.	30·83	21·25	1·45 : 1
67.......	0·92	0·25	0·25	0·02	55·02	44·30	100·76	Tr.	30·83	21·18	1·45 : 1
68.......	0·26	0·13	0·25	0·02	55·25	44·19	100·10	Tr.	30·96	21·13	1·46 : 1
69.......	0·16	0·18	0·36	0·02	55·02	44·84	100·58	Tr.	30·83	21·44	1·44 : 1
69A.....	0·46	1·02	0·44	0·02	53·93	44·70	100·57	Tr.	30·21	21·38	1·41 : 1
70.......	1·02	0·41	0·33	0·02	54·73	44·38	100·89	Tr.	30·66	21·22	1·44 : 1
71.......	1·10	0·64	0·36	0·07	54·32	44·09	100·58	Tr.	30·46	21·08	1·44 : 1
72.......	0·90	0·45	0·47	0·02	53·96	43·94	99·74	Tr.	30·23	21·01	1·43 : 1
73.......	7·54	0·70	0·98	0·04	79·20	11·50	99·96	0·02	44·37	5·50	8 : 1

60. Mile 6. Seven feet of yellowish buff Silurian dolomite.
61. Mile 9¼. Six feet of light brown Silurian dolomite.
62. Mile 13¼. Five feet of brown Silurian dolomite.
63. Mile 14. Three feet of yellow Silurian dolomite.
64. Mile 19¼. Six feet of yellow-buff Silurian dolomite.
65. Mile 29¼. Four feet of yellowish brown Silurian dolomite conglomerate.
66. Mile 39. Top 6 feet of buff Ordovician dolomite in quarry of Manitoba Marble Quarries.
66A. Mile 39. Next 13 feet of pinkish dolomite at same locality.
67. Mile 41½. Seven feet of yellowish brown and pink Ordovician dolomite.
68. Mile 52. Twelve feet of buff-grey Ordovician dolomite.
69. Mile 63. Top 5 feet of mottled pink and buff Ordovician dolomite.
69A. Mile 63. Bottom 3 feet of brick-red Ordovician dolomite.
70. Mile 69½. Fifteen feet of mottled red and buff Ordovician dolomite formerly quarried by Hudson Bay Marble and Granite Quarries.
71. Mile 78¾. Seven feet of tan and purplish Ordovician dolomite.
72. Mile 87. Twenty feet of tan and purplish red Ordovician dolomite.
73. Mile 353. Impure limestone in bed of Nelson river at Limestone rapids.

CHAPTER III

LIMESTONES OF SASKATCHEWAN

GENERAL DISTRIBUTION AND CHARACTERISTICS

The belt of Palæozoic limestones that crosses Manitoba continues on across northern Saskatchewan, but is very much narrower than in Manitoba. In no place in Saskatchewan is this limestone belt served by rail or water transportation and thus it cannot be considered to be of present economic importance. Where this limestone belt is exposed along the Flin Flon railway in Manitoba near the Saskatchewan boundary, it is all dolomitic, and presumably it maintains this characteristic for some distance at least into Saskatchewan.

The only other source of limestone in Saskatchewan is from the boulders of limestone which, as a component of the glacial drift in some areas, are plentifully bestrewn over the surface of the prairie. They are nowhere in sufficient quantity, however, to afford a continuous supply of limestone of uniform quality for any purpose requiring a considerable daily tonnage. They are mixed with boulders of other rocks and though predominantly dolomitic in composition they differ in purity. In appearance they resemble the limestones along the Hudson Bay and Flin Flon lines, all being fine-grained, but ranging in colour from pink, through yellow to brown. They have been used locally to make lime and have also been used for building purposes. A company at Moose Jaw proposes to use a mixture of limestone boulders, granite boulders, and other igneous rocks for making rock wool.

The following descriptions of limestone boulders available at various places in the province give a general idea of their characteristics. In all cases the boulders occur in ridges of glacial material.

Young

A large lime kiln was built west of this town in 1914 to use limestone boulders available in the vicinity for making lime. The kiln was operated only for a few weeks. Three types of boulder had been piled up near the kiln. One was a hard, fine-grained, dense, pinkish dolomite containing a network of shaly films. Sample 1 was taken from this type. Another type was fine-grained, hard and cavernous, yellow and buff-grey dolomite that weathered nearly white. Sample 1A represents this type. The third variety was a moderately hard, drab-brown, sugary-textured, magnesian limestone, the chemical composition of which is shown by the analysis of Sample 1B.

Watrous

From 2 to 3 miles south of Watrous the road to Regina crosses a stony belt about $\frac{1}{4}$ mile wide, in which are many boulders of pink, yellow, and brown dolomite and magnesian limestone. Some of the boulders are very large. Sample 2 was taken here.

Wakaw

South of the village are numerous boulders of fine-grained, hard, yellow dolomite mixed with some that are pink and a few that are brown. Mixed with them are boulders of granite, gneiss, quartzite, and other rocks. Sample 3 was taken from the yellow boulders only.

Saskatoon

In the vicinity of Sutherland, 2½ miles east of Saskatoon, limestone boulders are plentiful and they have been used for building purposes, chiefly for buildings of the University of Saskatchewan. Two main types were observed, one a fine-grained, pinkish, hard dolomite, the other a brown, faintly mottled, finely granular magnesian limestone. Sample 4 was taken from the pink dolomite and Sample 4A from the brown mottled magnesian limestone.

Moose Jaw

Three and one-half miles east of this city is a large gravel ridge close to the Canadian National railway in which are a great many boulders of granite, schist, gabbro, and dolomite, with the last being least numerous. In producing gravel from this ridge the boulders are screened out and have accumulated in considerable quantity. An analysis made at the University of Alberta of a boulder of dolomite from this ridge is as follows:

	Per cent
Silica	0·60
Alumina	0·28
Ferric oxide	0·02
Calcium oxide	31·08
Magnesium oxide	20·90
Loss on ignition	47·10
Total	99·98

Glacial Rock Insulation, Limited, a recently incorporated company, has built a small rock wool plant at this place and proposes to use the dolomite mixed with the granite and gabbro boulders in the making of rock wool.

Analyses of Limestone Boulders in Saskatchewan

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
1	1·12	0·40	0·30	0·04	54·78	44·39	101·03	Tr.	30·70	21·23	1·44 : 1
1A	0·68	1·22	0·58	0·04	55·14	42·70	100·36	Tr.	30·90	20·42	1·51 : 1
1B	2·06	0·49	0·51	0·04	62·05	35·97	101·12	Tr.	34·77	17·20	2·0 : 1
2	1·38	0·41	0·47	0·09	54·79	43·65	100·79	Tr.	30·73	20·87	1·47 : 1
3	1·36	0·57	0·34	0·07	54·66	43·56	100·56	Tr.	30·65	20·83	1·47 : 1
4	1·96	0·39	0·42	0·11	54·14	43·79	100·81	Nil	30·38	20·94	1·45 : 1
4A	0·94	0·67	0·39	0·07	60·20	38·46	100·73	Tr.	33·71	18·39	1·84 : 1

1.	Young.	Pink dolomite boulders used for making lime.
1A.	"	Yellow and buff-grey dolomite boulders.
1B.	"	Drab-brown magnesian limestone boulders.
2.	Watrous.	Boulders 2½ miles south of the town.
3.	Wakaw.	Yellow dolomite boulders.
4.	Saskatoon.	Pink dolomite boulders.
4A.	"	Brown mottled magnesian limestone boulders.

CHAPTER IV

LIMESTONES OF ALBERTA

GENERAL DISTRIBUTION AND CHARACTERISTICS

There are two limestone areas in Alberta, one in the northeastern part of the province along the valleys of the Athabaska, Peace, and Slave rivers, the other in the Rocky mountains, which form the southwestern boundary of the province. The area in the northeastern part is of little present importance owing to its location and was not examined.

The eastern ranges of the Rocky mountains are largely limestone, the estimated thickness of limestone strata, exclusive of interbedded shale formation, being about 9,000 feet. The geologic age is from Cambrian to Triassic, the major part belonging to either Devonian or Carboniferous systems. As may be expected in such a great thickness of limestone deposited over such a long period of time there is a wide variation in quality and type. Very pure high-calcium limestone, magnesian limestone, and dolomite are available, as well as the very impure grades of the same types. The limestones are mostly of various shades of grey, blue, and brown and have not been greatly metamorphosed by the agencies that pushed them up into the mountains.

An unfortunate feature of the limestones of the Rocky mountains is their variability. This is not confined to major differences between the several formations, thus leaving great thicknesses of uniform stone, but it persists in detail through the individual formations. The distinct banding of the Rocky Mountain limestone, apparent from a distance, gives a hint of this variation, and close observation shows that rarely is there a thickness of more than 40 feet of limestone strata free from interbeds of siliceous rock or of limestone of a different composition. Usually the interbeds of undesirable stone occur at much more frequent intervals than this. If the strata were either vertical or horizontal this variability would not greatly interfere with quarrying operations, but as the usual dip is between 20 and 70 degrees it is a handicap to quarrying but would not greatly interfere with mining.

To further appreciate the difficulties of locating quarry sites in the mountains, it is necessary to have in mind a clear picture of the topography. The mountains have a general northwest-southeast trend. The eastern ranges consist principally of lines of huge fault blocks having precipitous faces to the east and more gradual slopes to the west, the gradient of the western slopes usually corresponding quite closely to the angle of dip of the strata. Quarrying is out of the question on the steep eastern faces, the only possible locations, as Parks[1] has pointed out, being on the backs of the ranges and on the spurs of limestone which jut out into the valleys that have been cut through the ranges. In many of the favourable sites, however, only impure limestone or another type of rock is found. The available areas are further limited to the immediate vicinity of railway transportation. Thus, vast as is the quantity of limestone in the Rockies, only in comparatively few localities can a pure limestone be obtained by the usual quarry methods.

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[1] Parks, W. A.: "Building and Ornamental Stones of Canada", vol. IV, Mines Branch, Dept of Mines, Canada, Rept. No. 388, p. 112 (1916).

TABLE V

Rock Systems of Alberta Showing the Stratigraphic Position of the Limestones

System	Type of Rock
Quaternary	Unconsolidated deposits including tufa.
Eocene	Sandstone.
Cretaceous	Sandstones and shales.
Jurassic	Shales.
Triassic	Shales and impure limestone.
Permian	Shale.
Carboniferous	Limestones, quartzite, and shale.
Devonian	Limestone.
Cambrian	Limestones.

The following descriptions of the various limestone formations are very general, but generalities are particularly applicable to the Rocky Mountain limestones because different sections of strata only a few hundred feet apart and apparently at the same horizon usually differ markedly in detail. Sometimes this difference is so pronounced that there is little if any lithologic resemblance between the sections. The main factors contributing to this are: individual strata thicken and become thin and often disappear entirely; it is not unusual to find in a stratum a change in composition in a lateral direction and this change may be gradual or abrupt; in the Devonian limestones, particularly, are beds that are high-calcium in one place and dolomite in another; and the limestone beds may become more and more siliceous or shaly along their strike until they become wholly quartzites or shales.

Cambrian Limestones

The Cambrian formation, where seen on the southern end of the Sawback range, is composed principally of dolomite with subordinate amounts of quartzite, shale, and high-calcium limestone. Most of the dolomite is either blue or brown, fine-grained, much shattered, and contains siliceous beds and in places nodules of chert. Near the top of the section is a thickness of several hundred feet of medium-coarse-grained, grey dolomite that is of much better quality than is the remainder. This pure dolomite can be seen on the mountainside just east of the large gully midway between Mt. Edith and Mt. Hole in the Wall. Above this is a hard, black dolomite that becomes more and more shaly and siliceous until the shale and quartzite beds predominate. These siliceous beds are apparently the top beds of the Cambrian formation as exposed in the Sawback range. The maximum thickness of this section is about 4,000 feet. The Cambrian is exposed on Castle mountain, where it is composed chiefly of dolomite very similar to that in the Sawback range. In the Lake Louise district and near Stephen the Cambrian limestones are very impure. At Jasper the Cambrian rocks are principally schists, quartzites, and shales with little or no limestone. Farther south in the Crowsnest Pass area this formation is not known to occur.

No use is being made of the Cambrian dolomites, nor is the writer aware of any use that has been made of them in the past. Some of the dolomite is sufficiently pure for chemical uses and for lime-burning, but the high-calcium beds appear to be of little value. No analyses are available as yet.

Devono-Carboniferous Limestones

This heading pertains to the limestones of Devonian and Carboniferous ages, which together constitute the main part of the Rocky Mountain limestone. In the Banff area, where the greater part of the detailed work has been done on the Devonian and Carboniferous rocks, they have been subdivided and mapped as follows[1]:—

		Estimated Thickness in Feet
Carboniferous	Rocky Mountain quartzite	700
	Rundle limestone	2,400
	Banff shale	1,400
Devonian	Upper Minnewanka limestone	1,000
	Lower Minnewanka limestone	1,900

These divisions are applicable in other areas where the Devonian and Carboniferous limestones were examined, namely in the vicinity of Blairmore and Crowsnest pass; from Brûlé to near Jasper; at Nordegg (or Brazeau); and at Cadomin. Owing to the strong lithologic resemblance between the various limestone formations, however, it is very difficult to distinguish them by appearance alone, and where they have not been separately mapped it is necessary to deal with them collectively.

Between Kananaskis and Castle stations on the main line of the Canadian Pacific railway an excellent cross-section of the Devonian and Carboniferous formations is exposed. The formations strike northwest-southeast and on account of the faulted structure each is repeated several times. This is the type locality for the various formations of the Devonian and Carboniferous in the Rocky mountains. A brief description of each formation follows.

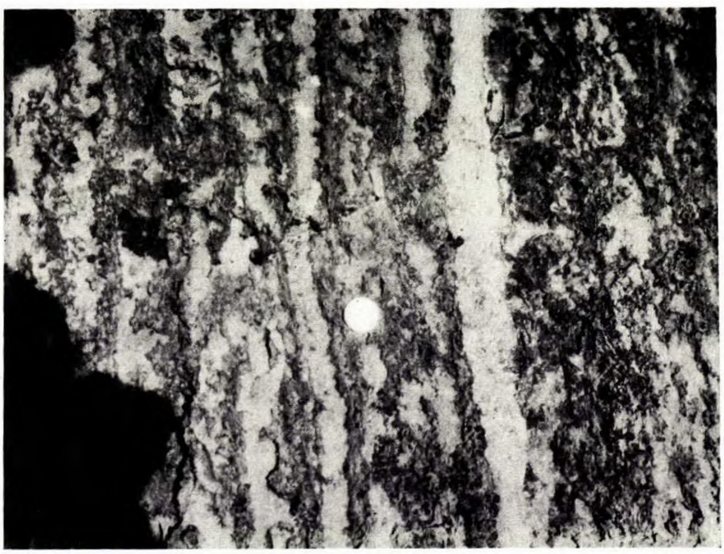
Lower Minnewanka Limestone

This formation is composed chiefly of fine-grained, dark brown dolomite, some of it quite pure, some of it shaly, and much of it filled with chert. In general it shows little promise as a source of dolomite for chemical purposes. The best quality of stone is in the middle part of the formation, which is composed of massive-bedded dolomite usually exposed in steep cliffs well up on the mountainsides, where it cannot be readily obtained. The lower part of the formation is thin-bedded and contains much quartzite and impure high-calcium limestone. Sections of this formation are exposed on the mountainside north of the west end of Lac des Arcs, on the east side of Sulphur mountain, on the ridge between Johnston creek and the base of Castle mountain, and in a number of less accessible localities. A wide variation in the quality and type of stone was observed in the different localities.

The only place where any use has been made of the Lower Minnewanka dolomite is at Castle station, where a small quarry was opened a number of years ago to supply stone for lime-burning. Some of the dolomite averages only about 1 per cent total impurities, but it is interbedded with high-calcium limestone and siliceous magnesian limestone, so that operations can be conducted only on a small scale. The Sulphur Mountain section contains the greatest amount of relatively pure dolomite free from interbeds of undesirable stone that was observed, but conditions are unfavourable for either quarrying or mining.

[1] Warren, P.S.: Geol. Surv., Canada, Mem. 153, p. 11 (1927)

A. Banded Carboniferous limestone, Kananaskis, Alberta. The light-coloured rock is high-calcium limestone, the dark-coloured is heavily mottled with magnesian material.



B. Close-up view of the weathered surface of the limestone mottled with magnesian material

Upper Minnewanka Limestone

This formation is of potential importance as a source of high-calcium limestone for making cement and lime. It is composed principally of heavily bedded, grey and blue, fine-grained, high-calcium limestone in which, parallel to the bedding, are zones containing magnesian material (Plate XV A, page 91). This material is of sugary texture, brown, and more resistant to weathering than is the limestone, and usually projects on the weathered surfaces as an irregular network (Plate XV B, page 91). On fresh fracture it shows as a faint brown mottling. Minor amounts of black chert are noticeable in some sections, and thin siliceous beds were also observed, but rarely are these impurities sufficiently in evidence to constitute a serious drawback. The magnesian bands are the main undesirable feature. They vary from a few inches to many feet in thickness, and rarely is there more than 40 feet of limestone altogether free from them. The above refers to the normal occurrence of the Upper Minnewanka limestone as seen in the vicinity of Kananaskis and at Exshaw. Some sections are composed almost entirely of the magnesian mottled stone, and on Sulphur mountain the Upper Minnewanka is largely dolomite. Overlying the Upper Minnewanka is a shale formation and usually the limestone becomes increasingly shaly towards the top.

Upper Minnewanka Shale

This formation consists largely of shale and contains no limestone of economic importance.

Rundle Limestone

The limestone of this formation differs from the Upper Minnewanka limestone largely in the matter of impurities. The mottled magnesian bands are not in evidence, but silica in the form of chert nodules is a characteristic feature. The lower part of the formation is composed chiefly of dark grey, fine-grained, high-calcium limestone in which chert nodules are so plentiful as to render the stone worthless for any chemical or metallurgical purpose (Plate XVI A, page 99). A few light grey, coarser grained, chert-free beds also occur in this lower part, but it is only in the middle and upper parts of the formation that they become of sufficient thickness to be of economic importance. Interstratified with this bed and becoming more numerous towards the top of the formation are beds of siliceous limestone and dolomite. The overlying formation is the Rocky Mountain quartzite. A thickness of 100 feet of coarse-grained, grey, high-calcium limestone, entirely free from chert or siliceous beds, was observed on Grotto mountain. A 75-foot thickness of the dark, fine-grained limestone free from these undesirable features was also observed. Usually the belts of pure stone occur between equally thick or thicker belts of impure stone. The siliceous beds may not be visible in weathered outcrops. They weather more rapidly than the pure limestone, and are found in shallow depressions generally covered by earth or leaves.

The Rundle limestone was examined on Rundle, Stoney Squaw, Tunnel, and Grotto mountains. The various sections differ in detail, but have a general resemblance. The difference in detail arises from the varying thickness of the beds which, in places, pinch out. In no two places a few hundred feet apart is the succession of beds exactly the same.

In chemical composition the chert-free stone is usually remarkably pure, containing from 95 to 98 per cent calcium carbonate.

Rarely is the better grade of limestone of this formation found in places where it can be readily quarried. It is usually exposed high on the mountains where, owing to its massive bedding and uniform composition, it forms steep cliffs. On the lower slopes it is usually overlain by the succeeding Rocky Mountain quartzite. In only one locality in the Banff area has the Rundle limestone been utilized, and that is on the south slope of Grotto mountain at The Gap, where prior to 1914 it was quarried for use in making Portland cement and lime.

Rocky Mountain Quartzite

The term "quartzite" is a misnomer when applied to this formation, which overlies the Rundle limestone, as it consists in very large part of sandy and cherty dolomite with only occasional beds of true quartzite. The formation has a wide variation in composition from bed to bed, and according to Warren[1] has a thickness of about 700 feet. As he states, the formation is usually found on the western slopes of the Rocky mountains. It weathers easily, however, and is usually covered by soil and talus, and good exposures are rare. No samples were taken, but from an examination of outcrops at Banff and in Crowsnest pass it appears that some parts of the formation would yield material suitable for making rock wool.

Triassic Limestone

The only limestone in the Triassic system in Alberta is that of the Spray River formation, the type locality for which is along the Spray river at Banff. This formation, according to Warren,[2] has a thickness of over 3,000 feet. It consists mostly of black shale, but at intervals through it are bands of impure, black, magnesian limestone. Like all impure limestones these limestone bands weather rapidly and there are few good exposures. There appears to be a wide variation in the composition of the various limestone bands. It is probable that rock suitable for making rock wool will be found in the Spray River formation.

PRODUCTION AND UTILIZATION OF LIMESTONE IN ALBERTA

Statistics on the production of limestone and lime are given in Tables VI and VII, and are shown graphically in Figures 3 and 4. Data prior to 1921 were obtained from the records of the Mines Branch; and for 1921 and subsequent years, from the records of the Dominion Bureau of Statistics.

The chief products from the Alberta quarries are stone for the making of Portland cement, for lime manufacture, for use in beet-sugar refineries, for flux, and for incorporation into livestock foods. Smaller quantities of limestone are processed for use as poultry grit, stucco dash, and road metal, and for use in the dusting of coal mines, in coal-washing plants, and for several chemical uses. Building stone for local use is produced as the demand arises.

The present production comes from the high-calcium limestones of the Devonian and Carboniferous formations, the centres of production being at Exshaw, Kananaskis, and Crowsnest pass. A small quantity of lime for local use is made at Cadomin.

Lime was formerly made at a number of places in the Rocky mountains, along the lines of the railways, but the industry is now centralized at Crowsnest pass and at Kananaskis, where white lime suitable for chemical uses is produced.

The Portland cement industry is established at Exshaw. Formerly, cement plants were in operation at Blairmore, Calgary, and at Marlboro.

Dolomite of excellent purity is available in the Rocky mountains but it is not being used at present, and in the past was used only in small quantities for making lime.

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1 Warren, P. S.: Geol. Surv., Canada, Mem. 153, p. 34 (1927).
2 Warren, P. S.; Op. cit., p. 39.

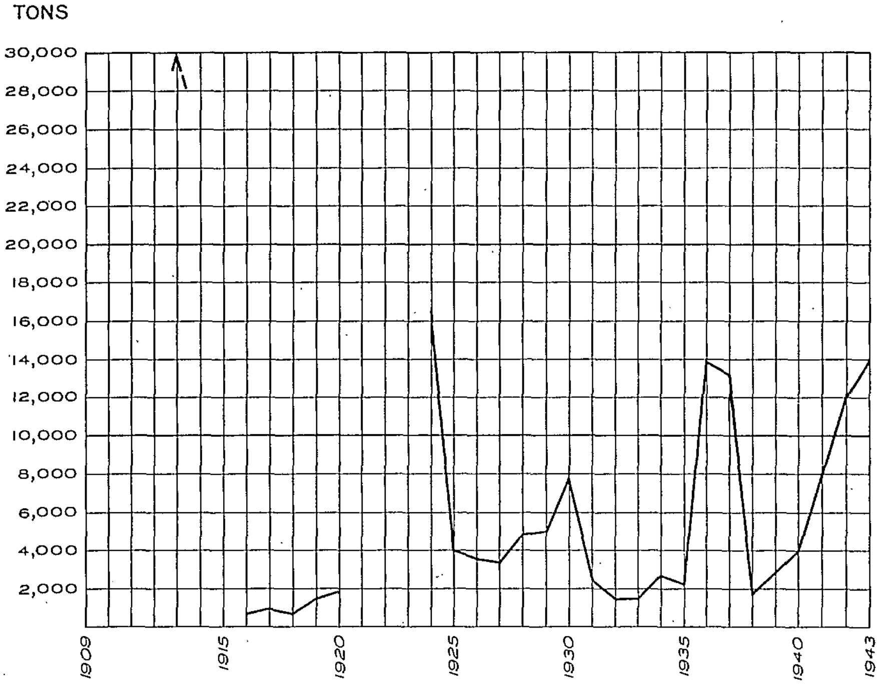


FIGURE 3. Production of limestone in Alberta.

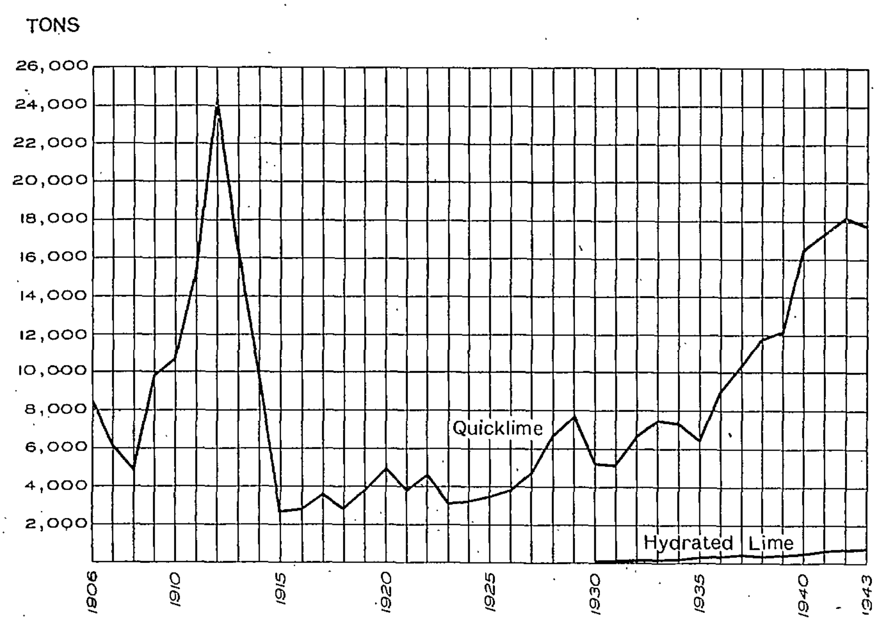


FIGURE 4. Production of lime in Alberta.

TABLE VI

Production of Limestone in Alberta

Year	Limestone	
	Tons	Value
		$
1908	....	....
1909	....	....
1910	....	....
1911	....	....
1912	....	....
1913	30,000	20,000*
1914	....	....
1915	....	....
1916	643	257
1917	960	672
1918	643	569**
1919	1,469	1,689***
1920	1,837	2,531
1921	....	....
1922	....	....
1923	....	....
1924	16,418	16,762
1925	3,979	6,868
1926	3,545	5,826
1927	3,367	7,830
1928	4,852	15,240
1929	4,975	12,046
1930	7,786	17,236
1931	2,429	5,842
1932	1,428	2,985
1933	1,472	4,317
1934	2,737	8,104
1935	2,242	6,981
1936	13,876	26,188
1937	13,182	24,935
1938	1,691	6,148
1939	2,888	8,166
1940	3,981	11,999
1941	7,942	24,303
1942	12,028	40,436
1943	13,961	47,899

* Railway ballast.
** Glass-making.
*** For use as furnace flux only.

Building stone for use in the neighbourhood of Banff is obtained as the demand warrants from a thinly bedded, very siliceous, magnesian limestone of Triassic age at Banff. It is used only for rock-face ashlar, being too hard for carving and cutting. Small quantities of building stone have been obtained from the limestones elsewhere, but the known deposits of Alberta are not capable of yielding limestone of the colour, texture, size, and workability demanded by the modern cut-stone industry.

TABLE VII

Production of Lime in Alberta

Year	Quicklime		Hydrated Lime		Total Lime	
	Tons	Value	Tons	Value	Tons	Value
		$		$		$
1906	8,400	56,200	....	....	8,400	56,200
1907	6,056	41,225	....	....	6,056	41,225
1908	4,725	34,500	....	....	4,725	34,500
1909	9,839	67,350	....	....	9,839	67,350
1910	10,613	69,268	....	....	10,613	69,268
1911	15,191	100,407	....	....	15,191	100,407
1912	24,641	166,520	....	....	24,641	166,520
1913	16,284	115,355	....	....	16,284	115,355
1914	9,809	58,321	....	....	9,809	58,321
1915	2,595	14,445	....	....	2,595	14,445
1916	2,731	20,033	....	....	2,731	20,033
1917	3,659	35,516	....	....	3,659	35,516
1918	2,814	44,141	....	....	2,814	44,141
1919	3,817	41,276	....	....	3,817	41,276
1920	4,880	72,477	....	....	4,880	72,477
1921	3,748	48,332	....	....	3,748	48,332
1922	4,544	70,992	28	336	4,632	71,328
1923	3,038	37,653	33	346	3,071	37,999
1924	3,143	36,083	14	196	3,144	36,279
1925	3,463	39,852	....	....	3,463	39,852
1926	3,791	39,517	....	....	3,791	39,517
1927	4,571	46,947	....	....	4,571	46,947
1928	6,672	69,588	....	....	6,672	69,588
1929	7,681	79,569	....	....	7,681	79,569
1930	5,123	49,330	13	195	5,136	49,525
1931	5,056	46,047	62	738	5,118	46,785
1932	6,529	55,336	113	1,241	6,642	56,577
1933	7,403	61,061	98	976	7,501	62,037
1934	7,300	64,143	155	1,554	7,455	65,697
1935	6,354	54,803	230	2,305	6,584	57,108
1936	8,879	75,756	250	2,503	9,129	78,259
1937	10,224	89,209	427	4,269	10,651	93,478
1938	11,744	103,922	309	3,090	12,053	107,012
1939	12,113	104,772	386	3,860	12,499	108,632
1940	16,421	145,210	451	4,510	16,872	149,720
1941	17,276	144,556	674	6,740	17,950	151,296
1942	18,117	148,720	704	7,040	18,821	155,760
1943	17,482	142,125	733	7,330	18,215	149,455

ALBERTA MINING LAWS RELATING TO LIMESTONE

Regulations concerning the leasing of lands containing clay, gravel, granite, gypsum, limestone, marl, marble, sand, slate, volcanic ash, or any building stone may be summarized as follows:—

Provincial lands containing any of the above-mentioned minerals may be leased at an annual rental of $1 an acre, payable in advance. These regulations do not apply to school lands or land within any city, etc., unless otherwise specially provided.

The term of the lease is for a period of 21 years, and is renewable for a further period of 21 years.

The maximum area of a quarrying location is approximately 40 acres, and only one location is allowed to one person. A railway company or municipality, requiring material for construction purposes or maintenance of railway or municipal works, may acquire more than one location. The location, if situated in unsurveyed territory, must be staked out according to the instructions contained in the regulations.

The fee for each application for a lease is $5, and the rental is at the yearly rate of $1 an acre.

The lessee must commence active operations within one year from the date of the notification and must quarry out or remove the quantity of the material as specified in the notification.

The royalty payable is whatever may be fixed by Order in Council. The present royalty is at the rate of 5 cents a cubic yard. O.C. 692, 1931.

TABLE VIII

Limestone Quarries in Alberta

Operator	Location of Quarry	Product
Canada Cement Co., Ltd., Box 290, Station B, Montreal.	Exshaw	Portland cement.
M. Errico, Cadomin	Cadomin	Quicklime.
Loder's Lime Co., Ltd., Kananaskis	Kananaskis	Quicklime both in lump form and pulverized, stucco dash, poultry grit, and calcium carbonate flour.
Summit Lime Works, Ltd., Box 273, Lethbridge.	Crowsnest Pass	Lump quicklime, pulverized quicklime, hydrated lime, stucco dash, poultry grit, stone for chemical use, pulverized limestone for dusting coal mines, and for various other uses.

DISTRIBUTION OF LIMESTONES BY DISTRICTS

Kettle Valley Branch of the Canadian Pacific Railway

Between Frank and the British Columbia boundary the Kettle Valley branch of the Canadian Pacific railway passes through the Rocky mountains via the valley of the Crowsnest river that has cut a trench through the mountains at right angles to their axis, thus exposing excellent sections of the Devono-Carboniferous limestone of which the mountains are composed. As elsewhere, the Rocky mountains in this district consist of great tilted fault blocks composed of strata dipping steeply west and having abrupt faces on the east. The only favourable quarry sites are on spurs that extend from the mountains into the valley of the Crowsnest river.

Both high-calcium and magnesian limestones are available, but no quarriable deposits of dolomite were observed. High-calcium limestone is being quarried for lime and for chemical, agricultural, and other uses by Summit Lime Works in Crowsnest pass. Formerly, limestone was quarried at Blairmore for use in the manufacture of Portland cement and lime.

Frank

Southeast of Frank a very large area is covered to a considerable depth with blocks of Carboniferous limestone that fell from Turtle mountain in the great Frank rockslide of 1903. The Frank Lime Company built three draw-kilns at Frank with the intention of using the limestone from the slide for making lime, but it was found impossible to select a sufficiently uniform grade to make a high-grade lime. Much of the limestone available in the slide material is very cherty, some is highly magnesian and siliceous, and only a relatively small proportion is of the pure high-calcium type.

Blairmore

Between Frank and Blairmore is a narrow range of the Rocky mountains, trending north and south, composed almost entirely of Carboniferous limestone. The Kettle Valley branch of the Canadian Pacific railway follows the valley of the Crowsnest river through this range, and on both sides of the railway the limestone is well exposed. The greater part of the limestone is typical of the Rundle formation (Carboniferous), in which hard, grey, fine- to medium-grained, high-calcium limestone alternates with bands of very cherty limestone and siliceous, magnesian limestone. The bands of pure limestone range in thickness from a few feet up to an observed maximum of 40 feet. Owing to the angle of inclination of the strata (65 degrees), and to the fact that the relatively narrow belts of pure stone are separated by wide zones of impure stone, there is in this area little possibility of obtaining large quantities of uniformly pure limestone by quarrying, but underground mining can be employed on some of the wider bands of pure stone.

Just east of Blairmore at the base of Turtle mountain, and on the south side of the railway, is the abandoned quarry of the Rocky Mountains Cement Company, Limited, which began operations in 1909 and closed down in 1915. Previously the quarry was worked to supply a lime plant. On this property the strata strike N. 26° W. and dip southwest at an angle of 65 degrees. The quarry has been worked along the strike for 300 feet into the north face of Turtle mountain and has a face 100 feet high. There is a wide variation in type and quality of the limestone exposed, and several openings were made in search of a wide band of low-magnesia limestone. The widest band observed is in the main quarry, where the succession of strata from west to east is as follows:—

15 feet—Very cherty, fine-grained, bluish grey limestone.
23 feet—Cherty and siliceous, somewhat magnesian limestone.
21 feet—Variable limestone, some high-calcium, and some cherty and otherwise siliceous.
8 feet—Siliceous, fine-grained, bluish grey magnesian limestone that has been left as a wall between the two openings.
40½ feet—Fine-grained, dark grey calcium limestone containing some cherty and magnesian bands. Sample 1 was taken from this band.
40 feet—Medium-grained, grey, highly fossiliferous high-calcium limestone. Sample 1A represents this band.

PLATE XVI

A. Bands and nodules of black chert parallel to bedding planes in Carboniferous high-calcium limestone, Exshaw, Alta.

B. Crowsnest pass, Alberta. The mountains on both sides are composed of Devono-Carboniferous limestone.

18 feet—Composed of 10 feet of very cherty, fine-grained magnesian limestone; 3 feet of coarse-grained, pure high-calcium limestone containing one 3-inch streak of siliceous limestone, and 5 feet of cherty and otherwise siliceous, fine-grained magnesian limestone. Sample 1B was taken across this 18-foot zone excluding chert nodules.

24 feet—Mostly pure, high-calcium, medium-grained, grey, highly fossiliferous limestone. The last 4 feet contains peculiar cavities up to 1 inch in diameter. Sample 1C was taken from this 24-foot section. This is the eastern edge of the quarry.

Eastward from the quarry the outcrops reveal mostly cherty limestone with minor bands of pure high-calcium limestone. West of the quarry the limestone is mostly siliceous, and about 250 feet west are beds of calcareous quartzite with, still farther west, more beds of limestone, and then more shaly and thin-bedded quartzite. It is probable that some of the transition beds between the limestone and the quartzite are approximately of the composition required for making rock wool.

A large draw-kiln for making lime has been built into or in part hewn out of the solid limestone at the southeast corner of the Rocky Mountain Cement Company's quarry. It was in operation prior to the taking over of the property by the company. The plant where the cement was made was 600 feet west of the quarry. It has since been dismantled.

Across the Crowsnest river from the company's property is a small quarry and kiln at the base of Bluff mountain that was worked until 1930 for making lime. A 30-foot band of medium-grained, grey, high-calcium limestone, similar to the best of that exposed in the quarry at the cement plant, occurs at this place. Sample 1X was taken from the 30-foot band. The lime produced was white and of good quality.

Crowsnest Pass

The Kettle Valley branch of the Canadian Pacific railway passes through the Rocky mountains via the Crowsnest pass, which is flanked on either side by mountains of Devono-Carboniferous limestone (Plate XVI B, page 99). The first section of limestone in the pass, close to the railway, is seen at Crowsnest lake, where from just east of a cave from which issues an underground stream (the headwaters of Crowsnest river or Oldman river) the limestone striking N. 55° W. and dipping southwest at an angle of 32 degrees is exposed for over 2½ miles along the track to near the British Columbia boundary (Plate XVII A, page 101).

East of the cave is a thickness of several hundreds of feet of interbedded calcium limestone, dolomite, and shale, the shale becoming increasingly prominent to the eastward until all is shale and shaly limestone. Near the east end of Crowsnest lake the Devono-Carboniferous rocks are in contact with Cretaceous rocks.

Westward from the cave is a band, over 1,000 feet thick, of massively bedded high-calcium limestone and mottled magnesian limestone that extends up the mountain (Plate XVII A, page 101). The basal 150 feet is fine-grained, dark brownish grey, high-calcium limestone, from which Sample 2 was taken.

Above this, and composing most of the lower and central sections of the band, is fine-grained, grey limestone heavily mottled with fine-grained, brown-weathering magnesian material. Sample 2A, taken from a 100-foot thickness of this mottled limestone, shows it to have a lower content of silica than the high-calcium limestone beneath it, but the magnesium carbonate content is midway between that of high-calcium limestone and dolomite. The upper 400 feet of the massive limestone is mostly unmottled, but there are occasional mottled beds. The mottling is always parallel to the bedding and is confined to certain beds.

PLATE XVII

A. Massively bedded Devono-Carboniferous limestone overlying shale, Crowsnest pass, Alta.

B. Heavily bedded Devono-Carboniferous limestone with irregular jointing, East quarry of Summit Lime Works, Ltd., Crowsnest pass, Alta.

Overlying the massively bedded limestone that is free from chert is 700 feet of cherty and shaly limestone and shale which in turn is overlain by 600 feet of extremely cherty, grey, calcium limestone, in which is an occasional band of pure limestone. Succeeding this is 400 feet of medium-grained high-calcium limestone in which are a few cherty beds and beds of siliceous magnesian limestone. At the top of this part of the section are located the quarries of Summit Lime Works.

Summit Lime Works, Limited; Head Office, Lethbridge, Alberta. This company has opened three quarries in the 400-foot band of limestone just referred to. These quarries are all of the side-hill type and are at the same elevation, their floors being about 65 feet above the railway tracks, or level with the tops of the kilns. No. 1 quarry, most easterly of the three, is a short distance east of the kilns and is worked only in winter. It has been worked into the mountainside for 100 feet across a width of 140 feet and has a face 100 feet high. The limestone is medium-grained, light grey, and heavily bedded, but badly fractured (Plate XVII B, page 101). Running through the eastern part of the quarry is a 6-foot band of fine-grained magnesian limestone that is discarded in quarrying. Because of the dip of the strata this magnesian band will pass out of the quarry as the latter is worked back into the mountainside. Sample 3 was taken in this quarry, with the magnesian band excluded.

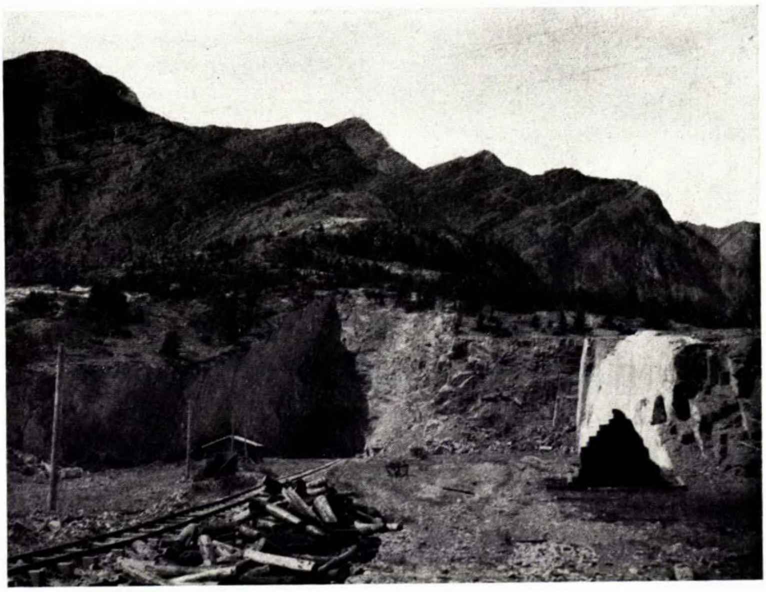
Five hundred and fifty feet west is a small quarry (No. 2) not now used, in which is exposed interbanded high-calcium limestone and magnesian limestone, the latter predominating. In between this and No. 1 quarry are three small openings made to test the rock. In the first, which is 130 feet west of No. 1 quarry, fine-grained, drab magnesian limestone is exposed; in the next, which is 150 feet farther west, interbedded high-calcium limestone and highly magnesian limestone are exposed; and in the third, 200 feet farther west, is medium-grained, grey, fossiliferous high-calcium limestone that crumbles to dust in the kilns and has not been quarried. This pit is separated from No. 2 quarry by 50 feet of magnesian limestone.

No. 3 quarry, which is being operated, is separated from No. 2 quarry by 40 feet of highly magnesian limestone. No. 3 quarry has been worked into the mountainside for 200 feet across a width of 80 feet. The sloping face is now 300 feet high. The limestone is medium-grained, brownish grey, and is in fairly heavy beds that strike N. 45° W. and dip southwest at an angle of 45 degrees. Sample 3A was taken in this quarry across the width of 80 feet. Sample 3B was taken from the magnesian limestone separating No. 2 and No. 3 quarries, and Sample 3C was taken from the cherty magnesian limestone overlying the stone being worked in No. 3 quarry. This cherty limestone extends for 400 yards to the west.

Jackhammers are used in the quarry. Holes 16 feet deep are drilled 12 to 14 feet apart and back 14 feet from the face. They are then sprung at the bottom and loaded heavily with from 75 to 100 sticks of dynamite. Blasted rock is loaded by a gasoline-driven shovel with a $\frac{3}{4}$-yard dipper into 3-ton, end-dump steel cars that are hauled by cable and dumped automatically into a gyratory crusher. The crushed rock is screened to sizes from $\frac{1}{2}$ inch to 6 inches. Rock 1 to 2 inches in size is shipped for glass-making, and rock 2 to 6 inches is shipped to beet-sugar factories. Rock 4 inches to 8 inches in size is used for making lime. Material under 1 inch is further ground and pulverized into various products, including poultry grit, stucco dash; pulverized limestone for use in coal-washing plants and for dusting coal mines; and calcium carbonate flour for use in stock feeds and for other agricultural purposes. Limestone for flux and for road metal is also marketed.

PLATE XVIII

A. Part of plant of Summit Lime Works, Ltd.. Crowsnest pass, Alta.



B. Quarry of Loder's Lime Company, Ltd., in Devono-Carboniferous limestone, Kananaskis, Alta.

The lime plant (Plate XVIII A, page 103) consists of four vertical kilns with a total capacity of 70 tons of lime a day; two of the kilns, Nos. 3 and 5, each have a capacity of 25 tons a day, and Nos. 2 and 4 can each produce 10 to 12 tons a day. Kilns Nos. 3 and 5 are equipped with semi-gas producers and with both forced and induced draught. Kilns Nos. 2 and 4 have semi-gas producers and natural draught. The lime produced is white and is marketed as lump lime in 190-pound barrels; as pulverized quicklime (processed lime) in 60-pound multi-wall bags; and as hydrated lime in 50-pound and 25-pound multi-wall bags. The hydrating equipment has a capacity of 3,000 pounds an hour and is of the company's own design.

On the southern side of the pass, steeply dipping beds of cherty limestone, mottled magnesian limestone, high-calcium limestone, and black shale are exposed along the highway for a mile opposite Crownsnest lake. East of Glacier creek is a band of high-calcium limestone in a quarriable position.

On the north side of the pass and westward from the company's quarry, limestone is exposed adjacent to the railway for 1½ miles to the contact with the overlying quartzite. It dips southwest at angles of from 35 degrees to 45 degrees. Most of the limestone is of the cherty calcium type and there are lesser thicknesses of high-calcium limestone and of impure, highly magnesian limestone. Four of the bands of pure limestone are worthy of special mention. The first two of these are just opposite the east end of Island lake, where one forms a spur of rock jutting out from the mountain to the east, and rises to a height of about 600 feet. At the base of this spur, on the west side, cherty limestone occurs overlying the pure limestone, but above this the entire spur consists of medium-grained, light grey, high-calcium limestone. The aggregate thickness of the beds of pure stone is at least 150 feet. There is little soil on the spur and its eastern flank is almost a cliff. Sample 4 was taken from the strata composing the spur. Underlying this is a mashed limestone formation having the appearance of a conglomerate, and large limestone boulders protrude from the outcrops. This in turn is underlain by 100 feet of medium- to coarse-grained, light grey high-calcium limestone comprising the other band referred to, and represented by Sample 4A. From here east to the company's quarry the limestone exposed is cherty and otherwise impure.

The other two prominent bands of pure limestone are opposite the island in Island lake. They are in a less favourable position for quarrying, however, as are the bands just described. The westernmost of these two bands is exposed on the western slope of a hill and is about 40 feet thick. It consists of fine-grained, dark blue limestone and is represented by Sample 5. It is overlain by shaly limestone and underlain by cherty limestone, strikes N. 40° W., and dips southwest at an angle of 35 degrees. Two hundred feet east is the second band, consisting of 30 feet or more of medium-grained, light grey high-calcium limestone. It is exposed in the western side of a valley leading from a tiny lake at the base of the mountain to Island lake. The strike and dip are the same as those of the band above it. Thus, it dips into the hillside and can be made available only by mining. Sample 5A was taken from this band.

From this locality to the interprovincial boundary only impure magnesian limestone and siliceous calcium limestone are exposed. The contact with the overlying quartzite is near the boundary.

Analyses of Limestones along the Kettle Valley Branch of the Canadian Pacific Railway between Frank and the British Columbia Boundary

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
1........	1·00	0·08	0·20	0·22	88·91	10·21	100·62	0·06	49·91	4·88	10 : 1
1A......	0·62	0·07	0·07	0·11	96·52	2·83	100·22	Tr.	54·11	1·35	40 : 1
1B......	8·38	0·17	0·21	0·09	64·75	27·27	100·87	0·03	36·37	13·04	2·8 : 1
1C......	0·18	0·04	0·12	0·09	98·87	1·20	100·50	Tr.	55·42	0·57	97 : 1
1X......	0·70	0·04	0·18	0·11	97·23	2·36	100·62	Tr.	54·51	1·13	48 : 1
2........	1·04	0·20	0·42	0·02	96·34	2·01	100·03	0·03	53·96	0·96	56 : 1
2A......	0·46	0·15	0·35	0·02	77·41	22·30	100·69	Tr.	43·36	10·66	4 : 1
3........	0·42	0·06	0·08	0·09	97·84	1·90	100·39	Nil	54·82	0·91	60 : 1
3A......	1·04	0·09	0·19	0·11	96·81	1·98	100·22	Nil	54·24	0·95	57 : 1
3B......	2·66	0·21	0·39	0·09	68·29	29·15	100·79	0·02	38·29	13·94	2·7 : 1
3C......	6·82	0·35	0·55	0·09	60·23	32·62	100·66	0·03	33·78	15·60	2·2 : 1
4........	0·58	0·18	0·10	0·07	97·00	2·34	100·27	Tr.	54·36	1·12	49 : 1
4A......	0·50	0·06	0·08	0·11	98·25	1·62	100·62	Nil	55·08	0·77	72 : 1
5........	0·64	0·17	0·13	0·04	94·66	4·22	99·84	Tr.	53·02	2·02	26 : 1
5A......	0·80	0·03	0·17	0·04	97·84	1·30	100·18	Nil	54·82	0·62	88 : 1

1.	Blairmore.	Quarry of Rocky Mountain Cement Company, 40½ feet of fine-grained, dark grey Carboniferous limestone at west wall.
1A.	"	Same quarry; adjoining 40 feet to east of medium-grained, highly fossiliferous limestone.
1B.	"	Same quarry; next 18 feet of cherty, fine-grained limestone.
1C.	"	Same quarry, next 24 feet of medium-grained, grey limestone.
1X.	"	Carboniferous limestone in small quarry formerly worked for lime on opposite side of Crowsnest river, from the quarry formerly worked for cement.
2.	Crowsnest pass.	Basal 150 feet of fine-grained, dark brownish grey Devono-Carboniferous limestone exposed by track at source of Crowsnest river.
2A.	" "	One hundred-foot thickness of mottled magnesian limestone overlying the above.
3.	" "	Devono-Carboniferous limestone in No. 1 quarry of Summit Lime Works, Ltd.
3A.	" "	Devono-Carboniferous limestone in No. 3 quarry of the same company.
3B.	" "	Magnesian limestone separating No. 2 and No. 3 quarries of this company.
3C.	" "	Cherty magnesian limestone overlying that worked in No. 3 quarry of Summit Lime Works.
4.	" "	Light grey, medium-grained Devono-Carboniferous limestone composing a spur from the mountain opposite the east end of Island lake.
4A.	" "	Similar appearing limestone underlying the above and separated from it by conglomeratic limestone.
5.	" "	Fine-grained, dark blue limestone exposed opposite the island in Island lake.
5A.	" "	Medium-grained, light grey limestone exposed 200 feet to the east of the above.

Main Line of the Canadian Pacific Railway

Limestones ranging from high-calcium limestone to dolomite and from less than 1 per cent total impurities to very impure are available along the Canadian Pacific railway between Kananaskis and the British Columbia boundary. They range in age from Cambrian to Triassic, but are mostly Devonian or Carboniferous. Dolomite is particularly prevalent in the Devonian formations. At Exshaw the limestone is being quarried for use in making Portland cement and it was formerly quarried for the same purpose at The Gap. High-calcium lime is being made at Kananaskis, and building stone for local use is obtained from limestone on the Spray river at Banff.

Radnor

On the north side of Bow river, opposite the station of Radnor, is a deposit of pale brown calcareous tufa on the lower part of the river bank for a distance of 200 feet along the river. The deposit apparently has come from a series of small springs that occur about halfway up the bank at the contact between shale beds and the overlying gravel. Much of the tufa is soft and crumbly but near the river's edge some of it is hard and coherent, and it is here that the tufa attains a maximum observed thickness of 8 feet. Elsewhere the deposit is much thinner, in many places being only 1 or 2 feet thick. The solid parts have a cellular structure somewhat similar to that of Italian travertine, and some was quarried in 1939 by Mr. E. J. Couch of Calgary for use as a decorative stone. Sample 6 was taken from the solid beds at the river's edge.

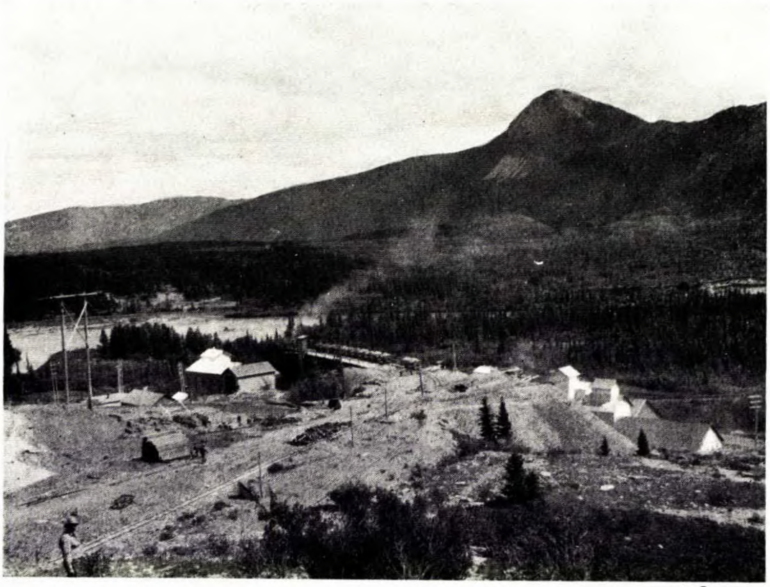
Kananaskis

At Kananaskis the Devono-Carboniferous limestone composing the major part of the first range of the Rocky mountains is well exposed close to the railway, which passes through the mountains via the valley of the Bow river. For 6 miles, from Kananaskis to The Gap, the river has cut through the mountains almost at right angles to their axis, and excellent sections of the strata are exposed. The easternmost mountain, just north of the railway at Kananaskis, is composed very largely of pure dolomite with lesser bands of high-calcium limestone interbedded with mottled magnesian limestone at the summit and the base. The strata strike N. 60° W. and dip at an angle of 35 degrees southwest. The dolomite is mostly fine-grained, steel-blue and dark brown, and in broken beds up to 6 inches in thickness, but one band 70 feet thick was observed that was coarse-grained and light grey. Sample 7 was taken across a 200-foot band of steel-blue dolomite that weathers grey, Sample 7A was taken from a 500-foot width of the brown, rusty-weathering dolomite, and Sample 7B from a 70-foot band of the light grey dolomite. Some of the dolomite is in large lenticular masses rather than in bands of great length, and when traced along its strike the dolomite turns abruptly into high-calcium limestone. Sample 7C was taken from the high-calcium limestone at a distance of 3 feet from where the stratum changed abruptly from dolomite similar in composition to Sample 7B. In the 3-foot transitional zone, dolomitization was in evidence along bedding planes and fractures. The dolomite lenses are, however, very large. Some cherty bands were observed, but they are thin and infrequent and thicknesses of hundreds of feet of strata are free from chert. Some bands of high-calcium limestone mottled with dolomite, similar to that illustrated in Plates XV A and XV B, page 91, also occur.

Loder's Lime Company, Limited, Kananaskis. This company has been producing lime from Devonian limestone at Kananaskis since 1880, when the original plant was built east of Kananaskis station. The present plant is about $\frac{3}{4}$ mile west of the station and just north of the railway. At this place a low spur of high-calcium limestone and dolomite projects in a southerly direction from the mountain to the railway. The high-calcium portion of this spur is being quarried for use in making lime. The quarry is about 500 feet north of the plant and the floor is level with the tops of the kilns. A narrow gauge railway runs from the quarry to the charging floor of the kilns. The quarry is 700 feet long and 150 feet wide, but only half of this width is being worked. It is being extended along the strike northwestward toward the mountain (Plate XVIII B, page 103). The present face is 90 feet high and will increase in height as the quarry is continued to the northwest. The strata strike N. 55° W. and dip southwest at 75 degrees. A fault plane forms the western wall of the quarry. A section across the quarry from west to east is as follows:—

6 feet—Nearly black, fine-grained high-calcium limestone. Sample 8.
13 feet—Fine-grained, dark grey high-calcium limestone with a narrow band that is faintly mottled with magnesian material. Sample 8A.
22 feet—Grey, fine-grained high-calcium limestone. Sample 8B.
22 feet—Light grey, fine-grained high-calcium limestone. Sample 8C.

PLATE XIX



A. Plant of Loder's Lime Company, Ltd., Kananaskis, Alta.

B. Heavily bedded, steeply dipping Devono-Carboniferous limestone in quarry of Canada Cement Company, Ltd., Exshaw, Alta.

Only the eastern half of the quarry is being worked to obtain stone for making lime. The limestone in the western half has a varying content of magnesium carbonate and has not been worked in recent years. In the past it was quarried and burned separately for use as masons' lime, in which a relatively high magnesia content is not detrimental. The section continues:—

10 feet—Fine-grained, grey high-calcium limestone mottled with dolomite. Sample 8D.
15 feet—Fine-grained, steel-grey dolomitic limestone that is discarded for all purposes. Sample 8E.
40 feet—Fine-grained, dark grey limestone mottled with dolomite. Sample 8F.
23 feet—Fine-grained, nearly black limestone. Sample 8G.

The high-calcium limestone on the western side of the quarry makes a white lime, whereas the magnesian limestone on the east side makes a cream-coloured lime.

West of the quarry the limestone includes narrow zones mottled with dolomite, but 72 feet west is an irregular band 66 feet wide of cream-coloured, very pure high-calcium limestone. Another band of the pure, cream-coloured limestone occurs 150 feet west of this, and a small quarry was at one time opened in it near the bottom of the hill southwest of the present quarry. These light-coloured bands are irregular in their trend and cut across the stratification.

The stone is quarried with jackhammers and after being broken to a size range of from 6 to 8 inches is loaded by hand into side-dump steel cars holding $2\frac{1}{2}$ tons, which are pulled by horse to the kiln. The empty cars run back to the quarry by gravity.

The lime plant (Plate XIX A, page 107) consists of three vertical draw-kilns, two of which are wood-fired and have capacities of 7 to 8 tons of lime a day. The third kiln was rebuilt in 1944 and is equipped with an Azbe centre burner and integral gas producer using local coal for fuel. It is equipped with both forced and induced draught, is 50 feet high, has an area of 50 square feet at the burning zone, and a capacity of 30 tons of lime a day.

The lime produced is very white. It is marketed in the lump form packed in barrels or in bulk; and as "Sno-white Processed Lime", which is all pulverized to minus 200 mesh.

Spalls from the quarry are used in a crushing and grinding plant for the production of poultry grit, stucco dash, and calcium carbonate flour, the last being used chiefly as an ingredient of stock food.

Exshaw

At Exshaw the *Canada Cement Company, Limited* is quarrying limestone for the manufacture of Portland cement from a hill of Devono-Carboniferous limestone just west of the village and adjacent to the railway. The hill is composed of strata striking N. 60° W. and dipping southwest at an angle of 45 degrees. It is 600 feet high and 1,200 feet across the base at right angles to the strike. The quarry is opened along the southwestern flank of the hill and is being extended northwesterly along the strike (Plate XIX B, page 107). It has been worked for 250 feet into the hillside and the sloping wall at the side of the quarry is 450 feet high. Approximately 100 feet of strata relatively low in magnesia are being worked. This series of beds is overlain at the edge of the hill by a toe of mottled magnesian limestone and is underlain by strata too high in magnesium carbonate for use in cement-making. The 100 feet of strata being quarried consist mainly of hard, brittle, fine-grained, dark grey high-calcium limestone, together with minor beds that are mottled with dolomite. The bedding is heavy and individual beds up to 3 feet thick are common. Sample 9 was taken, where opportunity offered, across the 100 feet of strata being quarried for use in the plant. It does not represent all the strata as it was impossible at the time to reach all the beds. Some of the beds are undoubtedly lower in magnesium carbonate than the analysis shows, for several magnesian beds occur interstratified with the others, thus raising the magnesium carbonate content of the whole.

The succession of beds beneath the series being quarried is as follows:—

20 feet—Heavily bedded, fine-grained nearly black limestone partly mottled with dolomitic material. At the top of this part of the section is the prominent bedding plane that forms the sloping wall of most of the quarry. Sample 9A.

5 feet—Finely granular, hard, steel-grey, highly magnesian limestone mostly in one bed. Sample 9B.

30 feet—Fine-grained, very dark grey limestone in beds up to 3 feet thick, some of which are mottled with dolomite. Calcite occurs as cavity fillings and in short veins. Sample 9C.

8 feet—Dark blue, fine-grained limestone mottled heavily with brown dolomitic material and in beds up to 3 feet thick. Sample 9D.

18 feet—Fine-grained, dark grey limestone lightly mottled with dolomitic material. Sample 9E.

At the edge of the hill a maximum thickness of 50 feet of the mottled magnesian limestone overlies the beds being worked, for about 60 feet up the hill, after which it disappears, because the dip of the strata is steeper than the slope of the hill. Sample 9F was taken from this toe of magnesian rock.

The coyote-hole system of blasting is used in the quarry. Several tunnels 60 feet long are driven one above the other into the rock along the strike of the strata at the sloping base of the beds to be blasted off the hillside. Chambers capable of holding eighty-five 50-pound cases of 60 per cent dynamite are made at the ends of the two upper tunnels, and one capable of holding one hundred cases is made on the bottom tunnel. By this means a very large tonnage of rock is brought down twice a year. Much secondary blasting is necessary to break up the large pieces obtained by this method from the heavily bedded rock. The broken rock is loaded on to 12-ton, side-dump, steel cars by an electric shovel with a 2¼-yard dipper and mounted on caterpillar treads. The cars are hauled over a standard-gauge track, in trains of two, by a gasoline locomotive to the crushing plant. From the No. 11 McCully gyratory primary crusher the rock is passed to a Pennsylvania hammer mill that reduces the limestone to 1-inch size, after which it is dried before being pulverized in ball mills and tube mills.

Three rotary kilns are installed at the plant, which is in process of being changed over from the dry to the wet process. The two kilns now in use are each 150 feet long and 9 feet 6 inches in inside diameter. They have a combined capacity of 2,000 barrels a day. A new kiln for use with the wet process is installed. It is 278 feet long and 10 feet in inside diameter, and will have a capacity of 2,000 barrels a day.

The remainder of the strata composing the hill in which the company's quarry is situated is very similar to the strata above described as being immediately beneath the quarry, except that magnesian beds seem to be more numerous. A band of dolomite 10 feet thick runs along the ridge of the hill, and along the east side of the hill is more dolomite, one band being 40 feet thick. Beneath this thick band of dolomite is cherty limestone.

Westward from the quarry the limestone becomes progressively more impure and shaly, and in places is dolomitic. At the sharp bend in the road about ½ mile west of the quarry, only shale is exposed. Possibly some of the shaly limestone in this vicinity is of the composition required for making rock wool.

Westward from here, to beyond the west end of Lac des Arcs, shaly, impure limestone and shale, with an occasional band of pure limestone, is exposed. The strata strike N. 60° W. and dip southwest at an angle of 45 degreees. This shaly limestone and shale is overlain by thin-bedded, fine-grained, nearly black dolomite containing yellow chert. Above this, however, is a great thickness of fine-grained, dark blue and dark brown dolomite. Sample 10 was taken from a band 40 feet thick of blue-grey, medium-grained dolomite enclosed in the dark-coloured dolomite and exposed in a quarriable position north of the highway and opposite the centre of a small lake (Gap lake) that lies between the highway and the railway west of Lac des Arcs.

Northeast of where Sample 10 was taken, and 500 to 600 feet higher up, is a prominent spur composed largely of fine-grained, dark blue high-calcium limestone in faulted contact with overlying mottled magnesian limestone to the west. Sample 10A was taken from the high-calcium limestone, and Sample 10B from the mottled magnesian limestone. The strata dip only at an angle of 18 degrees southwest.

The Gap

On the southern slope of Grotto mountain, and about 250 feet above the railway, the Alberta Portland Cement Company opened quarries in the Carboniferous limestone to supply its plant in Calgary, which operated from 1906 to 1914, after which it was dismantled. Nearby is a small quarry from which limestone was obtained for two lime kilns known locally as The Gap Lime Works; but it has not been in operation since 1913.

The quarries are opened on two ridges of limestone trending along the side of the mountain parallel to the strike of the limestone, which is N. 68° W. The dip is south at 45 degrees. The ridges are faced with high-calcium limestone that overlies cherty and magnesian limestone. This facing is 75 feet thick on the lower of the two ridges, but on the upper ridge, separated from the lower by 100 feet of cherty limestone and siliceous dolomite, the pure limestone is only 20 feet thick. Several quarries have been opened along the ridges, which can be traced for over a mile west along the face of the mountain. The main quarry is 340 feet long, 75 to 100 feet wide, and a maximum thickness of 75 feet of strata has been worked. The limestone is very fine-grained, dark bluish grey, and is in massive, indistinct beds flecked with tiny crystals of black calcite. At the sloping back or base of the quarry is about 10 feet of limestone that contains numerous peculiar pock-marks 1 to 1½ inches in diameter. These tiny pockets are filled with tiny loose calcitized fossils that eventually wash away, leaving the pocks. Most of the limestone emits a fetid odour on being struck with a hammer. Sample 11A was taken from the top 25 feet of strata exposed in the quarry, and Sample 11B from the bottom 50 feet.

In the second and higher ridge several small openings were made, but only 20 feet of limestone is free from chert and it is not so pure as the limestone in the lower ridge. Sample 12 is representative of the upper 18 feet of strata in one of these quarries, and Sample 12A of 5 feet of cherty limestone, excluding the chert nodules themselves. This limestone is similar in appearance to that in the lower ridge and is overlain by cherty calcium limestone.

Banff

Some excellent sections of Devonian and Carboniferous limestones are exposed in and around Banff and although the limestones in this locality are not likely to be quarried they were examined and sampled in order to determine the quality of limestone in the mountains of the vicinity and in nearby areas where it may occur, and which may become accessible in the future.

On the west face of Tunnel mountain, just east of the Lookoff, is an area in which siliceous dolomite and moderately pure magnesian limestone are much intermingled. All indications point to a dolomitization and silicification of the calcium limestone at this place. Warren[1] has mapped this particular limestone as being of Carboniferous age (Rundle formation). A partial analysis shows the dolomite to contain about 13 per cent of silica.

[1] Warren, P. S.: Geol. Surv., Canada, Mem. 153 (1927).

On the south end of Tunnel mountain an excellent section of the limestone of the upper part of the Carboniferous (Rundle formation) is exposed and has been measured in detail by Warren[1]. Of the vertical thickness of 2,400 feet of limestone here exposed, striking N. 55° W. and dipping southwest at an angle of 55 degrees, very little is of economic interest because of its variable nature. The bottom half of the formation is extremely cherty and consists of interbedded calcium limestone and siliceous dolomite. Much of the calcium limestone is impure. The beds are uneven in thickness and are mostly lenticular and can be traced only a short distance. In the upper half of the Rundle formation, as here exposed, chert is much less common, and there are some thick bands of relatively pure limestone composed of alternate beds of fine-grained, dark grey limestone containing from 1 to 3 per cent of silica, and of coarse-grained, light grey limestone containing, as a rule, less than 1 per cent of total impurities and less than 2 per cent of magnesium carbonate. Sample 13 represents the coarse-grained limestone from several beds, and Sample 13A the fine-grained variety. These samples are not representative of a quarriable thickness of the limestone, and there is probably a wider variation in quality than the two samples indicate. At the top of the formation are beds of sandy magnesian limestone from which Sample 13B was taken. The silica content of this magnesian limestone is much greater higher up in the formation, as there is a gradual transition from limestone to quartzite. Undoubtedly, some of the dolomitic quartzite has the proper composition for use in making rock wool. This formation is seldom well exposed, as it weathers easily and is usually covered by soil. It is found on the western slopes of the Rockies.

A section of Lower Devonian limestone is exposed on the east face of Sulphur mountain. Warren's[2] measurement of this section gives it a thickness of 1,968 feet. The lower 300 feet or so consists of thin-bedded impure limestone, impure dolomite, and magnesian limestone, all interbedded. Chert nodules are conspicuously absent. Above this is nearly 1,000 feet of massively bedded, moderately pure, fine-grained, grey, blue, and dark brown dolomite, also free from chert. The upper 250 feet consists of thinly bedded, light grey dolomite. Sample 14 was taken at intervals from the massively bedded dolomite composing the main part of the section.

Above this section is a further 1,000 feet of similarly appearing dolomite. It is well exposed in a gully on the east face of Sulphur mountain, south of the Upper Hot spring. Sample 14A was taken from this exposure at intervals over the full 1,000 feet.

Three-quarters of a mile up the Spray river from where it joins the Bow, fine-grained, siliceous, very dark grey magnesian limestone is exposed on the east bank of the river, where it has been quarried for local use as a building stone. The strata strike N. 55° W., or along the river bank, and dip at an angle of 60 degrees southwest, or toward the river, thus forming a steeply sloping bank over 100 feet high for several hundred yards. The beds range from 1 to 16 inches in thickness and are separated by 1 to 2 inches of shale. About 20 feet of strata have been quarried along the sloping face for a distance of 700 feet. Frequent joints occur at right angles to the bedding, and the stone is quarried by crowbars and allowed to slide to the bottom of the bank. When quarried the limestone is nearly black, but on exposure to the weather it turns brown. Sample 14B was taken across the 20 feet of strata that had been quarried, but the interbedded

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[1] Warren, P. S.: Op. cit., p. 28.
[2] Warren, P. S.: Op. cit., p. 16.

shale was not included. The stone was used for facing the Banff Springs Hotel, the Cave and Basin bath-house, and for a number of government buildings in Banff.

Sawback

A good cross-section of Cambrian limestone (Sawback formation) is exposed on the southern slopes of Mt. Edith north of the highway and railway. The formation consists of dolomite, impure calcium limestone, shale, and some quartzite. Along the southern slopes of Mt. Edith the Cambrian strata are exposed in beds striking N. 30° W. and dipping southwest at angles of 60 degrees and steeper. The dolomite appears to be the only part of the formation of commercial interest. Some of it is very pure. It forms prominent ridges that can be quarried. In between these ridges are the shales and impure calcium limestones that have weathered much more rapidly than the dolomite. These strata are exposed for more than 1,500 yards westward from the eastern edge of Mt. Edith and are close to the highway and railway. The lowest beds exposed, as seen on the eastern edge of Mt. Edith, are siliceous, finely granular, light blue dolomite veined with a network of white dolomite and quartz stringers, but from the first prominent valley in the mountainside westward the dolomite as exposed in the ridges is of a good grade. Sample 15 was taken from the siliceous dolomite near the base of the formation. Sample 15A was taken from fine-grained, brown dolomite overlying the siliceous dolomite. Sample 15B was taken from a prominent ridge of fine-grained blue dolomite on the eastern edge of a valley formed in a wide band of shale overlying the blue dolomite. Sample 15C represents 80 feet of coarse-grained, light grey dolomite forming the centre or crest of a ridge of vertically dipping, fine-grained, nearly black dolomite that rises on the west side of the same valley. This valley is just opposite the sharp bend in the highway $\frac{1}{2}$ mile west of the trail going northward between Mt. Edith and Mt. Norquay. The ridge forms the divide between two prominent gullies in the mountainside. Sample 15D is of the nearly black dolomite flanking the light grey dolomite.

The upper beds of Cambrian limestone as here exposed become increasingly siliceous towards the top, and though they consist mainly of dolomite there is some impure calcium limestone, calcareous quartzite, and shale.

At the eastern edge of Mt. Hole in the Wall, west of the section just described, is a band of impure calcium limestone 200 feet thick striking N. 40° W. and dipping southwest at an angle of 75 degrees. Sample 16 was taken from this band. West from here is shaly and fractured limestone for a considerable distance. This is succeeded by fine-grained siliceous dolomite, some of which is massive, some thin-bedded, and some contains nodules of blue chert. Occasional beds of very sandy dolomite also are present. This assemblage of strata forms the main part of Mt. Hole in the Wall. On the western edge of this mountain, however, is calcium limestone, most of which is mottled with dolomite. The unmottled limestone overlies the mottled, which is overlain by shale.

Johnston Canyon

Johnston creek, 3 miles east of Castle Mountain station on the Canadian Pacific railway, has cut a deep canyon through Cambrian limestone which strikes N. 60° W. and dips at angles of from 15 to 25 degrees northeast. The limestone is medium-grained, brownish grey and blue-grey, contains many fossils, and is for the most part heavily bedded and relatively free from siliceous impurities. At intervals, however, bands of fine-grained siliceous limestone containing chert occur. Well over 200 feet of strata are exposed along the canyon. At the entrance to the canyon the limestone beds exposed contain only about 6 per cent of magnesium carbonate. Sample 17 is representative of a 50-foot thickness of this limestone. Farther up the canyon most of the limestone seen is highly magnesian. Sample 17A represents the magnesian limestone.

Castle Mountain

East from Castle Mountain school, for 2½ miles, ridges of Cambrian limestone extend southeasterly from Castle mountain nearly to the highway. These ridges are composed of strata striking N. 50° W. and dipping northeast at angles of from 25 degrees to nearly vertical. There is a wide variation in the type of limestone exposed in the various ridges. The farthest ridge is composed of brown, coarse-grained, pure magnesian limestone in beds from a few inches to 2 feet in thickness. Blue chert occurs in certain beds, but there are thicknesses of 20 feet of strata free from it. Sample 18 was taken here. Nearby are outcrops of impure dolomite and of impure magnesian limestone. Near Castle Mountain most of the rock outcrops are dolomite.

On the north side of the road near the school is an old lime kiln, and adjacent to it a small quarry has been opened in dark blue-grey, fine-grained, pure dolomite. Sample 19 was taken in the quarry.

West of the quarry are exposures of moderately pure high-calcium limestone.

Analyses of Limestones along the Main Line of the Canadian Pacific Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
6.......	0·54	0·10	0·04	0·04	94·84	2·89	98·45	Tr.	53·14	1·38	38 : 1
7.......	0·52	0·20	0·22	0·04	56·05	42·79	99·82	Tr.	31·41	20·46	1·53 : 1
7A.....	0·42	0·26	0·04	Tr.	55·41	43·58	99·71	Tr.	31·03	20·84	1·49 : 1
7B.....	0·40	0·12	0·18	Tr.	55·70	43·98	100·38	Nil	31·19	21·03	1·48 : 1
7C.....	0·34	0·14	0·16	Tr.	98·21	1·20	99·05	Nil	55·00	0·57	96 : 1
8.......	0·31	0·14	0·08	0·01	98·10	1·08	99·72	Tr.	54·96	0·52	106 : 1
8A.....	0·22	0·13	0·09	Tr.	98·14	2·03	100·61	Tr.	54·97	0·97	57 : 1
8B.....	0·16	0·10	Tr.	Tr.	99·04	0·61	99·91	Nil	55·84	0·29	193 : 1
8C.....	0·16	0·12	Tr.	0·01	99·10	0·40	99·79	0·01	56·00	0·19	295 : 1
8D.....	0·21	0·12	0·14	0·02	87·71	11·69	99·89	Tr.	49·13	5·59	8·8 : 1
8E.....	0·18	0·35	0·10	0·02	66·05	33·73	100·43	0·01	37·00	16·13	2·3 : 1
8F.....	0·31	0·15	0·14	0·09	85·84	13·55	100·08	Nil	48·12	6·48	7·4 : 1
8G.....	0·70	0·20	0·21	0·07	91·61	7·43	100·22	0·03	51·34	3·55	14 : 1
9.......	1·25	0·25	0·20	0·02	94·90	3·21	99·83	0·01	53·17	1·53	35 : 1
9A.....	0·68	0·11	0·21	0·02	93·55	5·31	99·88	0·01	52·40	2·55	21 : 1
9B.....	1·06	0·32	0·18	0·02	68·46	30·11	100·15	0·01	38·35	14·40	2·7 : 1
9C.....	0·92	0·27	0·13	0·02	92·66	5·40	99·40	0·01	51·90	2·58	20 : 1
9D.....	2·04	0·28	0·76	0·02	81·57	15·68	100·35	0·02	45·69	7·50	6·0 : 1
9E.....	0·78	0·21	0·15	0·02	89·52	8·78	99·46	Tr.	50·14	4·20	12 : 1
9F.....	1·34	0·16	0·28	0·04	86·32	12·05	100·19	Tr.	48·36	5·76	8·4 : 1
10.......	0·36	0·17	0·19	0·02	55·39	44·28	100·41	Tr.	31·03	21·17	1·46 : 1
10A.....	1·10	0·26	0·08	Tr.	97·25	0·59	99·28	Tr.	54·46	0·28	195 : 1
10B.....	1·08	0·29	0·11	0·02	90·03	8·22	99·75	0·01	50·43	3·93	13 : 1
11A.....	0·86	0·28	0·30	0·04	97·50	0·92	99·90	0·01	54·62	0·44	124 : 1
11B.....	0·42	0·20	0·08	0·02	98·12	0·74	99·58	0·01	54·96	0·35	157 : 1
12.......	1·98	0·16	0·24	0·07	95·89	1·64	99·98	Tr.	53·74	0·78	69 : 1
12A.....	4·24	0·50	0·30	0·11	86·80	8·40	100·35	0·01	48·67	4·02	12 : 1
13.......	0·28	0·02	0·06	0·13	97·23	1·95	99·67	Nil	54·52	0·93	59 : 1
13A.....	2·28	0·26	0·20	0·16	92·84	4·81	100·55	0·02	52·13	2·30	23 : 1
13B.....	23·26	0·99	1·16	0·24	48·23	26·52	100·40	0·03	27·14	12·68	2·14 : 1
14.......	1·06	0·53	0·24	0·02	55·71	43·25	100·81	0·01	31·21	20·68	1·50 : 1
14A.....	1·16	0·48	0·26	0·04	55·39	42·79	100·12	0·02	31·03	20·46	1·51 : 1
14B.....	35·40	2·31	1·08	0·04	51·71	8·82	99·36	n.d.	28·97	4·22	6·8 : 1
15.......	17·70	0·61	0·35	0·09	45·30	36·26	100·31	Tr.	25·42	17·34	1·46 : 1
15A.....	0·82	0·34	0·20	0·02	55·84	43·48	100·70	0·01	31·28	20·79	1·50 : 1
15B.....	0·74	0·51	0·35	0·02	55·25	44·24	101·11	0·02	30·95	21·15	1·46 : 1
15C.....	0·12	0·38	0·12	Tr.	55·82	44·34	100·78	Tr.	31·26	21·20	1·47 : 1
15D.....	1·22	0·44	0·59	0·02	54·48	43·84	100·59	Tr.	30·52	20·96	1·45 : 1
16.......	7·28	0·47	1·25	0·09	87·71	2·68	99·48	Tr.	49·17	1·28	38 : 1
17.......	0·24	0·06	0·13	0·07	93·14	6·67	100·31	Nil	52·20	3·19	16 : 1
17A.....	0·49	0·18	0·20	0·09	72·87	26·88	100·71	Nil	40·86	12·85	3·3 : 1
18.......	0·50	0·11	0·06	0·15	79·46	20·06	100·34	0·02	44·58	9·59	5 : 1
19.......	0·20	0·28	0·14	0·04	55·48	44·17	100·31	Tr.	31·09	21·12	1·47 : 1

6.	Radnor.	Calcareous tufa on north bank of Bow river.
7.	Kananaskis.	Easternmost mountain north of the railway at Kananaskis; 200-foot band of steel-blue Devono-Carboniferous dolomite.
7A.	"	Same mountain; 500-foot band of brown, rusty-weathering Devono-Carboniferous dolomite.
7B.	"	Same mountain; 70-foot band of light grey Devono-Carboniferous dolomite.
7C.	"	Same mountain; high-calcium part of bed that is partly dolomite.
8.	"	Loder's Lime Company quarry in Devono-Carboniferous limestone; 6 feet of nearly black limestone at west edge.
8A.	"	Same quarry; 13 feet of dark grey limestone adjoining No. 8 to the east.
8B.	"	Same quarry; 22 feet of grey limestone adjoining No. 8A.
8C.	"	Same quarry; 22 feet of light grey limestone adjoining No. 8B.
8D.	"	Same quarry; 10 feet of mottled grey limestone adjoining No. 8C, but not now quarried.
8E.	"	Same quarry; 15 feet dolomitic limestone next to No. 8D, not now quarried.
8F.	"	Same quarry; 40 feet of mottled limestone next to No. 8E, not now quarried.
8G.	"	Same quarry; 23 feet of nearly black limestone next to No. 8F, not now quarried.
9.	Exshaw.	Canada Cement Company quarry in Devono-Carboniferous limestone; 100 feet of strata quarried for use in the plant.
9A.	"	Same quarry; 20 feet of partly mottled limestone underlying No. 9 and not now quarried.
9B.	"	Same quarry; 5 feet of magnesian limestone beneath No. 9A.
9C.	"	Same quarry; 30 feet of partly mottled strata beneath No. 9B.
9D.	"	Same quarry; 8 feet of heavily mottled strata beneath No. 9C.
9E.	"	Same quarry; 18 feet of lightly mottled limestone beneath No. 9D.
9F.	"	Same quarry; toe of mottled magnesian limestone partly overlying the 100 feet of strata being worked.
10.	"	Devono-Carboniferous dolomite; 40-foot band of medium-grained dolomite enclosed in fine-grained, dark blue and brown dolomite north of Gap lake.
10A.	"	Devono-Carboniferous high-calcium limestone in spur northeast of where Sample 10 was taken.
10B.	"	Mottled Devono-Carboniferous limestone overlying No. 10A.
11A.	The Gap.	Top 25 feet of Devono-Carboniferous strata exposed in old quarry formerly worked by Alberta Portland Cement Company.
11B.	"	Bottom 50 feet of strata in same quarry.
12.	"	Devono-Carboniferous limestone from small quarry in a higher ridge on the same property.
12A.	"	Cherty limestone on the same property excluding chert nodules.
13.	Banff.	Coarse-grained Carboniferous limestone on south end of Tunnel mountain.
13A.	"	Fine-grained Carboniferous limestone at same locality.
13B.	"	Sandy, magnesian, Carboniferous limestone at same locality.
14.	"	Fine-grained, massively bedded Devonian dolomite on the east face of Sulphur mountain.
14A.	"	Devonian dolomite on east face of Sulphur mountain south of Upper Hot spring.
14B.	"	Dark grey magnesian limestone in quarry worked for building stone on east bank of Spray river.
15.	Sawback.	Siliceous Cambrian dolomite near base of the Sawback formation as exposed on east face of Mt. Edith.
15A.	"	Fine-grained, brown Cambrian dolomite overlying the siliceous dolomite.
15B.	"	Ridge of fine-grained, blue Cambrian dolomite farther west on east side of a valley.
15C.	"	Coarse-grained, light grey Cambrian dolomite on west side of valley from Sample 15B.
15D.	"	Fine-grained, nearly black Cambrian dolomite flanking the light grey dolomite.
16.	"	Calcium limestone of Cambrian age on east side of Mt. Hole in the Wall.
17.	Johnston canyon.	Fifty feet of Cambrian limestone at entrance to the canyon.
17A.	" "	Magnesian limestone overlying that from which Sample 17 was taken.
18.	Castle Mountain.	Coarse-grained, Cambrian magnesian limestone about 2½ miles east of Castle Mountain school.
19.	" "	Cambrian dolomite in small quarry near old kiln near Castle Mountain school.

Nordegg Area

Devono-Carboniferous limestones, composing a large part of the Brazeau range, are exposed along the Canadian National railway to Nordegg, or Brazeau as the railway station is called. The limestone exposures begin at Mile 145·2 about 4½ miles northeast of Nordegg, and continue at intervals to the town itself. Those seen in the first ¾ mile consist mostly of impure magnesian limestone interbedded with shale and with minor amounts of dolomite. Much of the limestone is cherty and some of it has cavities filled with solidified bitumen. The general strike of the strata is east and west and the dip is mostly south at steep angles. A few hundred yards northeast of Mile 146 is a large exposure of

PLATE XX

A. Thinly bedded, steeply dipping Triassic limestone on bank of the Spray river, Banff, where it is quarried for local use as building stone.

B. Thinly bedded, Devono-Carboniferous limestone in railway cutting at Mile 148, Nordegg, Alta.

impure, fine-grained, dark grey, heavily bedded calcium limestone containing some chert, but with thicknesses of as much as 50 feet of strata free from it. Sample 20 is representative of a 50-foot section of chert-free stone. This limestone, dipping southerly at an angle of 60 degrees, forms a ridge east of the railway for a considerable distance.

In the cutting at Mile 146, brown, medium-grained, compact dolomite, underlain by cherty dolomite and overlain by mottled magnesian limestone, is exposed to a thickness of 250 feet. Sample 21 was taken from this dolomite, which is massively bedded and contains cavities filled with petroleum. The beds strike N. 70° W. and dip north at an angle of 60 degrees. Between the railway and the mountain to the east the rock is only lightly covered by soil. Farther south, thin-bedded and impure, fine-grained calcium limestone is exposed for a short distance, and after a covered interval of nearly a mile a shaly dolomite is exposed dipping south at a low angle.

At Mile 147 a small quarry was at one time worked in the impure dolomite, possibly for ballast.

Three hundred and fifty yards farther west, finely granular, brown dolomite very similar to that of Sample 21 is exposed and is underlain by mottled magnesian limestone. The strata dip southwest at an angle of 10 degrees. Sample 21A was taken from this dolomite, which is probably a repetition of that represented by Sample 21.

From here westward most of the limestone exposed is impure and shaly. This shaly, thin-bedded limestone is well exposed in the cutting at Mile 148 (Plate XX B, page 115), where it lies in beds dipping southerly at a low angle.

At Mile 148·5 or 1 mile east of Nordegg, a quarry for ballast has been opened in pure calcium limestone just east of the trestle bridge. Twenty feet of limestone, striking N. 50° W. and dipping southwest at an angle of 14 degrees, is exposed. The top 10 feet of beds consists mostly of fine-grained, nearly black limestone. The beds are 4 to 9 inches thick with wavy bedding planes. Some beds are filled with fossils, and such beds are coarse-grained. Sample 22 was taken from the top 10 feet of limestone. The bottom 10 feet of limestone consists in part of dolomite and in part of high-calcium limestone, together with some mottled magnesian limestone. No sample was taken. In the railway cut east of the quarry, however, where lower beds are exposed, a belt of moderately coarse-grained, pure, grey, heavily bedded high-calcium limestone 40 feet thick appears. Sample 22A was taken from these strata, which are underlain by shaly calcium limestone and overlain by strata similar to those exposed in the bottom 10 feet of the quarry. Vugs filled with solid bitumen are plentiful in certain of the beds in this locality.

At Mile 149 broken beds of shaly calcium limestone and of cherty dolomite are exposed, but 300 yards farther west, or just outside the railway yard limit, is a cutting exposing 15 feet of fine-grained, grey, porous dolomite in uneven beds and containing many cavities filled with solid bitumen. Sample 23 was taken from the porous dolomite. Four hundred and fifty feet farther westward a brittle, dense, grey dolomite is exposed.

In the creek bed, at Mile 149·4, very impure, black, fine-grained magnesian limestone is exposed in nearly horizontal beds. Parks[1] gives the following analysis as being representative of this stone:—

	Per cent
Insoluble mineral matter	47·36
Soluble silica	0·36
Ferric oxide	0·14
Ferrous oxide	0·57
Alumina	0·45
Calcium carbonate	33·03
Magnesium carbonate	12·62
Total	94·53

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. No. 388, p. 148 (1916).

Analyses of Limestones in the Nordegg Area

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
20.......	5·26	0·49	1·73	0·13	85·62	6·56	99·79	0·15	48·02	3·14	15 : 1
21.......	0·90	0·19	0·33	Tr.	57·29	41·33	100·04	0·01	32·08	19·76	1·62 : 1
21A.....	0·68	0·20	0·42	Tr.	60·20	39·46	100·97	0·02	33·71	18·87	1·78 : 1
22.......	0·42	0·06	0·17	0·02	95·25	4·20	100·12	0·01	53·37	2·01	27 : 1
22A.....	0·24	0·04	0·21	0·02	97·96	2·00	100·47	Tr.	54·87	0·95	58 : 1
23.......	1·60	0·30	0·57	0·02	55·14	42·83	100·46	0·03	30·89	20·48	1·50 : 1

20. Nordegg. Devono-Carboniferous limestone several hundred yards northeast of Mile 146 on Canadian National railway.
21. " Devono-Carboniferous dolomite in cutting at Mile 146.
21A. " Same dolomite 350 yards west of Mile 147.
22. " Devono-Carboniferous limestone. Top 10 feet in quarry at Mile 148·5.
22A. " Forty feet of Devono-Carboniferous limestone in railway cut and at lower horizon than that in the quarry.
23. " Devono-Carboniferous dolomite at Nordegg railway yard limit.

Cadomin Area

Devono-Carboniferous limestones are exposed south of Cadomin along the Mountain Park branch of the Canadian National railway, which follows the McLeod river through the easternmost range of the Rocky mountains. The exposures begin $\frac{3}{4}$ mile south of Cadomin, or about 1,000 feet north of Mile 25, and continue southerly for 2 miles. The first limestone seen south of Cadomin is fine-grained, brown-grey calcium limestone in broken beds that dip vertically and are in faulted contact with sandstone and shale to the north. Some of the limestone is mottled with magnesian material and some is cherty. It forms a ridge about 500 feet long and 50 to 75 feet high, east of and parallel to the railway.

South of this the limestone that forms a mountain east of the railway is exposed adjacent to the track. The strata strike east and west and dip south at angles ranging from 35 to 60 degrees. The underlying beds, as exposed along the track for a distance of 300 feet, consist of badly fractured, very fine-grained, brownish grey, calcium limestone, some of which is mottled with brown-weathering magnesian material and some contains nodules of black chert. Sample 24 was taken from these beds as exposed over a distance of 300 feet along the track, excluding any cherty beds.

Between here and the 25-Mile post and overlying the mottled limestone is a fine-grained, brownish grey high-calcium limestone in broken beds that vary widely in thickness and dip south at an angle of 35 degrees. It is nearly free from mottled magnesian beds and chert. This band of limestone forms the southern slope of the mountain above referred to, and is available in a quarriable position east of the railway. Sample 25 was taken from this type of limestone where exposed for a distance of 200 feet along the track.

Lime is being made 1 mile south of Cadomin by Mike Errico from limestone similar to that of Sample 21. The plant consists of two pot kilns, only one of which is being used at present. The production is small, and the lime is used locally.

Southerly from the 25-Mile post most of the limestone exposed is magnesian and impure, some of it being cherty and much being shaly. On the north side of Cadomin creek is a triangular exposure of moderately pure, fine-grained, brownish grey, calcium limestone on a small ridge. Sample 25A was taken from this limestone. Underlying this unmottled limestone is impure magnesian limestone, dipping south at an angle of 25 degrees. South of Cadomin creek the limestone exposed is mostly impure and magnesian in composition and is interbedded with shale. At Mile 26·7, where the limestone exposures end, a cherty and siliceous dolomite is in contact with shale.

Analyses of Limestones in the Cadomin Area

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
24.......	0·98	0·23	0·29	0·02	92·45	5·90	99·87	0·02	51·78	2·82	18 : 1
25.......	1·14	0·24	0·22	0·02	96·00	1·83	99·45	Tr.	53·77	0·87	62 : 1
25A.....	0·98	0·30	0·22	0·01	95·03	3·01	99·55	0·02	53·22	1·44	37 : 1

24. Cadomin. Devono-Carboniferous mottled limestone 1 mile south of the village.
25. " Devono-Carboniferous unmottled limestone overlying the above.
25A. " Devono-Carboniferous unmottled limestone in ridge on the north side of Cadomin creek.

Main line of Canadian National Railway

For a distance of more than 30 miles, from Brûlé to just north of Jasper, limestones and shales of the Devono-Carboniferous formations composing the Rocky mountains are exposed along the Canadian National railway, which follows the valley of the Athabaska river through the mountains. The limestones are exposed on both sides of the valley, generally in steeply dipping beds. They have the same characteristics as the limestones of the Banff area, but shaly phases are more common and dolomite, though present, is not conspicuous, and is generally siliceous. Some pure high-calcium limestone is available, although most is of the ordinary calcium variety and contains more than 3 per cent total impurities and well over 3 per cent of magnesium carbonate. No quarriable deposits of dolomite were observed.

No use is being made of the limestone in this area, though at one time a fairly large lime plant was in operation at Roche Miette, and, from 1917 until 1930, a quarry was worked near Jasper to supply limestone for the manufacture of Portland cement.

Brûlé

West of Brûlé station, limestone can be seen high up on the mountainside, but the first that is available for quarrying is at Ogre canyon 2½ miles to the south (Plate XXI A, page 119). At this place the limestone forms a ridge that is 275 feet high on the south side of the canyon and that increases rapidly in height on the north side. The strata dip south at angles of from 25 to 35 degrees and present a very steep face to the north. The ridge is composed of interbedded, fine-grained, very dark grey high-calcium limestone and mottled magnesian limestone. Thin films of shale are present in some beds. Bedding is massive and a thickness was observed of 50 feet of limestone without a definite break. Sample 26 is representative of both mottled and unmottled beds and was taken from a 200-foot thickness of strata.

PLATE XXI

A. Massively bedded Devono-Carboniferous limestone at Ogre canyon, near Brûlé, Alta.

B. Massively bedded Devono-Carboniferous limestone containing nodules of black chert in rows parallel to bedding, Brûlé, Alta.

A short distance southwest, another ridge rises from the back of the one just mentioned. It is composed of very fine-grained, dark grey high-calcium limestone in massive beds that dip almost vertically. At intervals thin magnesian bands occur, some of which contain chert nodules. These bands were not included in Sample 27 which was taken on this ridge. Like the other ridge this one presents a steep face to the north and a gradual slope to the south. This southern flank is composed of mottled magnesian limestone, some of which is cherty.

A little over ½ mile west is another limestone ridge composed of rather shaly, nearly black, fine-grained calcium limestone containing some chert and numerous beds mottled with magnesian material. Sample 27A was taken from limestone of this character where the ridge adjoins the railway at a place between two lagoons of the river. Westward from here for 1 mile is a succession of beds of mottled and unmottled limestone, some of which is highly magnesian and much of which is shaly. The general strike of the strata is N. 70° W., and the dip is nearly vertical.

In the next range to the southwest, separated from the easternmost range by a valley 3 miles in width, shaly limestone, with only occasional bands of fairly pure limestone, predominates.

Roche Miette

Across the Athabaska river at the northwest end of Roche Miette, at the locality known as Disaster point, the Devono-Carboniferous limestones composing the mountain are well exposed along the old railway right of way on the river bank. The northernmost exposures consist of interbedded mottled and unmottled, fine-grained, nearly black, high-calcium limestone. The strike is N. 65° W., and the dip is nearly vertical. Two samples were taken from the massive limestone at the northern side of Roche Miette, Sample 28 from the mottled beds, and Sample 28A from the unmottled beds.

From here southerly, for ¼ mile, to the property at one time owned by Fitzhugh Lime and Stone Company, the limestone is mostly shaly and impure. In the old quarry formerly worked for lime, which was burned in three draw-kilns that are still standing, a great variation in the limestone is noticeable. This quarry is 25 feet wide and has been worked for 50 feet along the strike to the east, and a face 30 feet high is developed. A section across the quarry and adjacent strata from north to south is as follows:—

12 feet	—Fine-grained, dark-grey calcium limestone with many veinlets of calcite. Edge of quarry.
11 feet	—Brownish black, fine-grained, highly magnesian limestone.
1 foot	—Fine-grained high-calcium limestone.
6 inches	—Fine-grained dolomite.
4 feet	—Very fine-grained, grey high-calcium limestone.
11 feet	—Fine-grained high-calcium limestone to edge of quarry.
45 feet	—Impure magnesian limestone to contact with calcareous shale.

Sample 29 represents the high-calcium beds in the quarry, and Sample 29A the 11 feet of highly magnesian stone on the northern edges of the quarry.

Henry House

The limestone composing the Bosche range on the west bank of the Athabaska river opposite Disaster point is mostly shaly and otherwise impure. This same shaly limestone, with occasional bands of moderately pure limestone and bands of cherty dolomite and quartzite, occurs on both sides of the river to within 4 miles of Jasper. The dip in most places is generally very steep to the north. Near Henry House station, however, which is 7 miles north of Jasper, nearly

PLATE XXII

A. Thinly bedded Devono-Carboniferous limestone east of old quarry of Marlboro Cement Company, Ltd., near Jasper, Alta.

B. Sandy Devono-Carboniferous limestone east of old quarry of Marlboro Cement Company, Ltd., near Jasper, Alta.

horizontal limestone strata compose a mountain known as the Palisade, on the west side of the river. At the southeast end of this mountain the strata dip southeast and are exposed adjacent to the railway, where they were quarried for the making of Portland cement by The Marlboro Cement Company, Limited, which ceased operations in 1930. The lower strata in this mountain consist of impure, fine-grained, brown calcium limestone in beds ½ to 1¼ inches thick, separated by shale of a drab brown colour (Plate XXII A, page 121). Sample 30X was taken of the limestone beds only, leaving out the interbedded shale.

This shaly limestone is overlain by sandy limestone (Plate XXII B, page 121), which in turn is overlain by 200 feet of brownish grey, fine-grained, heavily bedded calcium limestone containing a network of shale films without shale interbeds. Occasional strata in this zone are lightly mottled with magnesian material. Overlying this is 150 to 200 feet of calcium limestone, in which horizon the company's quarry was opened.

This quarry is 4½ miles north of Jasper and immediately west of the railway. It is 300 feet long, 150 feet wide, and has a face 90 feet high. It is of the hillside type and is opened in strata that strike N. 70° E. and dip southeast at an angle of 25 degrees. The ridge in which the quarry is opened rises at about the angle of dip of the strata, and has only a light covering of overburden for a considerable distance northwest of the quarry. The limestone exposed is very fine-grained, nearly black in colour, and is in beds up to 6 feet in thickness. Films of shale, so thin as to be scarcely noticeable on fresh fracture, traverse much of the stone, and on weathering the limestone splits along these films, giving it a rubbly appearance in the outcrops. In all, owing to the dip, about 140 feet of strata are exposed in the quarry. Sample 30 was taken from this 140 feet. A few minor beds of mottled magnesian limestone were observed, particularly in the upper part of the face. Sample 30A was taken from a 3½-foot bed of this type midway up the quarry face. When this quarry was being operated the limestone was crushed to 2 inches and under in the nearby crushing plant, and then shipped by rail to the cement plant at Marlboro, 140 miles west of Edmonton, which was built in 1912 to utilize local marl deposits, and when these proved unsatisfactory the quarry just described was opened in 1917.

In a railway cut just south of the quarry, limestone strata considerably higher than those in the quarry are exposed. The lowest beds seen are mottled with magnesian material, but they are overlain by 150 feet of unmottled calcium limestone similar to that in the quarry and having a similar strike and dip. In the next cutting to the south a 50-foot band of shale overlain by heavily bedded limestone is seen, and from here to the bridge over Pyramid creek, 1 mile south of the quarry, the limestone becomes increasingly shaly and consists in part of impure dolomite. The dip of the strata also increases in this direction.

Analyses of Limestones Along the Main Line of the Canadian National Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
26.......	1·32	0·20	0·60	0·02	91·59	6·29	100·02	Tr.	51·30	3·01	17 : 1
27.......	1·02	0·16	0·56	0·02	96·95	1·03	99·74	Nil	54·30	0·49	111 : 1
27A......	3·76	0·27	0·43	0·02	86·36	9·64	100·48	0·01	48·37	4·61	10 : 1
28.......	0·62	0·20	0·20	0·02	95·09	4·18	100·31	0·01	53·26	2·00	27 : 1
28A......	0·66	0·11	0·23	Tr.	97·16	1·76	99·92	Nil	54·41	0·84	65 : 1
29.......	1·44	0·18	0·28	0·02	96·78	1·51	100·20	0·04	54·21	0·72	75 : 1
29A......	5·46	0·65	1·17	0·02	62·44	30·59	100·33	0·15	34·98	14·63	2·4 : 1
30.......	1·82	0·25	0·43	0·04	95·00	2·34	99·88	0·04	53·22	1·12	47 : 1
30A......	3·48	0·38	1·14	0·11	85·68	9·05	99·84	0·12	48·04	4·33	11 : 1
30X......	11·08	0·56	1·92	0·15	81·98	4·18	99·87	0·02	45·99	2·00	23 : 1

26.	Brûlé.	Two hundred feet of Devono-Carboniferous limestone exposed at Ogre canyon.
27.	"	Devono-Carboniferous limestone on next ridge to the southwest of Ogre canyon, excluding some mottled beds.
27A.	"	Devono-Carboniferous limestone from ridge 1½ miles west of where Sample 27 was taken.
28.	Roche Miette.	Mottled beds of Devono-Carboniferous limestone on the northern side of the mountain.
28A.	" "	Unmottled beds of Devono-Carboniferous limestone at the same locality.
29.	" "	High-calcium limestone (Devono-Carboniferous) in the quarry formerly worked by Fitzhugh Lime and Stone Company.
29A.	" "	Highly magnesian beds on the northern edge of the same quarry.
30.	Henry House.	One hundred and forty feet of Devono-Carboniferous limestone in quarry formerly worked by Marlboro Cement Company, Ltd.
30A.	" "	Three and one-half foot bed of mottled magnesian limestone in the same quarry.
30X.	" "	Thin-bedded shaly limestone from a horizon below that in which the Marlboro Cement Company's quarry was opened.

CHAPTER V

LIMESTONES OF BRITISH COLUMBIA

GENERAL DISTRIBUTION AND CHARACTERISTICS

Rock structures in most parts of British Columbia have been rendered very complex by mountain-building agencies and by great invasions of igneous rocks, so that the original character of the sedimentary rocks in many places has been completely destroyed, and instead of occurring in easily recognizable formations, as in most other parts of the Dominion, they are folded, faulted, broken, and metamorphosed, and in many places left as remnants that bear little resemblance to one another or to the original rock. This has made it difficult to correlate the various limestone deposits and has given rise to much difference of opinion as to the geological age to which they belong. It has also made necessary the adoption of local formational names throughout the province. It is thus not

TABLE IX

Rock Systems of British Columbia showing the Stratigraphic Position of the Limestones

System	Type of Rock
Quaternary	Unconsolidated deposits including tufa and marl.
Oligocene	Volcanics.
Eocene	Sandstones, conglomerates, and igneous intrusions.
Cretaceous	Sandstones, shales, and volcanic rocks.
Jurassic	Shales, volcanics, and limestones.
Triassic	Volcanics, shales, limestones, and argillites.
Carboniferous	Limestones, schists, argillites, quartzites.
Devonian	Shales and limestone.
Silurian	Limestone.
Ordovician	Limestones, shale, and quartzite.
Cambrian	Sandstones, quartzites, shales, and limestones.
Precambrian	Schists, quartzites, limestones, greenstones.

possible to discuss in any detail in this report the limestones of British Columbia by their geological age grouping as has been done with the limestones of the other provinces. Instead the following generalized notes are given.

Precambrian Limestones

Limestones of this age occur in the Selkirk and Columbia mountains and along the lower parts of Kootenay lake. They are all highly metamorphosed and, except for narrow bands, are rarely of a high degree of purity. They are commonly magnesian. At Marble Head a bluish grey marble was quarried until recently from a large deposit of Precambrian limestone, and a deposit of nearly white magnesian limestone opposite Kaslo was at one time worked on a small scale for marble. At Lardeau and near Procter, Precambrian limestone deposits were worked for flux.

Cambrian Limestones

Limestones of Cambrian age occur along the eastern boundary of the province and around Shuswap lake. They are highly metamorphosed and are commonly dolomitic. The deposits at Grant Brook and Yoho and some of those in the Windermere valley are believed to be of Cambrian age, as are some of the deposits between Notch Hill and Sicamous. In the latter locality the limestones are low in magnesium carbonate. Several deposits of Cambrian limestone have been investigated as sources of marble, but there has been no sustained production.

Ordovician and Silurian Limestones

The Beaverfoot and Brisco formations, named after the mountains bordering the Windermere valley in which they occur, are the principal representatives of the Ordovician and Silurian systems in British Columbia. They are composed of pure dolomite and of siliceous calcium limestone and have not been highly metamorphosed as have most of the British Columbia limestones.

Carboniferous Limestones

Carboniferous limestones are widely distributed in British Columbia and in many places they are exceedingly pure. The Pavilion and Marble mountains, northwest of Ashcroft, are composed almost entirely of Carboniferous limestone, some of which approaches calcite in purity. Carboniferous limestones are also available in quantity near Wardner where, however, they consist in part of dolomite and magnesian limestone. Many of the deposits of high-calcium limestone around Grand Forks and in the Fraser and Thompson River valleys are of Carboniferous age as are those along the Canadian National railway at Hansard and Lindup. The limestone is almost invariably fine-grained and is generally blue. The deposit at Fife being worked for flux is of Carboniferous age. A small quarry at Agassiz producing limestone for agricultural use is also opened in Carboniferous limestone.

Triassic and Jurassic Limestones

Most of the limestone deposits of the coastal islands and adjacent mainland are believed to be either of Triassic or Jurassic age. With the chief exception of some deposits on Texada and southern Vancouver islands, the deposits are very highly metamorphosed. They are all predominantly high-calcium in composition, although bands of magnesian limestone and of true dolomite are present in many of the deposits. A deposit of this age on Redonda island contains granules of brucite disseminated through it, and is similar to the brucitic limestone deposits in Ontario and Quebec. These Triassic or Jurassic deposits provide by far the greater part of the output of limestone in British Columbia, as well as all the lime.

PRODUCTION AND UTILIZATION OF LIMESTONE IN BRITISH COLUMBIA

Statistics on the production of limestone, marble, and lime are given in Tables X and XI, and those of lime, limestone, and hydrated lime are shown graphically in Figures 5 and 6. Data prior to 1921 were obtained from the records of the Mines Branch, Ottawa, and for 1921 and subsequent years from the records of the Dominion Bureau of Statistics.

Limestones are well distributed throughout British Columbia, but the principal centres of production are in the coastal region. An exception to this is the large quarry at Fife where flux is produced. Many of the deposits along the coast of British Columbia are of large size and of a high degree of purity and their products in part are marketed in the west coast cities of the United States, as large deposits of high-grade limestone are relatively scarce along the United States west coast.

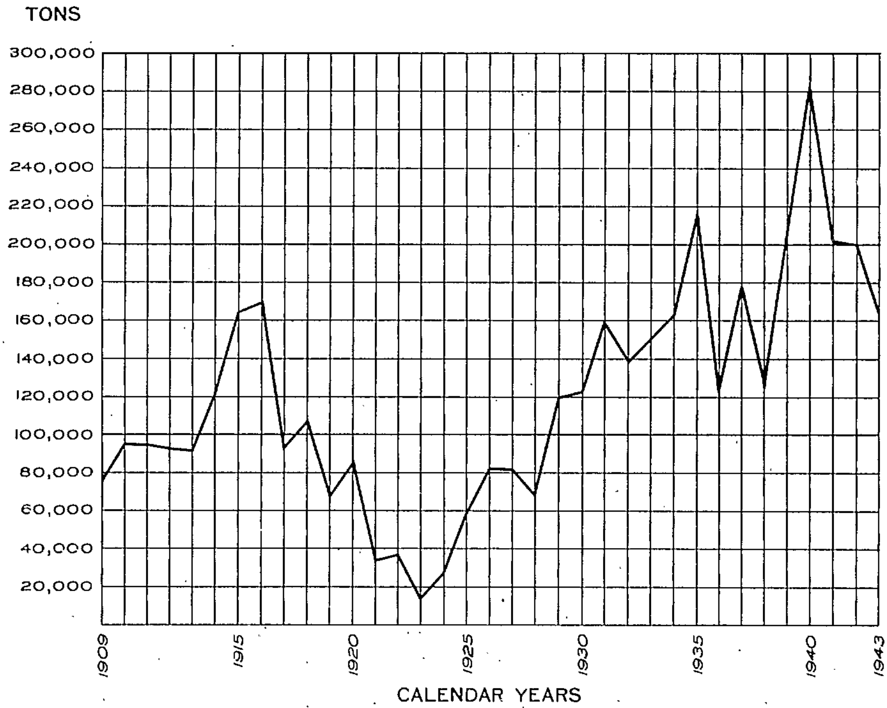


FIGURE 5. Production of limestone in British Columbia.

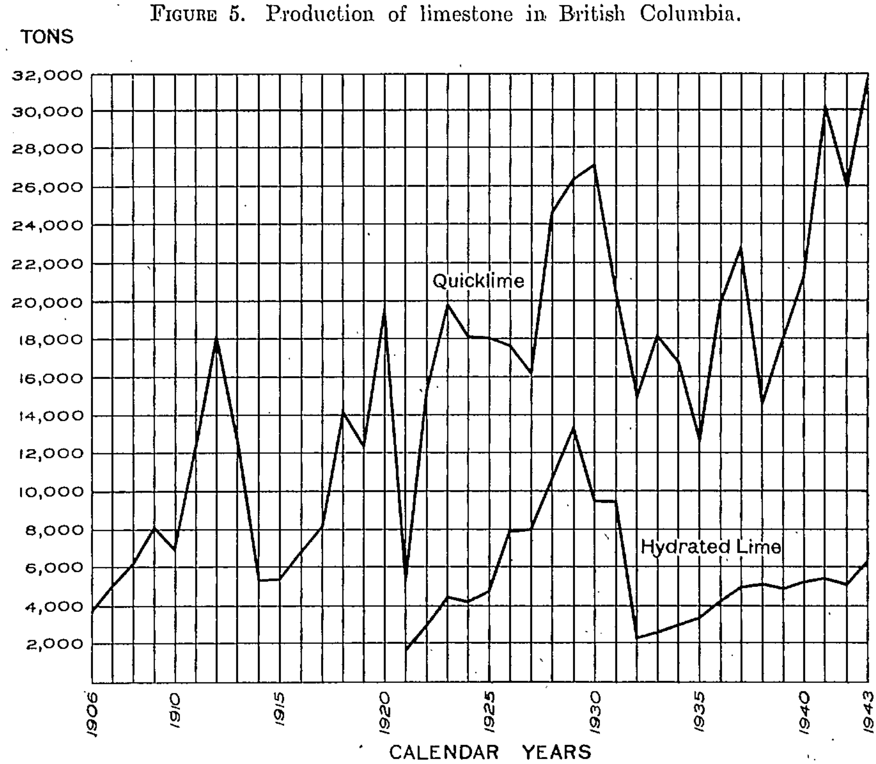


FIGURE 6. Production of lime in British Columbia.

The main products are stone for use in sulphite-pulp mills, for the making of Portland cement, for flux, for lime, for agricultural use, stucco dash, poultry grit, for dusting coal mines, asphalt filler, and calcium carbonate flour for use in stock foods.

Stone for use in pulp-mills is quarried at Vananda on Texada island, at Quatsino sound in the northern part of Vancouver island, and at Koeye river on the coast near Namu. It has been quarried at a number of other places including Nelson island, Gunboat passage, Redonda island, and near Swanson Bay. The white, highly metamorphosed limestone is preferred for this purpose to the dark grey limestone.

A Portland cement plant is in operation at Bamberton on Vancouver island. Part of its limestone requirements is obtained from an adjacent quarry and part from Texada island. Another Portland cement plant formerly operated at Tod Inlet across Saanich inlet from Bamberton, and a small plant was in operation for a short time near Princeton.

TABLE X

Production of Limestone and Marble in British Columbia

Year	Limestone		Marble	
	Tons	Value	Tons	Value
		$		$
1908	....	....	1,481	8,000
1909	74,515	37,258	920	25,000
1910	94,772	43,121	1,935	3,697
1911	94,633	56,780	360	1,600
1912	92,695	55,617	....	....
1913	91,369	38,830	....	600
1914	121,214	51,435	....	3,343
1915	164,354	79,583	....	1,700
1916	169,459	92,769	....	....
1917	92,982	89,808	....	....
1918	107,259	139,338	....	....
1919	67,107	102,328*	83	1,932
1920	85,155	92,070	....	....
1921	33,816	42,536	....	....
1922	36,566	44,583	....	....
1923	13,711	19,284	....	....
1924	27,053	21,881	....	....
1925	58,172	54,059	....	....
1926	81,844	106,220	....	....
1927	81,008	107,984	600	18,600
1928	68,179	83,193	950	31,400
1929	119,222	143,319	196	5,282
1930	122,409	145,443	6,363	31,141
1931	159,198	152,269	810	8,761
1932	138,132	109,399	482	4,029
1933	150,805	130,706	300	2,547
1934	161,755	142,560	150	1,416
1935	215,933	189,381	604	5,471
1936	122,535	123,607	175	2,110
1937	176,513	177,939	....	....
1938	125,842	124,322	....	....
1939	205,045	200,842	....	....
1940	282,170	282,095	180	2,600
1941	201,359	229,702	300	2,800
1942	199,496	230,139	100	1,820
1943	163,127	213,544	85	1,450

* For use as furnace flux only.

Lime produced in British Columbia is all of the high-calcium variety. The only commercial lime plant is the large plant at Blubber Bay from which the lime is marketed as lump quicklime, pulverized quicklime, and hydrated lime. Another lime plant is operated by the paper company at Ocean Falls to provide lime solely for use in its mills.

Limestone for flux is produced at Fife and at Vananda and Blubber Bay on Texada island. Small quantities for foundry use are produced near Victoria.

Marble for interior decorative use has been produced in small quantities from a number of deposits, and until 1930 there was a steady production of bluish white marble for monumental use from a quarry at Marble Head, north of Kootenay lake. At present the only marble being quarried for use as such is at Malahat near Victoria, and on Texada island near Vananda. At both places it is being converted into stucco dash, poultry grit, and marble flour.

TABLE XI

Production of Lime in British Columbia

Year	Quicklime		Hydrated Lime		Total Lime	
	Tons	Value	Tons	Value	Tons	Value
		$		$		$
1906	3,717	26,694	....	....	3,717	26,694
1907	5,099	49,847	....	....	5,099	49,847
1908	6,175	44,027	....	....	6,175	44,027
1909	8,094	75,076	....	....	8,094	75,076
1910	6,891	72,657	....	....	6,891	72,657
1911	12,285	117,756	....	....	12,285	117,756
1912	18,107	181,905	....	....	18,107	181,905
1913	12,690	115,365	....	....	12,670	115,365
1914	5,309	56,767	....	....	5,309	56,767
1915	5,328	49,725	....	....	5,328	49,725
1916	6,791	66,301	....	....	6,791	66,301
1917	8,153	58,067	....	....	8,153	58,067
1918	14,055	143,697	....	....	14,055	143,697
1919	12,294	187,963	....	....	12,294	187,963
1920	19,466	341,632	....	....	19,466	341,632
1921	5,355	234,779	1,622	17,851	6,977	252,630
1922	15,181	254,320	2,909	30,321	18,090	284,641
1923	19,774	338,443	4,410	50,051	24,184	388,494
1924	18,115	320,312	4,157	50,517	22,272	370,829
1925	18,027	304,223	4,718	60,212	22,745	364,435
1926	17,606	317,733	7,896	99,149	25,502	416,882
1927	16,175	279,230	7,936	97,453	24,111	376,683
1928	24,512	345,131	10,637	128,865	35,149	473,996
1929	26,300	355,013	13,291	155,579	39,591	510,592
1930	27,104	251,479	9,413	83,578	36,517	335,057
1931	20,364	195,078	9,462	82,191	29,826	277,269
1932	14,902	141,998	2,250	18,003	17,152	160,001
1933	18,147	144,479	2,570	18,449	20,717	162,928
1934	16,721	135,528	2,966	18,328	19,687	153,856
1935	12,685	83,664	3,319	16,296	16,004	99,960
1936	19,885	119,563	4,274	15,222	24,159	134,785
1937	22,799	131,709	4,940	22,328	27,739	154,037
1938	14,518	140,347	5,137	33,814	19,655	174,161
1939	18,035	165,036	4,816	32,223	22,851	197,259
1940	23,200	200,138	5,188	34,396	28,388	234,534
1941	30,075	206,769	5,427	37,282	35,502	244,051
1942	25,977	204,438	5,057	32,466	31,034	236,904
1943	31,714	261,526	6,333	43,895	38,047	305,421

Agricultural limestone is made at Vananda, Blubber Bay, and Agassiz. Marl is being utilized for the same purpose from deposits at Popkum, Solsqua, and Valemont.

Poultry grit, stucco dash, marble flour, and whiting substitute are made from white marble at Vananda and Victoria.

BRITISH COLUMBIA MINING LAWS RELATING TO LIMESTONE

Limestone, marble, and building stone or construction stone are not considered as mineral under the Mineral Act of British Columbia, but quarries are subject to regulations set forth in the mining laws of British Columbia as regards method of operation, statistics, and protection of workmen. Information on these regulations may be had on application to the British Columbia Department of Mines, Victoria.

TABLE XII

Limestone and Marble Quarries in British Columbia

Operator	Location of Quarry	Product
Agassiz Lime Quarry, Agassiz......	Agassiz..............	Agricultural limestone.
Agostinelli and Vannuchi, Trail.....	Fife..................	Flux.
Beale Quarries, Limited, 744 W. Hastings St., Vancouver.	Vananda............	Limestone for chemical use, stucco dash, poultry grit, agricultural limestone.
British Columbia Cement Co., Ltd., 500 Fort St., Victoria.	Bamberton.......... Blubber Bay.	Portland cement. Stone for Portland cement manufacture.
British Columbia Pulp and Paper Co., Limited. Bank of Nova Scotia Bldg., Vancouver.	Quatsino Sound.......	Limestone for use in pulp mills.
Koeye Limestone Co., Namu.......	Koeye River.........	Stone for making lime.
Marble and Associated Products, 507 Ellice St., Victoria.	Malahat.............	White marble for stucco dash, poultry grit, flux, marble flour.
McKay and McKay, Vananda.....	Vananda.............	White marble for stucco dash, poultry grit, and marble flour.
Pacific Lime Co., Ltd., 744 W. Hastings St., Vancouver.	Blubber Bay.........	Lump quicklime, pulverized quicklime, hydrated lime, stone for chemical and metallurgical use.

DISTRIBUTION OF LIMESTONE BY DISTRICTS

Vancouver Island

Limestone is abundant on Vancouver island, particularly along the west coast where, in some localities, it is the principal rock composing entire mountains. On the east coast it is less plentiful although large deposits occur in the vicinity of Beaver cove, and small deposits are numerous in the southern part of the island.

Most of the deposits are characterized by a low content of magnesium carbonate, the only dolomite observed being present as minor bands and patches in some deposits of calcium and high-calcium limestone. Differences of opinion exist as to the age of the numerous deposits, but the consensus is that they are either Triassic or Jurassic in age. Much of the limestone has been highly metamorphosed by invasions of igneous rock, and the colour has been changed from the original dark blue to light blue, white, and grey. Certain of the highly metamorphosed deposits on Nootka sound and at Beaver cove have been investigated as sources of marble, and, though there is some marble of good quality available, the market has not been sufficiently large to sustain production.

Present quarrying is confined to deposits on the northern and southern extremities of the island. In the north, limestone for use in a sulphite pulp mill at Port Alice is quarried from the shore of Quatsino sound, and in the south two quarries are being worked in the Sutton limestone near Victoria, one to supply rock for the manufacture of Portland cement, and the other for the production of white stucco dash, foundry flux, terrazzo, poultry grit, and marble flour. Formerly the Sutton limestone of the southern part of the island was quarried for making lime and for road metal, but neither of these products has been made in recent years from Vancouver Island limestone.

Aside from lack of transportation facilities at many of the deposits the principal drawback to their greater utilization is the presence of numerous dykes and sills from the surrounding igneous rocks. This foreign rock penetrates the deposits in all directions and necessitates some form of beneficiation before the limestone can be used for many purposes.

West Side of Esquimalt Harbour

One of the larger deposits of Sutton limestone on Vancouver island extends westerly from the shore of Esquimalt harbour for more than a mile and is exposed in a ridge 100 to 500 feet in width. For many years lime was produced here by *Rosebank Lime Company, Limited,* but operations ceased in 1932 and the plant has been dismantled. Quarrying was done in a number of places along the ridge at distances of from 500 to 1,000 yards back from the shore. The two kilns were at the water's edge and, as the ridge rises over 100 feet above the water, the floors of the shallow quarries were above the level of the tops of the kilns.

The limestone is very fine-grained, ranges from dark blue to nearly white, and weathers to a pale grey. It is badly fractured (Plate XXIII A, page 131) and the fracture planes are coated with a rusty chloritic film that gives the broken rock a poor appearance and also detracts from the appearance of the lime, since it burns to a brown colour, giving a dark surface colour to an otherwise white lime. The deposit apparently dips vertically. It is cut in all directions by vertical dykes of green igneous rock from a few inches to 50 feet in thickness. Rarely is there an area as much as 50 feet square free from a dyke and in places the dykes are so numerous as to render the limestone worthless. The limestone adjacent to some of the dykes has been whitened for a short distance, but in most places there has been no noticeable alteration. Dyke rock is usually joined firmly to the limestone and when broken away it leaves a scale on the latter. Nearly all the limestone is high-calcium, but here and there, mostly near the edges of the deposit or adjacent to one of the larger dykes, are patches and small masses of highly magnesian limestone.

The largest of the series of quarries opened on the property is 250 by 150 feet in area and the maximum height of face is 50 feet.

Sample 1 was taken in the quarry 1,000 yards west of the shore, where stone for making lime was being obtained in 1929. Sample 1A was taken in a quarry from which shipments of rock were being made to British Columbia Cement Company's plant at Bamberton; and Sample 1B was taken from a small mass of highly magnesian limestone alongside the tramway leading to the quarry from which the rock for cement-making was obtained. Shipments from the quarries and plant were made mostly by water from a wharf adjacent to the kilns.

A. Highly metamorphosed Sutton limestone in vertical, mashed beds in old quarry of Rosebank Lime Company, west side of Esquimalt harbour, B.C.

B. Part of the quarry of British Columbia Cement Company, Ltd., in Sutton limestone, Bamberton, B.C.

One-half mile west of the Rosebank Lime Company's quarries, and apparently in the same lens of Sutton limestone, is another small quarry from which stone for making lime was once obtained. The limestone contains much pyrite and is in part magnesian.

Langford

One mile east of Langford station on the Esquimalt and Nanaimo railway is a lens of Sutton limestone in which a quarry was worked many years ago to obtain stone for making lime for the manufacture of sand-lime brick. The small draw-kiln and what remains of the brick plant are on the north side of the railway and the quarry is on the south side. It is opened in the north side of a ravine and a 50-foot face of fine-grained, light blue high-calcium limestone is exposed. Exposures of the limestone extend for 200 to 300 yards on both sides of the quarry and similar limestone occurs north of the track. On the west side of the quarry a few small masses of blue dolomitic limestone appear, but dolomite was not observed elsewhere. Sample 2 is representative of the limestone exposed in the quarry, exclusive of the dolomite. Several twisted dykes of diabase cut through the limestone in the quarry and 10 to 20 feet of sand covers the rock a short distance back from the edge of the ravine. The railway passes over the main part of the deposit and only a small quarry operation can be carried on without moving the track.

Parsons Bridge

There are three small lenses of fine-grained, blue, high-calcium Sutton limestone near Parsons Bridge and quarries have been opened in two of them. One of these quarries, worked to supply a small lime kiln known as Atkins kiln, is in a small lens on the east side of the highway near the head of Esquimalt harbour. The lens is much intersected by igneous dykes and appears to be nearly worked out. Sample 3 was taken in the quarry. A short distance north of this another small lens of Sutton limestone occurs on the same side of the highway. Three-quarters of a mile east is a small lens of Sutton limestone in which at some time between 1902 and 1911 a quarry was worked to supply flux for the smelter of the Tyee Copper Company at Ladysmith.

Strathcona

A small lens of blue Sutton limestone occurs ½ mile south of Strathcona and east of Shawnigan lake. Its western tip is crossed by the highway and the Esquimalt and Nanaimo railway.

Bamberton

British Columbia Cement Company, Limited, 500 Fort St., Victoria, quarries a large lens of Sutton limestone at Bamberton, on the west shore of Saanich inlet, for the manufacture of Portland cement. The lens is 400 feet wide, extends from the water's edge northwesterly up the mountainside for 700 yards, and dips northeast at angles ranging from 60 degrees to nearly vertical. Most of the limestone is dark bluish grey, very fine-grained, brittle, and high-calcium in composition. In places, however, are bands and irregular masses of dolomitic limestone similar in appearance to the high-calcium limestone, though it is sometimes distinguishable owing to its tendency to be lighter in colour. One such magnesian band 20 feet thick and containing 17 to 40 per cent of magnesium carbonate occurs along the east side of the lens. Like all the Sutton limestone this deposit is enclosed in volcanic rock and invaded by numerous igneous dykes. One large igneous dyke 40 feet thick runs lengthwise of the deposit, and many smaller ones 5 to 16 feet thick intersect the limestone in various directions, but are mostly vertical. Some of these igneous dykes contain as much as 11 per cent of magnesia according to information supplied by the company. The limestone is apparently cut off by igneous rock 100 feet beyond the present quarry and thus the lens is nearly worked out on the present levels.

The quarry is worked in two levels. The lower level is opened 80 feet above sea-level and has a face 150 feet in height across the full width. The upper level (Plate XXIII B, page 131) has a face 100 feet high. Sample 4 was taken at intervals across the limestone exposed in the upper level, but because much igneous rock is mixed with the limestone in quarry operations the sample is not representative of the output. To the output of this quarry is added a proportion of pure limestone obtained from the company's quarry on Texada island (*see* page 148) in order to bring the mix to the proper chemical composition for making Portland cement.

In operating the quarry, drifter drills are used, horizontal holes being drilled at intervals of 2 to 3 feet for a distance of 22 feet into the face at the bottom and half way up the face. They are loaded with Forcite gelatin and are fired simultaneously. The limestone tends to break into large pieces and this method of drilling and blasting gives the best fragmentation. On the upper level the igneous dyke rock is mostly sorted out and taken to a waste dump. The remaining limestone is loaded into end-dump cars of 4-yard capacity by an electric shovel equipped with a $\frac{7}{8}$-yard dipper. The cars are dumped into a glory hole leading to the bottom level and there reloaded and taken to the crushing plant. On the bottom level all broken rock including igneous dyke rock is loaded by an electric shovel with a $1\frac{1}{8}$-yard dipper on to side-dump 4-yard cars. These are hauled by a gasoline locomotive over a 3-foot gauge track to the slope leading to the primary crusher, up which they are pulled by cable. The total output of the quarries is about 500 tons a day.

The cement plant has a capacity of 3,500 barrels a day and operates on the wet process of making cement. Three rotary kilns are installed, one of which is 200 feet long and 10 feet in inside diameter, the other two are each 150 feet long and 9 feet in inside diameter. Powdered coal is used for fuel.

Along the shore of Saanich inlet on either side of the main lens of limestone at Bamberton are some narrow bands of siliceous limestone having generally the same strike and dip as the main lens. Two small quarries were formerly worked in these bands, one $1\frac{1}{4}$ miles south of the cement plant, and the other 300 yards north, and the rock was transported in scows to the plant. Both quarries have been idle for years. An average analysis, supplied by the company, of the limestone obtained from the south quarry was:

	Per cent
Silica	6·96
Oxides of iron and alumina	3·92
Calcium oxide	49·06
Magnesium oxide	0·63
Loss on ignition	38·08
Total	98·65

Siliceous limestone also occurs much higher up on the mountain. The following analyses of samples from this deposit were supplied by the company:—

	Per cent	Per cent	Per cent
Silica	6·64	9·86	6·68
Oxides of iron and alumina	4·56	5·82	4·70
Calcium oxide	48·95	45·17	48·66
Magnesium oxide	1·20	1·07	1·25
Loss on ignition	37·78	35·44	38·46
Total	99·13	97·36	99·75

PLATE XXIV

A. Blue-grey Sutton limestone in quarry of British Columbia Cement Company, Ltd., Bamberton, B.C.

B. Quarry of Marble and Associated Products, in Sutton limestone near Malahat, B.C.

Prior to the building of the cement plant, lime was burned on the shore of Saanich inlet at the site of the present quarry. It is said that the limestone crumbled during calcination and that the lime was of poor quality.

Tod Inlet

At Tod Inlet, across Saanich inlet from Bamberton, are two other lenses of Sutton limestone that were formerly quarried to supply the now largely dismantled cement plant at that place. This plant, the first rotary kiln plant in British Columbia, was built in 1904 by Vancouver Portland Cement Company, Limited, which in 1916 amalgamated with Associated Cement Company (Canada), Limited at Bamberton under the name of British Columbia Cement Company, Limited. In 1922 the Tod Inlet plant was closed down.

While the plant was in operation, three quarries were opened to supply the limestone. The first of these is just north of the plant, and when the quarry was worked out it was converted by Mr. Butchart, the President of the company, into a sunken garden now widely known as Butchart's Gardens.

The second quarry is immediately south of the first and is adjacent to the cement plant. It is 500 feet long, 200 feet wide, and 75 feet deep, and is opened in a lens of Sutton limestone that trends northwest-southeast and dips vertically. The limestone is somewhat darker than at Bamberton, but is otherwise similar in appearance and composition. Numerous igneous dykes intersect the limestone in all directions. On the edges of the quarry some small masses of highly magnesian limestone veined with white calcite were observed. Presumably this magnesian limestone is close to the contact with the surrounding igneous rock, which was not visible on account of the heavy mantle of soil.

The third quarry opened to supply the plant is 1,200 yards east and about 200 feet higher. Stone was transported to the plant by aerial tramway. This quarry is 500 feet long, 200 feet wide, and is said to be 70 feet deep, but it is now nearly full of water. Soil covers the rock to depths of 10 to 20 feet and little limestone is visible. Such as can be seen is dark bluish grey, very fine-grained, and much shattered. Thin veins of white calcite occur in the fracture planes and many igneous dykes were encountered in quarry operations. Across the ends of the quarry such limestone as is seen is high-calcium in composition, but on both sides some masses of dolomitic blue limestone are visible. Sample 5 was taken across a width of 50 feet of limestone at the northern end of the quarry. This quarry was not completely worked out when the plant ceased operations, but, according to the company officials, the increasing depth of soil on top of the rock as the quarry is extended makes it doubtful if it will ever be reopened.

Malahat

A lens of white and bluish grey, fine-grained Sutton limestone enclosed in volcanic rock occurs on Green mountain, 2½ miles southwest of Malahat station on the Esquimalt and Nanaimo railway. It is reached from the Island highway by a road built on the grade of a former logging railway that goes southwest from the Shawnigan Lake road just where the latter crosses the railway at Malahat station. The deposit is on the land of Robert Stebbins and is being quarried under lease by *Marble and Associated Products, 507 Ellice St., Victoria,* for the manufacture of stucco dash and other products.

In the vicinity of the quarry the limestone forms a band 75 to 250 feet wide striking north 80 degrees west and dipping south at angles ranging from 45 degrees to 80 degrees. It, together with its enclosing volcanic rock, forms a low ridge extending westerly from a tiny lake for 200 yards. Overburden is light and outcrops are numerous. Where the ridge ends to the west in swampy ground, the limestone has a maximum width of 250 feet and it probably extends considerably farther in that direction. The limestone is intersected, chiefly in the direction of its strike, by dykes of green igneous rock up to several feet in width. These dykes, however, form a relatively small part of the deposit. The whitest limestone is, in general, adjacent to a dyke. Occasional films of white siliceous matter occur in places in the limestone, but it is mostly of a good grade of purity, as shown by the analysis of Sample 6.

The quarry (Plate XXIV B, page 134) is opened along the axis of the ridge at about 20 feet above the level of the lake and has a face of 25 feet, which will increase as it is worked to the west. Drilling is by jackhammer and the broken rock is loaded by hand on to a truck for hauling 22 miles to the crushing and screening plant in Victoria. The plant at 507 Ellice street is equipped with an 8-inch by 12-inch jaw crusher, a hammer mill, shaking and vibrating screens, and the necessary elevators and bins. Products made include crushed marble for use in cemeteries, flux for foundry use, stucco dash, marble sand, poultry grit, and marble flour used in the making of putty.

Cobble Hill

A circular hill of light grey high-calcium limestone about 90 acres in area occurs on the west side of the Esquimalt and Nanaimo railway about ½ mile southwest of Cobble Hill station. Lime was made here many years ago by John Raymond.

The limestone is partly fine-grained and partly coarse-grained, and is veined with white calcite. In some parts of the deposit irregular patches and narrow streaks of siliceous material show as protuberances on the weathered surface. On the southwest side of the hill, however, is a large area of limestone nearly free from this siliceous material, as shown by the analysis of Sample 7 taken there.

On the east edge of the deposit are the small quarry and ruins of the draw-kiln formerly operated by Mr. Raymond. Siliceous patches are visible in the limestone in this part of the deposit. Sample 7A was taken from the 20-foot face of the quarry. A little higher up on the hill from this quarry is another smaller quarry in a purer limestone.

Sample 7B was taken along the western edge of the hill. Sample 7C was taken across the hill from east to west, and represents an average of all the limestone exposed.

There is a light overburden of soil on the hill and much of the limestone is hidden by moss, but no igneous dykes so characteristic of the Sutton limestone were observed in the exposed areas, and no magnesian areas were seen. This deposit can be cheaply quarried. The distance from the eastern edge of the exposed limestone to where the railway siding was formerly is about ¾ mile.

Beaver Cove

White and blue, fine-grained, heavily bedded high-calcium limestone rises in a high bluff along the northwest side of Tsulton river, about 1¾ miles southwest of Beaver Cove. It seems to form part of a band of limestone about 700 yards wide that strikes northwest-southeast and dips southwest at a steep angle. Persons living in this neighbourhood say that this limestone appears again to the south and can be followed southerly along the west side of the valley of Kokish river (which joins Tsulton river at Beaver Cove) to Bonanza lake where it forms high bluffs along the lake shores. Similar limestone is also reported to occur in great quantity at Nimpkish lake.

At Tsulton river the limestone is exposed on lots 1 and 8, which are owned by Canadian Forest Products, Limited, Vancouver, and also on lot 1583, where a claim has been staked by Cooper Drabble of Vancouver. Most of the limestone is white and has a sugary texture, but bands of fine-grained, blue limestone are interbedded with the white. The most obvious impurities are occasional small nodules of quartzite or of chert, and in places some thin dykes of pale green igneous rock are present. Igneous rocks occur on both sides of the limestone band. The cliff is at least 200 feet high and rises nearly vertically. Sample 8 was taken from the white limestone that composes the major part of the band, and Sample 8A was taken from several of the interbeds of blue limestone. There is little difference in chemical composition between the white and the blue. Near the contacts with the igneous rocks the limestone is generally less pure than in the centre of the band. Because of its heavy bedding and favourable grain this limestone has been investigated as a source of marble, the intention being to float the blocks down Tsulton river to Beaver Cove in small scows, but no development has taken place. An unfavourable feature from the standpoint of its being used for marble is the excessive jointing. Good shipping facilities exist at Beaver Cove.

Port McNeill

Cliffs of "coloured marble" are reported on McNeill brook, about 3 miles inland from the mouth of the brook.

Quatsino Sound

High-calcium limestone of Triassic or Jurassic age is plentiful in Quatsino sound and is being quarried on Neroutsos inlet (Southeast arm) for use in the pulp mill of British Columbia Pulp and Paper Company at Port Alice. Dolmage[1] refers to this limestone as follows:—

> The limestone occurs chiefly in one large bed, which outcrops continuously along the east shore of the Southeast arm, through the narrows, and as far west as Marble creek, in Rupert arm. It also appears on the west shore of the Southeast arm, and on the West arm. It has been mapped separately and named provisionally the Quatsino limestone. Above and below it, interbedded with thin flows and beds of tuff are numerous thin beds of similar limestone, in places slightly argillaceous.

Gunning[2] gives a more detailed description of the limestone itself, as follows:—

> The purer and larger beds are white to grey and are generally distinctly crystalline. Exceedingly fine-grained beds form a small percentage of the whole and siliceous or cherty varieties are likewise sparingly developed. Every specimen effervesced freely in dilute hydrochloric acid. The most important limestone horizon in the area is that shown on the map (Geol. Surv., Canada, Map No. 225A) along the east side of Neroutsos inlet and which continues southeast past Alice lake, Kathleen lake, and then across the valley of Elk river into Raging River valley. In its lower portion, in the vicinity of Kathleen and Alice lakes, this limestone contains small interbeds of lava and above it lies a mixed series of argillites, quartzites, and volcanics in which there are small beds of argillaceous limestone. The Quatsino limestone is the host rock for several mineral deposits, including the Old Sport and June mines, the Alice Lake group, and others, and on Neroutsos inlet certain beds are quarried by the B.C. Pulp and Paper Company for their pulp mill at Port Alice. The continuation of the Quatsino limestone to the northwest of Quatsino narrows is not definitely established, as there is faulting of considerable importance in this vicinity.

The present quarry of *British Columbia Pulp and Paper Company, Limited* is on Neroutsos inlet of Quatsino sound, on lot 1582, Quatsino mining division.

[1] Dolmage, E.: Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 32.
[2] Gunning, H. C.: Geol. Surv., Canada, Sum. Rept. 1929, pt. A, p. 103.

Analyses, supplied by the company, of the quarried stone as delivered to the mill from the present quarry and from other quarries previously worked on Quatsino sound are as follows:—

	1 A	1 B	2	3	4	5
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Silica	0·52	0·20	0·34	0·4	6·0	1·3
Oxides of iron and alumina	0·86	0·19	0·33	0·3	1·3	0·6
Calcium carbonate	77·64	88·10	98·00	82·3	98·3	92·1
Magnesium carbonate	21·58	11·33	1·20	0·7	14·2	6·0

1. A and B. Analyses of limestone presently obtained.
2. Sample of dense-textured, dove-grey limestone sent to the Mines Branch, Ottawa, in December, 1929.
3. Compilation of minimum amounts of the various constituents in limestone from quarries on Quatsino sound, worked prior to 1929.
4. Compilation of the maximum amounts of the various constituents in limestone from the same quarries.
5. Average analysis of limestone obtained prior to 1929.

Analyses[1] made in the Bureau of Mines laboratories of four samples supplied by the company are as follows:—

—	1	2	3	4
	Per cent	Per cent	Per cent	Per cent
Silica	0·24	0·48	0·80	0·74
Ferric oxide	0·05	0·05	0·13	0·08
Alumina	0·12	0·17	0·66	0·19
Calcium phosphate	0·04	0·04	0·04	0·04
Calcium carbonate	87·00	83·51	57·72	87·90
Magnesium carbonate	12·42	14·65	39·74	10·71
Total	99·87	98·90	99·09	99·66
Sulphur	0·02	0·01	0·02	0·02

1. Grey, fine-grained limestone from bottom of face.
2. Dove-grey, fine-grained limestone representative of 10 feet of beds above Sample 1.
3. Dove-grey, fine-grained limestone representative of 8 feet of beds above Sample 2.
4. Dove-grey, fine-grained limestone representative of 2 feet of beds above Sample 3.

High-calcium limestone is reported to occur on the eastern end of Limestone island at the entrance to Neroutsos inlet.

Marble creek, in Rupert arm east of Neroutsos inlet, flows through a narrow canyon of blue limestone for half a mile, at a place 1 mile above its mouth. The limestone walls of the canyon rise 50 to 150 feet perpendicularly.[2] In places the limestone is magnesian.

Limestone is also reported to occur in quantity west of Hankin point on the north shore of Holberg inlet (West arm of Quatsino sound).

Nootka Sound

The enormous bodies of limestone occurring on Nootka sound have been mentioned frequently in geological literature dealing with the west coast of Vancouver island. In 1908 Nootka Quarries, Limited of Vancouver undertook the quarrying of marble from this limestone at Deserted creek on Tlupana arm

[1] Analyst, J. A. Rivington.
[2] Carmichael, H.: Rept. Minister of Mines, B. C. 1903, p. 203.

and erected a fully equipped marble mill on its property. Operations, however, lasted only a year. The following description of the limestone of this area is largely abstracted from W. A. Parks' report on the Building and Ornamental Stones of British Columbia,[1] which treats of the limestone in considerable detail.

The east side of Tasis canal from the narrows at the entrance to the head, a distance of 16 miles, is composed almost entirely of limestone of Triassic or Jurassic age. It forms mountains 3,000 feet high. It is also exposed along the west side of the head of the canal and appears to continue far to the north and west. On Tlupana arm, to the east, the limestone again occurs in great quantity and outcrops also occur along the southern side of Muchalat arm, near the entrance and near the head.

Most of the limestone on the east side of Tasis canal is a fine-grained, dark bluish high-calcium limestone that has been much fractured and is recemented along the fracture planes by white calcite. Dykes of igneous rock intersect the limestone in many places. Near the head of Tahsish arm and on the west side, the limestone has been highly metamorphosed by igneous rock and is much lighter in colour. Some of it is dolomitic and some contains much tremolite. Some exploration was done in this area for marble, but the results were not promising.

On Tlupana arm the limestone is much intersected by igneous dykes and is lighter in colour and coarser in grain. It is well exposed for more than a mile along both sides of Deserted creek and it is on the northeast side of this creek that the marble-working plant was built by Nootka Quarries, Limited. Quarries were opened on both sides of the creek, but little quarrying was done. Parks states, however, that a considerable number of satisfactory blocks were obtained despite the shallowness of the quarries. The marble is grey of various shades streaked with white. The grain is medium to coarse. Parks[2] gives the following analyses of the white and of the bluish grey varieties.

	Per cent 1	Per cent 2
Insoluble matter	1·16	0·20
Soluble silica	0·10	0·10
Ferrous oxide	0·13	0·06
Ferric oxide	Tr.	Tr.
Alumina	0·04	0·04
Calcium carbonate	95·62	97·86
Magnesium carbonate	2·35	0·92
Total	99·40	99·18
Sulphur	0·015	0·011

1. White limestone.
2. Bluish grey limestone.

Bands of dolomite are also present in the limestone on Tlupana arm, but there is no information as to the amount available.

Parks[3] also mentions the presence of some hard dolomitic bands that "have a peculiar spotted appearance. The spots are dark when fresh, but on weathering they become white and soft". The same author[4] states that these "crystals or crystalline aggregates of foreign matter" are about 5 mm. in maximum diameter and that they are more soluble than the bulk of the stone and weather out leaving a white residue in the bottom of the pits. The present writer did not have the opportunity to examine this deposit, but is of the opinion that the crystals referred to by Parks consist of the mineral brucite.

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. 452, p. 163.
[2] Parks, W. A.: Op. cit., pp. 167, 168.
[3] Parks, W. A.: Op. cit., p. 166.
[4] Parks, W. A.: Op. cit., p. 169.

Parks gives the location of the spotted stone as near a small opening on the opposite shore of Deserted creek from the main marble quarry and ¾ mile distant in a direction S. 30° E. from the quarry.

On Muchalat arm on the eastern side of Nootka sound, Webster[1] reports the occurrence of crystalline limestone on a small brook about 8 miles east of Camp cove. It is much cut by igneous dykes. The strike is S.70° E. and the dip is south at an angle of 45 degrees. Limestone in a band 250 yards wide occurs on the west side of the southerly extension of Muchalat arm, about ½ mile south of the point at the entrance to this southerly extension. It is not so highly crystalline as are most other limestones on Nootka sound. It strikes N. 60° W. and dips southwestward at an angle of 30 degrees.

Flores Island to Barkley Sound

Webster[2] reports the occurrence of limestone bands at the following places between Flores island and Barkley sound:—

North Arm. On a small island one mile south of the eastern entrance to Shelter arm a 30-foot band of crystalline limestone occurs, striking east and west.

Herbert Arm. Three-quarters of a mile east of Charles point at the southern entrance to Herbert arm, "dark-weathering crystalline limestone having harder and somewhat siliceous bands" is exposed. The strike is S. 40° E.; dip very irregular, but generally to the southwest at angles of from 30 to 60 degrees. Small outcrops of limestone occur a short distance east of this and at a place on the east shore 1 mile from the head of the arm. Small exposures occur also on the west shore of Herbert arm.

Bedwell Sound. In Race narrows, between Bedwell sound and Warne bay, white limestone weathering to an ochreous yellow is exposed on the most southern part of the north shore. Towards the west the limestone assumes a schistose character and strikes N. 40° to 50° W., and dips northeast at an angle of 30 degrees.

Tofino Inlet. A limestone band 150 yards wide striking S. 60° W. to due east and west is exposed on the west shore at the mouth of Tranquil creek. Limestone also occurs at the head of Tofino inlet on the banks of Tofino creek. White limestone is exposed at the rapids on Kennedy river on the east side of Tofino inlet, and similar limestone occurs on both sides of a deep bay on the south side of Kennedy lake and at the mouth of Elk river on the east side of Kennedy lake.

In 1931 a sample of very coarsely crystalline, grey high-calcium limestone said to have come from Tofino inlet was forwarded to the Mines Branch for examination. This sample had the following analysis:—

	Per cent
Silica	0·80
Oxides of iron and alumina	0·14
Calcium carbonate	96·84
Magnesium carbonate	2·16
Total	99·94

This sample yielded a white lime of good quality except that it tended to crumble somewhat on calcination.

[1] Webster, Arthur: Geol. Surv., Canada, Sum. Rept. 1902, pt. A, p. 71.
[2] Webster, Arthur: Op. cit., pp. 63-69.

Barkley Sound. Numerous small deposits of limestone are mentioned as occurring along the shores of Barkley sound, but little information is available concerning them. On the north side of Pipestem inlet, near its head, a deposit of fine-grained, blue limestone is reported and it is said that white crystalline limestone on Effingham inlet has been quarried for marble. The amount so quarried must have been very small since there is no record of quarrying activity in that locality, which is in the northwest part of Barkley sound. Limestone striking N. 50° E. and dipping southeasterly at angles of 25 to 45 degrees is reported to occur on a small island at the mouth of Uchucklesit harbour, on the west side of the entrance to Alberni canal. White crystalline limestone, much cut by dykes of igneous rock, forms the north shore of Ecoole harbour for a mile or more. Crystalline limestone intimately associated with igneous rock occurs on the northeast end of Copper island and down the east shore as far as Clifton bay. These limestones cross the middle of the island and can be traced as far as Marble cove on its west side. Limestone is reported to occur a short distance up the Sarita river on the east side of Barkley sound, just north of Numukamis bay.

Barkley Sound to Port San Juan

Masses of metamorphosed high-calcium limestone, separated by wide areas of intrusive granitic rocks, are reported by Clapp[1] to underlie a belt 10 to 12 miles wide extending eastward from Numukamis bay on Barkley sound to the mouth of the Gordon river at Port San Juan bay, a distance of over 30 miles. Clapp considers these limestone masses to be either of Jurassic or Triassic age.

The limestone masses are small and narrow at both ends of this belt, but on Nitinat lake, midway between Port San Juan and Barkley sound, they attain a great thickness. Clapp[2] states:

> The marbles are sometimes thick-bedded and not greatly jointed, such as those exposed at the southern end of Nitinat lake to the northeast of the Indian reservation; more commonly, however, the marbles are thin-bedded and greatly jointed and fractured. Shear zones are frequent, along which alteration of the marble has taken place, producing the dark weathering, silicified varieties.
>
> . . . . There are many areas of white, usually coarsely crystalline limestone or marble, but the larger portion of the original limestones appears to have been profoundly altered by invading magmas. The purer, white marbles, are seen on microscopic examination to consist essentially of calcite in irregular grains, firmly cemented by the same material. The accessory constituents are small in amount and include quartz, which occurs in very small grains, sericite, and epidote. Pyrite is usually present in small disseminated grains, which weathering to limonite, slightly stain the exposed surfaces.
>
> The chemical composition of one of the purer outcrops on the west shore of the southern end of Nitinat lake, northeast of the Indian Reservation, is as follows:—

	Per cent
Insoluble mineral matter	2·64
Ferric oxide and alumina	0·40
Phosphorus	Trace
Sulphur	0·01
Calcium carbonate	96·89
Magnesium carbonate	0·42
	100·36

Analyst: F. G. Wait, Mines Branch, Ottawa.

Webster[3] mentions a band of highly crystalline limestone 40 feet thick as occurring on the Gordon river 5 miles from its mouth. He reports, also, a band

[1] Clapp, C. H.: Geol. Surv., Canada, Mem. 13, p. 44 (1912).
[2] Clapp, C. H.: Op. cit., p. 46.
[3] Webster, A.: Geol. Surv., Canada, Ann. Rept., vol. XV, p. 63 et seq. (1902-3).

of fine-grained crystalline limestone 200 feet thick striking S. 50° to 60° E. and dipping southwesterly at an angle of 50 degrees on Dixon point on the east shore of Alberni canal.

At Poett cove and extending for half a mile into Numukamis bay, limestone bands are reported by Webster and he also states that crystalline limestone occurs on the southeast end of Santa Maria island in Barkley sound.

Analyses of Limestones on Vancouver Island

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
1........	1·08	0·12	0·44	0·04	97·64	1·26	100·58	0·06	54·70	0·60	91 : 1
1A......	1·32	0·15	0·34	0·02	95·78	1·03	98·64	0·07	53·65	0·49	105 : 1
1B......	1·52	0·33	0·15	0·04	63·80	34·28	100·12	Tr.	35·75	16·39	2·18 : 1
2........	1·12	0·20	0·31	0·04	96·76	1·41	99·84	0·05	54·21	0·67	81 : 1
3........	1·28	0·16	0·21	0·04	96·90	1·74	100·33	0·03	54·29	0·83	65 : 1
4........	1·01	0·20	0·18	0·04	96·16	2·21	99·80	0·04	53·87	1·05	51 : 1
5........	1·42	0·31	0·21	0·04	96·50	1·21	99·69	0·02	54·07	0·58	93 : 1
6........	1·40	0·28	0·88	0·04	95·80	1·38	99·78	0·01	53·66	0·64	84 : 1
7........	0·56	0·08	0·20	0·09	96·25	1·89	99·07	Nil	53·95	0·90	60 : 1
7A......	2·76	0·09	0·22	0·07	94·59	1·72	99·45	Tr.	53·01	0·82	64 : 1
7B......	4·08	0·13	0·15	0·09	94·45	0·48	99·38	Tr.	52·94	0·23	230 : 1
7C......	4·02	0·13	0·17	0·09	93·98	1·43	99·82	Tr.	52·68	0·68	77 : 1
8........	1·04	0·16	0·12	0·04	96·98	0·71	99·05	0·02	54·34	0·34	160 : 1
8A......	1·74	0·23	0·25	0·04	96·52	1·03	99·81	0·02	54·08	0·49	110 : 1

1.	West side Esquimalt harbour.	Sutton limestone in quarry 1,000 yards from the shore, formerly worked by Rosebank Lime Company.
1A.	" " "	Quarry from which shipments were made to British Columbia Cement Company.
1B.	" " "	Small mass of highly magnesian limestone near the tramway leading to the quarry from which stone for cement-making was taken.
2.	Langford.	Quarry in Sutton limestone, 1 mile east of the station.
3.	Parsons Bridge.	Quarry formerly worked to supply Atkins lime kiln.
4.	Bamberton.	Sutton limestone in upper level of the quarry of British Columbia Cement Company.
5.	Tod Inlet.	Sutton limestone across northern end of quarry 1,200 yards east of the old Tod Inlet cement plant.
6.	Malahat.	Sutton limestone in quarry worked by Marble and Associated Products, 2½ miles southwest of Malahat station.
7.	Cobble Hill.	Southwest side of hill of Sutton limestone, west of the railway and ½ mile southwest of the station.
7A.	" "	Twenty-foot face in small quarry.
7B.	" "	Western edge of hill.
7C.	" "	Across the hill from east to west.
8.	Beaver Cove.	White limestone composing the major part of the band on Tsulton river.
8A.	" "	Interbeds of blue limestone in the same deposit.

Texada Island

Texada island, a high rocky island 60 miles long and averaging about 4 miles in width, lies in the Strait of Georgia between the southern part of Vancouver island and the mainland. It has long been noted for its deposits of high-grade limestone that are yielding stone for the manufacture of chemical lime, Portland cement, and sulphite pulp, and also for flux, agricultural limestone, poultry grit, stucco dash, whiting substitute, and for dusting coal mines, as well as for a variety of minor uses. These products are obtained from the Marble Bay limestone formation in the northern part of the island. Another limestone formation known as the Anderson Bay formation, and found only in limited areas in the southern part of the island, has possibilities of yielding a marble of unique appearance.

The island has been mentioned in many geological reports but most of the detailed work on the limestones was done by R. G. McConnell.[1] He mapped the limestone areas and much information concerning the deposits is given in his report.

He considers the Marble Bay limestone to be either Lower Jurassic or Triassic in age and not Carboniferous as it was previously considered. His work has shown that the formation is confined to the northern part of the island where it occurs "in two large and a multitude of small areas, some only a few feet across, separated by igneous rocks". The largest area, covering approximately 14 square miles, begins at the northern end of the island and extends from there in a gradually narrowing strip 1 to 1½ miles wide, along the northeast coast to 1 mile beyond Vananda, from where it extends due south in a belt, as much as 2 miles wide in places, to within about ⅓ mile of the west coast opposite Welcome bay, where it terminates.

The second largest area, covering about 3 square miles, is near the west coast midway down the island, its northern tip being opposite Mouat bay and its southern tip opposite Davies bay.

In addition to the two large areas, numerous limestone inclusions, mostly too small to map, occur in the porphyrites from Davies bay northward to Crescent bay. The inclusions are variable in size and shape, ranging from angular shreds a few yards in lengths to rounded or lenticular areas traceable for a quarter of a mile or more. They are considered to be fragments of a limestone area which originally covered the island from its northern tip south to Davies bay, and an unknown distance beyond, and was largely destroyed by the porphyrites.

The small limestone areas are always coarsely crystalline and are more impure than the large areas. Cherty layers are common, and some of the areas are rimmed, impregnated, and occasionally partially replaced with various contact metamorphic minerals both metallic and non-metallic.[2]

The Marble Bay limestone is preponderantly high-calcium, but in many places it contains irregular masses and interbeds of magnesian limestone. It is also cut by numerous dykes of igneous rock from a few inches to 20 feet thick that have branched out from stocks and masses of intrusive diorite. The dykes appear in most instances to have had little effect on the limestone, but in the neighbourhood of stocks and masses of diorite and quartz diorite the limestone is generally much metamorphosed. The unaltered limestone occurs mostly in the northern tip of the island (except on the east side of Blubber bay), and also composes the area on the west coast between Mouat bay and Davies bay. In these places the limestone is dark bluish grey to nearly black, is very fine-grained, and occurs in thick undulating beds devoid of shale partings. On the east side of Blubber bay and around Vananda and south thereof are stocks and masses of diorite, and at Vananda and at Welcome bay are masses of quartz diorite that have greatly affected the limestone. In these areas the limestone is light blue to light grey, with ocasional patches of white, and ranges in texture from sugary to very coarse. Adjacent to these intrusive masses, mineralization of the limestone has occurred and mines have been worked for gold, copper, and magnetite. Non-metallic minerals observed in the contact zones were garnet, epidote, pyroxene, serpentine, and chrysotile.

The interbeds of magnesian limestone occurring in the Marble Bay formation are distinguishable from the high-calcium limestone on weathered outcrops by their brown colour and characteristically scarred surface, as contrasted with the grey colour and smooth surface of the high-calcium limestone. On fresh fracture the two varieties are almost identical in appearance and are distinguishable in the quarry only by etching with dilute acid, which leaves the dolomite crystals standing in relief on the glazed surface of the calcite. No

[1] McConnell, R. G.: Geol. Surv., Canada, "Texada Island, B.C." Mem. 58 (1914).
[2] McConnell, R. G.: Op. cit., p. 18.

beds were observed consisting entirely of dolomite, but tiny dolomite crystals occur irregularly disseminated and as thin veins through the high-calcium matrix. There are many indications that the dolomite is due to replacement. It is found, for instance, in irregular zones rather than in well-defined beds and is commonly more abundant in the vicinity of intrusive masses of diorite. At Blubber bay magnesian interbeds are common in the top strata over much of the area, but are absent at depth in the quarries of Pacific Lime Company. The limestone is also virtually free from magnesian beds on the northeast tip of the island, east of Vananda, and opposite Welcome bay on the west coast. Where these magnesian beds are absent the Marble Bay limestone commonly consists of over 98·5 per cent calcium carbonate.

The thickness of the Marble Bay formation is unknown, but the shaft of the Marble Bay mine at Vananda had reached a depth of 1,700 feet when work was stopped and it was still in the limestone.

The light-coloured limestone is preferred for use in sulphite-pulp mills, for poultry grit, and for stucco dash, but the fine-grained, dark-coloured limestone makes the better lime, and, with the exception of that from some of the surface beds, is snowy white and of excellent quality. Blubber Bay and Vananda are the present quarry centres.

The Anderson Bay limestone as mapped by McConnell occurs only in the southern tip of the island in the form of relatively small lenses, the largest, ½ mile long, being near Anderson bay on the east coast. It is older than the Marble Bay limestone. (McConnell considers it to be probably of Triassic age.) It consists mostly of calcium limestone with some masses of dolomite and is not of high purity. Its commercial possibilities are limited to its use as marble.

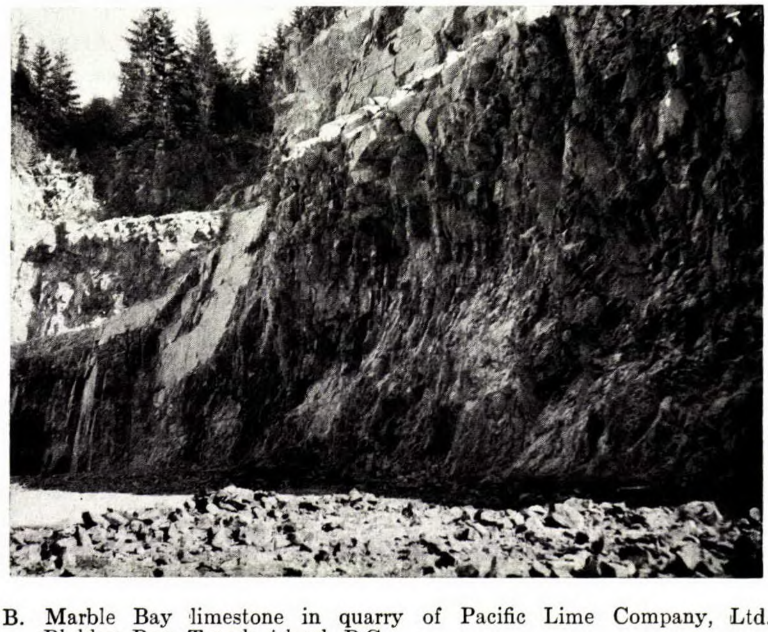
Blubber Bay

At this bay on the northern tip of the island are the quarry and lime plant of Pacific Lime Company, Limited and a quarry operated by British Columbia Cement Company, Limited. Blubber bay is sheltered from most winds and the water is deep.

Pacific Lime Company, Limited, Head Office, Pacific Bldg., 744 Hastings St. W., Vancouver. This company has been producing high-calcium lime and limestone at Blubber Bay since 1909. The lime is white and of a high purity, and is marketed for chemical and construction purposes in British Columbia and along the Pacific coast of the United States as far south as San Francisco. The company owns over 1,500 acres of land underlain by limestone on the northern part of Texada island, but operations to date have been confined to the property on the southwest corner of Blubber bay. Here the Marble Bay limestone in a comparatively unaltered state lies in gently dipping beds having a roughly domed structure. The upper beds to a depth of 20 to 40 feet consist in part of magnesian limestone, but beneath and extending to an unknown depth is remarkably pure, massive, very fine-grained, dark blue-grey, high-calcium limestone. Dykes of intrusive igneous rock, mostly diorites, cut the limestone in various directions, but the main dykes are nearly vertical and the majority trend roughly east and west. They vary in thickness, usually from a few inches to 10 feet, but one which runs between Quarry No. 1 and Quarry No. 2 has a thickness of 20 feet in places. The dykes on the average are about 75 feet apart, and though the dyke rock interferes with complete mechanization of the quarry operations it is easily distinguishable and readily removed by the hand-cobbing methods commonly employed in quarries producing stone for making lime, and a pure product is thus obtained. The dykes have had little

PLATE XXV

A. Plant of Pacific Lime Company, Ltd., Blubber Bay, Texada island, B.C.



B. Marble Bay limestone in quarry of Pacific Lime Company, Ltd., Blubber Bay, Texada island, B.C.

effect on the limestone. Adjacent to some dykes there is a slight lightening in colour and also a small development of iron and copper sulphides in the limestone, but adjacent to others there is no visible change.

The lime plant (Plate XXV A, page 145) is at the shore and the quarries have been opened immediately south on a gently sloping hillside that rises to a height of 130 feet at a distance of 600 feet south of the kilns. No. 1 Quarry, the nearest to the kilns, is 240 feet by 175 feet in area and was worked to a depth of 300 feet. It is slowly filling with water. Although it is close to the shore and was worked to a depth far below low water there was no seepage of salt water. The limestone exposed in this quarry is very fine-grained, and for the most part is dark bluish grey, although in the deeper part it is lightly mottled with grey. Except for the upper 25 feet it is remarkably pure and uniform in composition, as shown by the analyses of Samples 9, 9A, 9B, and 9C, each of which represents a channel sample of a vertical section 20 feet thick beginning 50 feet from the surface. The last of these samples was taken in 1937 while the quarry was being worked. This quarry is bounded by igneous dykes on the south and west sides.

No. 2 Quarry (Plate XXV B, page 145) now being worked, adjoins No. 1 Quarry to the south and is separated from it only by a wide igneous dyke trending east and west. This quarry in 1944 was approximately 400 feet long, east and west, and 200 feet wide. It was being extended towards the west as well as being deepened. It has a face of 60 to 70 feet high, of which the top 20 to 30 feet contains magnesian beds, as is shown by the analysis of Sample 9D, representing the top 30 feet of strata on the south side of the quarry. Beneath this the limestone is uniformly low in magnesium carbonate, as shown by Sample 9E, representing the next 30 feet in the quarry face vertically below the top 30 feet. The domed structure of the limestone beds is easily recognizable in this quarry, as the strata dip at low angles to the east on the east side, to the west on the west side, and to the north on the north side. The north wall of this quarry consists of the dyke of igneous rock 10 to 20 feet thick that separates it from Quarry No. 1. One hundred feet south a thin dyke of soft, green igneous rock crosses the quarry from east to west, and 80 feet south of this is another thin dyke, 3 to 4 feet wide, also crossing the quarry in an east and west direction. One hundred and twenty feet farther south an igneous dyke 10 feet thick trends east and west just south of the southern limit of the quarry. These dykes all have a general dip steep to the south.

Directly east of Quarries No. 1 and No. 2, limestone for flux was formerly quarried over an area about 250 feet square, but no rock has been taken from this area in recent years and the old quarry is used in part for storage of spalls. The strata include interbeds of magnesian limestone. Sample 9F was taken from 30 feet of strata composing the eastern face of this quarry. An igneous dyke trending northeast-southwest was observed in this area, in addition to the dykes trending east and west.

The limestone is drilled with jackhammers in 12-foot benches. The rock breaks readily and any large fragments remaining after blasting are sledged into pieces having a maximum diameter of 10 inches. The broken rock is then loaded on trucks by a gasoline-driven, $1\frac{1}{4}$-yard shovel. The trucks dump on a sloping grizzly set at 3 inches. Oversize is taken by buckets on an elevated cable-way to the storage bins above the kilns, and the undersize is taken by bucket on another cable-way to the spall pile for subsequent shipment for use as flux, or for the manufacture of Portland cement. Stone from the spall pile is recovered by dragline scraper, which loads a 4-ton car that is pulled by cable over a narrow-gauge railway laid on a trestle, from the end of which it dumps to a scow.

Feed for the rotary lime kiln is loaded on trucks in the quarry by a $\frac{3}{4}$-yard gasoline-driven shovel and delivered to a No. 4 Austin gyratory set to crush to a minimum size of $1\frac{1}{2}$ inches. From the crusher it is elevated to a double-deck vibrating screen placed over the kiln-feed bins, and two sizes, minus $1\frac{1}{2}$ inch plus $\frac{3}{4}$ inch and minus $\frac{3}{4}$ inch plus $\frac{1}{2}$ inch, are recovered. The undersize is passed through a chute to a bin from which it is taken to the spall pile.

The lime plant equipment includes four vertical kilns and a rotary kiln having a combined capacity of 120 tons of lime per day, a Clyde hydrator, grinding mills for pulverizing quicklime, and bagging machines. Two of the vertical kilns have steel shells and the other two are constructed of stone. The kilns with the steel shells burn sawdust which is fed into semi-gas-producer fire-boxes, and the kilns work under both forced and induced draught. Each has a capacity of 26 tons of lime per day. In the stone kilns, slabs from the adjacent sawmill operated by the company are used for fuel. Each of these kilns has a capacity of 16 tons of lime per day. The rotary kiln is 124 feet long and 5 feet in inside diameter. It is oil-fired and produces 42 tons of lime per day. The snowy white lime produced at Blubber Bay is made from limestone obtained 30 feet and more below the surface, as it was found that much of the stone from the surface beds yielded a brownish grey lime. The reason for this is the presence of small amounts of manganese in the surface beds. According to the company, if the amount of MnO exceeds 0·03 per cent in the limestone the resulting lime will be yellowish or brownish.

The lime is marketed as lump lime, pebble lime, crushed lime, pulverized lime (processed lime), and hydrated lime. Facilities are available at the plant for loading the lime into standard railway box cars brought to the plant on large scows, but most of the output is bagged or barrelled and loaded on large covered scows for transportation to the mainland cities along the coast.

Diesel engines are used to generate electrical energy for the quarry and plant. Steam is also available from boilers, under which is burned waste from the sawmill operated by the company.

Fogh Property, Blubber Bay. This property lies immediately east of Pacific Lime Company's property and also fronts on Blubber bay. It comprises all of lot 9 and is 200 acres in area. It has been optioned several times. Small quarries have been opened, and a lime kiln and a small dock have been built, but there is no activity at present.

The property is underlain by limestone of the Marble Bay formation, most of which is dark bluish grey, but near the centre, or just to the southeast of what is known as the Paris mine, is a mass of white high-calcium limestone. Dykes and stocks of igneous rock invade the limestone in the various parts of the property. In many places the limestone beds are much disturbed and the dip is at a high angle. Many of surface strata contain interbeds of magnesian limestone and occasional outcrops of highly magnesian limestone were observed. The average content of magnesium carbonate in 35 samples taken at various places over the property was 5·8 per cent, although there are relatively large areas where the magnesium carbonate content averages between 1·5 and 2 per cent, one such being in the centre of the lot near the shore of Blubber bay.

Near the lime kiln a small quarry has been opened in very fine-grained, dark blue-grey limestone, which is traversed by an irregular branching dyke of soft, green, igneous rock. Adjacent to this dyke some of the limestone is whitened. Sample 10 was taken in this quarry and from outcrops in the immediate vicinity.

Three hundred feet south of the kiln and on higher land is another quarry 25 feet wide, 40 feet long, and with a face 20 feet high. The strata in this quarry appear to strike N. 80° W. and to dip south at an angle of 55 degrees. The limestone exposed is mostly very fine-grained, blue-grey calcium limestone in heavy beds. Etching with acid reveals the presence of tiny grains of dolomite in the limestone and at the north end of the west wall of the quarry are some bands of very fine-grained, blue-grey dolomitic limestone, up to 19 inches thick, interbedded with the calcium limestone. Sample 10A was taken in this quarry, but does not include the dolomitic bands. A winding dyke, 19 inches thick, of bluish igneous rock cuts the limestone at the south end of the quarry.

The greater part of the limestone on lot 9 is similar to that just described, but southeast of the Paris mine, which is near the centre of the lot, white, medium- to fine-grained high-calcium limestone forms a hill about 250 feet in diameter only lightly covered with overburden and extends westerly from this hill in a narrow zone for 300 yards. A short distance north is a large mineralized mass of igneous rock trending east and west. Between the dyke and the white limestone is a band of blue limestone in places 50 feet wide. Light blue, highly magnesian limestone occurs around the margin of the white limestone, but none was observed within it, though possibly some is present in the covered areas. Sample 10B is representative of the white limestone comprising the hill. Subsequent to the examination of this area of white limestone a quarry was opened in it.

The lime kiln on this property stands at the shore of Blubber bay, close to a small dock. It is a draw-kiln 55 feet high and is constructed of concrete and lined with firebrick.

Blubber Bay Property of British Columbia Cement Company. British Columbia Cement Company operates a quarry at Blubber Bay to obtain pure limestone for admixture with the output of the quarry at Bamberton. The property consists of lot 12, which takes in the entire northeast tip of the island including the east shore of Blubber bay, and comprises 275 acres. The limestone is much disturbed and is lighter in colour and coarser in grain than that west and south of Blubber bay. These changes were probably brought about by a large diorite intrusion along the shore. The general strike of the strata appears to be N. 24° W., and the dip is northeast at a steep angle. Overburden is light over most of the area.

Four quarries have been opened along the shore between the crusher house and the tip of the bay, with the floors of each 45 feet above high water. A tramway of 3-foot gauge runs from the crusher to the farthest quarry, about 4,000 feet distant. The nearest quarry to the plant, Quarry No. 1, is opened in medium-grained to coarse-grained, blue limestone relatively free from igneous dykes, but containing interbeds of magnesian limestone. Sample 11 was taken from the face that was worked in 1929. The land back of the quarry rises gradually to a height of 200 feet above the quarry floor, and back of this hill there are areas where the magnesian limestone is less evident on the surface than in the immediate vicinity of the quarry where numerous beds of highly magnesian limestone are visible.

Quarry No. 2 was opened a short distance north of Quarry No. 1 and exhibits much the same type of rock.

Quarry No. 3 was opened near the south end of the mass of diorite previously mentioned as occurring along the shore, but the numerous dykes extending southeasterly from this mass made it difficult to obtain a limestone product low in silica, although the magnesium carbonate content was much lower than that in Quarries No. 1 and No. 2. This quarry has a face 100 feet high and the limestone is very fine-grained and is dark blue-grey in colour. The dykes exposed in the quarry vary in thickness up to 20 feet, but they appear to be thinner and less numerous on the hillside east of the quarry.

Quarry No. 4 (Plate XXVI A, page 149), which is now being worked, was opened in light blue, medium-grained, sugary-textured, high-calcium limestone near the northeast tip of Blubber bay, and north of the diorite intrusion. The limestone here is nearly free from interbeds of magnesian limestone and in general is low in magnesium carbonate. Igneous dykes are present, particularly

A. Part of quarry of British Columbia Cement Company, Ltd., Blubber Bay, Texada island, B.C.

B. Loading dock for limestone shipments. British Columbia Cement Company, Ltd., Blubber Bay, Texada island, B.C.

in the southern part of the face, but are not sufficiently numerous to be unduly troublesome. Sample 11A is representative of the limestone in the quarry and from the outcrops in the vicinity. The following analysis was supplied by the company as being an average of shipments received at Bamberton during July 1944, from Quarry No. 4:

	Per cent
Silica	1·00
Oxides of iron and alumina	0·60
Calcium oxide	55·10
Magnesium oxide	0·49
Loss on ignition	43·30
Total	100·49

There appears to be a large area of limestone with a low content of magnesium carbonate at this locality, but the land rises only from 50 to 60 feet above the quarry floor. The present quarry face is 30 feet high.

Leyner drills are used in the quarry and the system of drilling is varied according to the height of face. Where the face is low, vertical holes are drilled from the top, and where it is high, horizontal breast holes are also drilled along the foot of the face. The limestone tends to break in large blocks that have to be reduced by secondary blasting. The broken stone is loaded on 5-ton, side-dump, steel cars by either a gas-electric, 1-yard shovel or by a diesel-powered shovel of the same capacity, both of which are mounted on caterpillar treads. A compressor having a capacity of 400 cubic feet of air per minute is also mounted on the gas-electric shovel. The loaded cars are hauled in trains of two by a gasoline locomotive over the 3-foot gauge track to the crusher. The crushing plant consists of a No. 6 gyratory, set to deliver rock crushed to a 4-inch maximum size. (A new 3- by 4-foot jaw crusher was being installed in 1944.) The quarried rock is first passed over a roll grizzly set to 3 inches, the undersize from which goes to a rotary screen with ½-inch holes. Undersize from the screens is sent to waste and the oversize joins the material that has passed through the primary crusher. The crushed rock is either elevated to the storage bin or is discharged direct to a 32-inch conveyer used for loading 500-ton scows (Plate XXVI B, page 149). The present capacity of the crushing plant is 200 tons an hour, but this will be increased to 500 tons when the new primary crusher is in operation. Electric energy for operating the crushing plant is generated by two Crossley diesel engines, one of 150 h.p. and the other of 300 h.p. boosted up to 450 h.p. by a supercharger.

The output of this quarry is towed on scows to the cement plant at Bamberton 90 miles distant.

Limekiln Bay

Property of Tacoma Steel Company. A number of years ago this company made lime at Limekiln bay from the Marble Bay formation, which lies in heavy, gently undulating strata with a prevailing dip west. The company's property consisted of lots 22 and 23, which include all the west shore of Texada island from its northwest tip to Marshall point, approximately 1½ miles. The quarry and kilns are on lot 23. There has been no production since 1908. The quarry is 550 feet long, 75 feet wide, and 17 to 25 feet deep. It is near the shore, in fairly level land on which is a dense second-growth of trees. Soil is from 1 to 2 feet deep. A section of the face from top to bottom in the northwest end of the quarry is as follows:

1 foot —Soil.
18 inches—Very fine-grained, dark blue-grey high-calcium limestone that weathers to a light blue.

9 inches —Very fine-grained magnesian limestone slightly lighter in colour than the high-calcium limestone and weathering to a brown. No definite line of parting between the magnesian limestone and the high-calcium limestone.
5 feet —Very fine-grained, blue-grey high-calcium limestone in a massive but much shattered bed.
14 inches—Very fine-grained magnesian limestone.
40 inches—Very fine-grained, bluish grey high-calcium limestone.
3 inches —Sill of igneous rock.
13 inches—Very fine-grained, blue high-calcium limestone containing pyrite.
4 feet —Very fine-grained, dark blue-grey high-calcium limestone.

The section varies somewhat in different parts of the quarry, because the magnesian beds differ in thickness from place to place and there is some minor faulting.

Sample 12 was taken from the high-calcium beds and Sample 12A from the magnesian beds. An average sample from the entire quarry face would contain about 7 per cent magnesium carbonate.

Below the quarry floor, which is from 30 to 35 feet above high water, is heavily bedded limestone with magnesian streaks similar to that in the quarry.

Four vertical draw-kilns constructed of limestone blocks and lined with firebrick stand near the quarry and when the property was examined in 1929 there were many barrels of lime lying around that had split open from the expansion caused by air-slaking. All the lime had a pinkish tinge. As the waste dumps show, an effort was made to cob out the dolomitic bands, but it is extremely difficult to distinguish the magnesian limestone from the high-calcium limestone when only freshly broken surfaces are seen.

The water is shallow in Limekiln bay and there is no shelter from westerly winds.

Crescent Bay

On the northern part of lot 24, which is in the north part of Crescent bay on the west coast of Texada island, immediately south of Limekiln bay, is a small area of Marble Bay limestone in which magnesian beds are particularly numerous. A rough sample showed a magnesium carbonate content of 16 per cent.

Eagle Bay

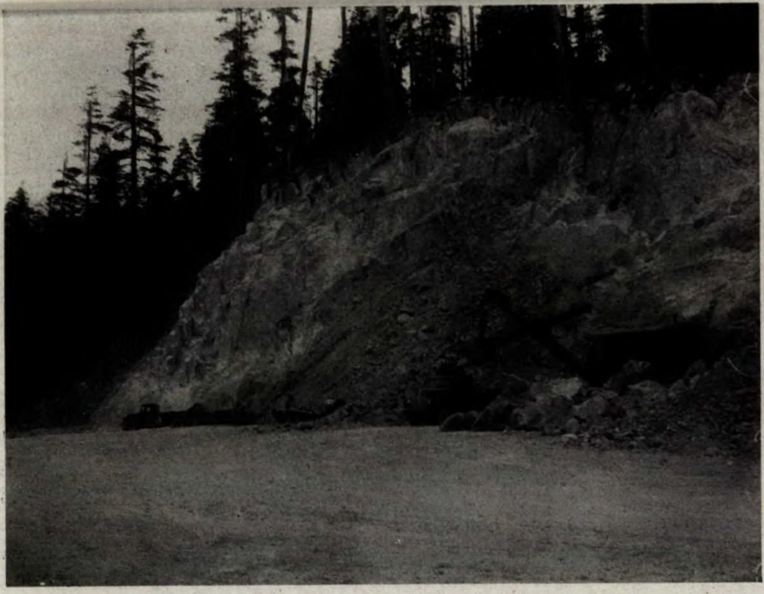
At this small bay on the east coast, 1 mile north of Sturt bay, fine-grained, blue-grey limestone of the Marble Bay formation is exposed in a favourable position for quarrying along a small ravine that extends southerly from the head of the bay. The limestone contains little silica, but contains about 6 per cent of magnesium carbonate because of interbedded magnesian layers. On top of the plateau to the southwest these interbeds are not so noticeable, although it is possible that they occupy the hollows between the outcrops.

Sturt Bay

Sturt Bay Property of Pacific Lime Company, Limited. Pacific Lime Company owns the southern half of lot 3, Texada island, which includes the head of Sturt bay. About 4,000 feet from deep water in Sturt bay, and in the angle between the trail to Crescent bay and the main road between Blubber Bay and Vananda, a cliff of fine-grained, blue high-calcium limestone rises to a height of 30 feet. The limestone is uniform in appearance and in the part examined no igneous dykes were observed. Sample 13 was taken from limestone exposed in the cliff.

PLATE XXVII

A. Quarry in Marble Bay limestone at Marble bay, Texada island, B.C.



B. Quarry of Beale Quarries, Limited, in Marble Bay limestone, Vananda, Texada island, B.C.

Marble Bay

Marble bay is the name of a small bay on the south side of Sturt bay. It is well sheltered and makes a good harbour for small craft. It is from this bay that the Marble Bay limestone formation takes its name. On both sides of the bay the limestone is intruded by stocks of diorite, with a resultant coarsening of the grain, lightening of the colour, and development of some contact metamorphic minerals. Tacoma Steel Company built its first lime plant at Marble bay, but on finding the stone unsuitable for making lime, the lime-burning operation was transferred to Limekiln bay at the north tip of the island (*see* page 150). Powell River Company, Limited took over the Marble Bay quarry and for a number of years the limestone was quarried by the latter company for use in making sulphite pulp at Powell River. Shortly after the Beale quarry at Vananda was opened in 1933 the requirements of the pulp mill were obtained there, and the Marble Bay quarry has not been worked since 1935.

The quarry (Plate XXVII A, page 152) is opened in the wooded hillside near the beach, and a face 60 feet high and 250 feet long was worked. The limestone varies in grain from fine to coarse, and in colour from blue through greenish grey to white. The several colours are in bands and presumably represent bedding. Bands of highly magnesian limestone alternate with bands of high-calcium. The dip is into the hill at an angle of 30 degrees and the strike is N. 50° W. An igneous dyke 10 feet thick cuts through the centre of the quarry in a southerly direction, and only that part east of the dyke was worked by the paper company. The dip of the strata flattens out noticeably in the vicinity of the dyke, where most of the white limestone occurs, but there is also some blue limestone adjacent to the dyke. Some of the limestone is highly magnesian, as is shown by the following analyses kindly supplied by Powell River Company:—

	1 Per cent	2 Per cent	3 Per cent	4 Per cent	5 Per cent	6 Per cent
Insoluble	1·72	2·16	0·88	1·33	1·44	3·15
Oxides of iron and alumina	0·65	0·14	0·36	0·42	0·24	0·84
Calcium carbonate	62·48	94·30	98·50	68·10	95·65	62·80
Magnesium carbonate	35·15	3·42	0·30	30·15	2·68	36·24
Total	100·00	100·02	100·04	100·00	100·01	100·03

1. Grey, fine-grained limestone.
2. Light grey, moderately coarse limestone.
3. Grey, very coarse limestone.
4. Grey, fine-grained and rather slaty appearing limestone.
5. White, coarse-grained limestone.
6. Blue limestone.

Sample 14 was taken from the entire face and includes all varieties. The average grade of limestone available is too impure to yield a high-grade lime.

The lime plant consisted of one small draw-kiln built of granite blocks and lined with firebrick. It stands on the shore and the quarry from which the limestone was obtained is a short distance back of it. The limestone exposed in the quarry is similar to that sampled.

Vananda

The Marble Bay limestone around Vananda is considerably altered by intrusions of diorite and quartz diorite and most of it is lighter in colour and coarser in grain that that found elsewhere. Much of it is also mineralized and several copper mines have been worked in the vicinity. The limestone in and around the village is mostly of the calcium variety and little dolomite was observed. The high shoreline and numerous ridges of limestone afford good opportunities for quarrying. Sample 15 was taken from a large outcropping of light blue, medium-grained limestone at the north edge of the village.

LeRoy[1] gives the following analysis of the limestone in the vicinity of the Marble Bay mine:—

	Per cent
Insoluble	6·00
Oxides of iron and alumina	0·30
Calcium carbonate	86·00
Magnesium carbonate	7·60
Total	99·90

Beale Quarries, Limited, Head Office, Pacific Building, Vancouver. This company is quarrying and processing limestone from the Marble Bay formation for use in sulphite-pulp mills, for flux, agricultural use, poultry grit, stucco dash, asphalt filler, whiting substitute, and for dusting coal mines. The quarry being worked is on the shore about 1 mile east of the village. There are several openings between a mass of quartz diorite on the west and the usual Texada Island porphyrite rock on the east. The distance between these two masses of igneous rock is about 700 yards and throughout this distance the limestone forms a 50-foot cliff along the shore and rises rather steeply back from the shore to a height of several hundred feet. The land is wooded, but the soil covering is thin. Igneous dykes are numerous in the vicinity of the quartz diorite and the quarry openings have been made successively farther east in order to avoid them. The present quarry (Plate XXVII B, page 152) has a face 200 feet long and 140 feet high. The floor is 50 feet above high water. The limestone is light blue-grey, mostly very coarse-grained, and is in massive formation, but apparently dips steeply inland and strikes parallel to the shore. There are few dykes of igneous rock. Sample 16 was taken in 1935 from the quarry then in operation, and Sample 16A was taken in 1944 from material being shipped. The limestone is drilled with jackhammers. Pieces of limestone too large for one man to lift are broken by sledging or by secondary blasting. One-man size stone is loaded by hand into 2½-ton buckets or skips, which are taken by a Brooks Load Lugger and dumped into a chute leading to a scow for shipment to pulp mills. Spalls are loaded into other skips and taken to the grinding plants. A gasoline-driven power shovel with a 1-yard dipper is also used for loading stone on trucks for conveyance to the grinding plants.

Two grinding plants are operated at the quarry, one for the production of agricultural limestone and the other for the production of limestone flour. The agricultural limestone plant has a capacity of 10 tons an hour, and the principal items of equipment are an 18-inch by 24-inch jaw crusher, an air-swept Jeffrey hammer mill, and vibrating screens. The plant making marble flour has a capacity of 5 tons an hour, and the principal items of equipment are a jaw crusher, a Sturtevant ring-roll mill, and vibrating screens. The products are marketed in multi-wall paper bags. Diesel engines supply the power to operate both plants, which adjoin each other at the western end of the quarry. All products are shipped on scows.

Adjacent to the mass of quartz diorite west of the quarry, the limestone is more magnesian than elsewhere on the quarry property and is somewhat similar to that at Marble bay, in that beds of rather highly magnesian limestone alternate with those consisting mostly of calcite. A quarry was opened here a number of years ago to obtain limestone for shipment to pulp mills but it has not been operated in recent years. The limestone is bluish grey, medium-grained, and is traversed by numerous dykes that emanate from the quartz diorite. The strike

[1] LeRoy, O. E.: Geol. Surv., Canada, Rept. 996, p. 55 (1908).

is northwest-southeast and the dip is southwest at 30 degrees. The quarry is opened in an escarpment facing northeast, and is 200 feet long with a face 100 feet high. No sample was obtained.

At Vananda village, *Beale Quarries, Limited* operates a small plant for the production of stucco dash, poultry grit, and whiting substitute. This plant has a capacity of 10 tons a day and the principal items of equipment are an 8-inch by 12-inch jaw crusher and vibrating screens. The limestone used is fine-grained, white limestone obtained by Messrs. S. J. McKay and D. J. McKay from a small quarry in the Marble Bay formation about 3 miles south of Vananda. The analysis of a sample of the whiting substitute produced from this limestone is as follows:—

	Per cent
Silica	0·20
Ferric oxide	0·26
Alumina	Tr.
Calcium carbonate	97·84
Magnesium carbonate	1·72
Total	100·02

Welcome Bay

Bluish grey-weathering limestone of the Marble Bay formation caps cliffs of igneous rock to a thickness of 400 or 500 feet back from the shore of Welcome bay on the west coast of Texada island. An igneous rock (porphyrite) forms the shoreline and extends inland for $\frac{1}{4}$ to $\frac{1}{2}$ mile, underlying a slope that rises to 400 feet or so before it is capped by the limestone. At the contact between the igneous rock and the limestone the latter is usually white, coarse-grained, and has various contact metamorphic minerals in it. These minerals, including garnet, tremolite, diopside, and magnetite, were also observed in the limestone adjacent to some intrusive dykes near the main contact zone. Higher up on the hill, and forming by far the greater part of the mass, the limestone is light blue, medium-grained, and very pure, as is shown by the analyses of Samples 17 and 17A. Sample 17 was taken over a large area of the medium-grained, blue limestone, and Sample 17A from outcrops of the coarse-grained, white limestone near the contact with the igneous rock. A few igneous dykes intrude the limestone, but they are not sufficiently numerous to interfere with quarry operation and apparently an enormous tonnage of high-grade limestone is available. The chief drawback is the lack of a suitable harbour on this coast.

Davies Bay

Opposite Davies bay, which is about midway along the west coast of Texada island, and at a considerable distance back from the shore is an area of Marble Bay limestone 3 miles long and 1 mile wide. A number of years ago Tacoma-Texada Lime Company made a road 1,100 yards long from Davies bay to the deposit, but no further development work was done. At the end of this road the limestone is exposed in low ridges on a gently sloping hillside, and then farther inland composes a steep-sided hill rising to a height of 850 feet above the sea. It is fine-grained, hard, and brittle. It is dark grey-blue on fresh fracture, and weathers to a light grey. Igneous dykes, so prevalent in many areas of the Marble Bay limestone, are few in this area. The general strike of the limestone is northwest-southeast, or parallel to the coast, and the dip is southwest, frequently at a steep angle. On lot 235, which extends from Davies bay to the face of the steep-sided hill abovementioned, the high-calcium limestone has interbedded with it some thin bands of the highly magnesian, brown-weathering limestone that is characteristic of much of the Marble Bay formation. Sample 18 was taken from a great number of outcrops on this lot, and Sample 18A is representative of one of the interbeds of magnesian limestone. Back on the high land on lot 395 the limestone is similar in appearance, but the interbeds of magnesian limestone are possibly not so numerous. Sample 18B was taken from a number of outcrops on the hillside. The magnesium carbonate content of the limestone here is mainly due to tiny crystals of dolomite evenly distributed throughout much of the limestone. A sample of limestone sent to the Bureau of Mines from lot 303, which is west of lot 235, had the following composition:—

	Per cent
Insoluble	0·36
Oxides of iron and alumina	0·66
Calcium carbonate	89·43
Magnesium carbonate	9·68
Total	100·13

Davies bay provides a fairly well sheltered anchorage for scows and small boats, but is not a suitable harbour for larger craft.

Mouat Bay

The large mass of Marble Bay limestone on the west coast of Texada island extends northerly from Davies bay to a place opposite Mouat bay, or Lower Gillies bay as it is sometimes called. At its northern end it is 1 mile inland from the bay and no outcrops of rock were observed between the limestone and the shore. The limestone has the same appearance as that examined opposite Davies bay, being dark blue-grey, fine-grained, and comparatively free from igneous dykes. Interbeds of magnesian limestone are less prevalent than opposite Davies bay. Sample 18C was taken from numerous outcrops, chiefly on lot 21. Mouat bay affords poor shelter.

Anderson Bay

At Anderson bay, on the east coast and near the southern end of the island, a band, or series of lenses, of white and reddish brown, crinoidal limestone 200 feet thick occurs interbedded with schists and volcanics. The limestone trends nearly parallel to the coast and dips southwest at a steep angle. Because of its fine and unusual appearance when polished, this limestone has attracted attention as a source of marble and was quarried for this purpose in small amounts sometime prior to 1912 by Malaspina Marble Quarries Company, Limited, Vancouver, and by a Mr. A. Henderson of Nanaimo, who was the first to draw attention to the possibilities of the deposit. The marble obtained was used in the Post Offices at Victoria and Nanaimo; in the Postal Station at Main and 15th Streets, Vancouver, and in the Merchants Bank building, Grenville and Pender Streets, Vancouver.

The limestone occurs in a band, or possibly a series of lenses, in a ridge on the steeply sloping mountainside, 300 yards inshore from the head of Anderson bay. The country in the vicinity is heavily forested and soil and moss cover most of the rock. In the neighbourhood of two small quarries that were opened many years ago, the limestone band is 120 to 200 feet wide and extends north 20 degrees west for nearly ½ mile. On the east side it is in contact with a red slaty schist, and on the west with a fine-grained, greenish grey, amygdaloidal volcanic rock. Considerable variation in appearance and composition of the limestone is in evidence throughout the band. In places it is very coarse-grained and in others fine-grained. The colour ranges from nearly white through pink to chocolate-brown. Crinoid stems composed of white calcite are present throughout the deposit, but appear particularly plentiful in the brown portions. Most of the limestone is of the calcium type, although in places, particularly in the eastern half, are lenticular masses of fine-grained, pink dolomite heavily veined with white calcite. This dolomite weathers brown in contrast to the grey and pink of the calcium limestone. Films of green and red micaceous material are present in some of the limestone and in places are sufficiently numerous to impart a laminated structure, particularly near the edges of the band and around the perimeters of some of the lenticular masses of purer limestone. This lenticular arrangement of the several colours of marble is typical of the deposit. It would make it difficult to obtain uniformly coloured marble by any regular system of quarrying. Two samples were taken: Sample 19 across the entire width of 200 feet of marble in the vicinity of the small quarries at the head of Anderson bay, exclusive of some obviously impure limestone on both edges; and Sample 19A from one of the lenses of dolomite veined with white calcite.

Analyses of Limestones on Texada Island

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
9........	0·14	0·14	0·06	0·04	98·70	0·50	99·58	Nil	55·29	0·24	230 : 1
9A......	0·26	0·13	0·11	0·02	99·48	0·63	100·63	Nil	55·72	0·30	186 : 1
9B......	0·26	0·07	0·09	0·04	98·45	0·46	99·37	Nil	55·15	0·22	251 : 1
9C......	0·21	0·14	0·09	0·03	98·83	0·46	99·76	Nil	55·37	0·22	252 : 1
9D......	0·76	0·18	0·10	0·04	90·80	8·72	100·60	Nil	50·87	4·17	12 : 1
9E......	0·29	0·25	0·10	0·04	98·60	0·55	99·83	Nil	54·94	0·26	211 : 1
9F.......	0·68	0·26	0·10	0·04	94·36	4·45	99·89	Nil	52·86	2·13	25 : 1
10.......	0·52	0·34	0·14	0·04	96·16	2·21	99·41	0·14	53·87	1·05	51 : 1
10A.....	0·84	0·41	0·09	0·02	92·28	6·23	99·87	Nil	51·69	2·98	17 : 1
10B.....	0·50	0·11	0·08	0·02	96·82	1·74	99·27	Nil	54·23	0·83	65 : 1
11.......	0·76	0·34	0·17	0·02	91·41	6·78	99·48	0·10	51·20	3·24	16 : 1
11A.....	0·72	0·25	0·30	0·02	98·45	0·94	100·68	0·08	55·15	0·45	123 : 1
12.......	0·54	0·10	0·09	0·02	98·57	1·09	100·41	Tr.	55·21	0·52	106 : 1
12A.....	0·42	0·45	0·29	0·04	65·57	33·85	100·62	Tr.	36·74	16·19	2·3 : 1
13.......	0·24	0·11	0·08	0·02	99·07	0·82	100·34	Nil	55·49	0·39	142 : 1
14.......	2·30	0·31	0·22	0·07	83·45	13·70	100·05	0·03	46·77	6·55	7 : 1
15.......	1·02	0·21	0·14	0·02	94·52	4·43	100·36	0·01	52·94	2·12	25 : 1
16.......	0·65	0·18	0·25	0·02	97·59	1·41	100·10	0·02	54·83	0·67	82 : 1
16A.....	0·72	0·14	0·30	0·02	97·12	1·75	100·05	0·02	54·42	0·84	65 : 1
17.......	0·82	0·08	0·18	0·02	97·34	0·86	99·30	Nil	54·51	0·41	133 : 1
17A.....	0·62	0·09	0·23	0·04	97·60	0·94	99·52	Nil	54·68	0·45	121 : 1
18.......	0·94	0·38	0·22	0·11	93·48	4·54	99·67	0·10	52·41	2·17	24 : 1
18A.....	1·72	0·63	1·03	0·04	68·02	29·03	100·47	0·12	38·11	13·88	2·8 : 1
18B.....	1·11	0·19	0·12	0·04	93·02	5·67	100·15	Tr.	52·12	2·71	19 : 1
18C.....	0·78	0·22	0·10	0·04	96·90	2·04	100·08	Nil	54·29	0·98	55 : 1
19.......	3·39	0·45	0·22	0·11	91·46	5·08	100·71	Nil	50·69	2·43	21 : 1
19A.....	4·94	1·56	0·85	0·46	58·55	33·88	100·24	Tr.	33·02	16·20	2 : 1

9.	Blubber bay.	Pacific Lime Company, Quarry No. 1. Twenty-foot section of quarry face beginning 50 feet from surface.
9A.	" "	Pacific Lime Company, Quarry No. 1. Next 20-foot section (70–90 feet.).
9B.	" "	Pacific Lime Company, Quarry No. 1. Next 20-foot section (90–110 feet).
9C.	" "	Pacific Lime Company, Quarry No. 1. Next 20-foot section (110–130 feet).
9D.	" "	Pacific Lime Company, Quarry No. 2. Top 30 feet of strata.
9E.	" "	Pacific Lime Company, Quarry No. 2. Next 30 feet of strata.
9F.	" "	Pacific Lime Company. Thirty feet of limestone in face of old quarry formerly worked for flux.
10.	" "	Fogh property (lot 9). Small quarry and outcrops adjacent to the lime kiln.
10A.	" "	Fogh property (lot 9). Sample exclusive of magnesian bands from quarry 300 feet south of the kiln.
10B.	" "	Fogh property (lot 9). White limestone near Paris mine.
11.	" "	British Columbia Cement Company property. Sample taken in 1929 from Quarry No. 1.
11A.	" "	British Columbia Cement Company property. Sample from Quarry No. 4 and outcrops on the northeast tip of Blubber bay.
12.	Limekiln bay.	Tacoma Steel Company quarry. Sample of high-calcium beds.
12A.	" "	Tacoma Steel Company quarry. Magnesian beds in the quarry.
13.	Sturt bay.	Pacific Lime Company property. Thirty feet of Marble Bay limestone exposed in a cliff.
14.	Marble bay.	Powell River Company quarry. Sixty-foot face.

15.	Vananda.	Large outcropping of light blue medium-grained Marble Bay limestone at the north edge of the village.
16.	"	Beale Quarries, Limited. Sample taken in 1935 from the eastern end of the quarry then being operated.
16A.	"	Beale Quarries, Limited. Sample taken in 1944 of material as shipped.
17.	Welcome bay.	Sample taken over large area of medium-grained, blue limestone exposed on the hillside.
17A.	" "	Sample of coarse-grained, white limestone lower down on the hillside near the contact with the porphyrite.
18.	Davies bay.	Outcrops of Marble Bay limestone on lot 235, exclusive of bands of magnesian limestone.
18A.	" "	Magnesian limestone band exposed on lot 235.
18B.	" "	Outcrops of Marble Bay limestone on the steep hillside on lot 395.
18C.	Mouat bay.	Outcrops of Marble Bay limestone on lot 21.
19.	Anderson bay.	Sample across 200 feet of marble of the Anderson Bay formation at the head of Anderson bay.
19A.	" "	Lens of dolomite in the marble band.

Queen Charlotte Islands

Limestone deposits on the Queen Charlotte islands were not examined in connection with the present report. The following information concerning them is taken from reports of the Geological Survey of Canada.

South Island (Sandilands Island)

High-calcium limestone occurs on the southeast end of South island, which is a small island at the east entrance to Skidegate channel. J. D. MacKenzie[1] describes the deposits as follows:—

> They consist of massive beds of light grey, partly crystalline limestone, cut by irregular veinlets of recrystallized calcite from paper-thin sheets to 2 inches or more in thickness. They are strongly bituminous, and give a markedly foetid odour when struck.
>
> Under the microscope the rock is seen to be made up of rounded and sub-rounded granules of calcite, averaging 0·02 mm., without any appreciable matrix. Occasional grains of detrital plagioclase are to be seen. Between the grains and in little veinlets is black bituminous matter, and this also occurs along suture-like cracks. Bitumen is almost wholly lacking in the recrystallized veins.

Maude Island

This island lies to the north of South island. MacKenzie states:—

> On the south shore of Maude island, near the top of the formation, bands of buff and grey, partly crystalline limestones occur in beds up to 8 inches thick, containing, scattered through them, groups of striated cubes of pyrite.

Moresby Island

R. G. McConnell in the Summary Report of the Geological Survey for 1909 gives the following information on limestone on Moresby island.

> Massive greyish limestones, usually more or less crystalline, are widely distributed in small areas, mostly as inclusions in the later intrusive rocks. Fragments of limestone, ranging in size from a few feet to half a mile or more across, occur along the east coast from Carpenter bay, north to Lockeport, and were also seen at Tasoo harbour on the west coast. They are of considerable economic importance, as many of the ore bodies of the island have formed in or near them. (page 74)

On page 81 of the same report further information is given on the limestone at Tasoo harbour to the effect that it occurs as a large inclusion in hornblende porphyrite on the Warwick group of claims, south of the entrance to the south arm of Tasoo harbour. It is at an elevation of 1,160 feet and is interbanded with magnetite.

[1] MacKenzie, J. D.: Geol. Surv., Canada, Mem. 88, p. 88 (1916).

Copper Island

This small island is in Skincuttle inlet on the east coast of Moresby island 4 miles north of Jedway. McConnell[1] says "A wide band of massive greyish crystalline limestone crosses the island."

Coastal Mainland and Adjacent Islands Excepting Vancouver Island, Texada Island, and Queen Charlotte Islands

A great many limestone deposits occur on the mainland adjacent to the coast and on the islands off the coast between Seechelt peninsula and Portland canal. These deposits are similar in many respects. They are predominantly high-calcium. Such dolomite as is present is usually in bands and irregular masses in the high-calcium limestone, and only in a few deposits is the dolomite present in bands sufficiently large to be quarried. Intrusive igneous dykes are present in nearly all deposits and they are particularly numerous in those south of Ocean Falls. North of Ocean Falls, however, they are much less numerous and are scarcely noticeable in some deposits. Northwards also, the degree of metamorphism that the deposits have undergone increases, and from Smith inlet northwards most of the limestone is white and coarse-grained, whereas to the south the limestone is mostly blue. Only one quarry is being worked in the area, and that is at Koeye river, where white limestone is being quarried for use in the pulp mill at Ocean Falls.

Seechelt Peninsula

A small deposit of blue calcium limestone occurs on the west side of Seechelt inlet opposite the north side of Narrows arm.

Narrows Arm

A thin band of calcium limestone dipping steeply east was observed at the Narrows on Narrows arm. Neither this band nor the deposit on Seechelt peninsula was examined in detail, as they are very small.

Queens Reach

Blue, fine-grained high-calcium limestone is available in a deposit of unknown extent on the west shore of Queens reach, about 1 mile south of the head of the inlet, according to information supplied by a fisherman who had a sample of the limestone with him.

Nelson Island

A deposit of white and bluish white high-calcium limestone occurs on the northwest side of Nelson island and apparently continues westerly beneath the water to the northern end of adjacent Hardy island. These islands are at the mouth of Jervis inlet, 60 nautical miles north of Vancouver.

The limestone on Nelson island was quarried during the years 1929 to 1936 for shipment to the sulphite mill of British Columbia Pulp and Paper Company at Woodfibre, and the ruins of a lime kiln at the deposit show that lime was made there many years ago. The limestone is much intersected by dykes of igneous rock. It extends westerly from the beach at a point just south of a small brook on the shore of Blind bay, up the steeply sloping side of the island to a height of about 900 feet. The lower part of the deposit is on lot 5377 and the upper part on lot 5570 of New Westminster mining division.

The lower part of the band is 80 to 100 feet wide and is enclosed in trap rock, which in turn is enclosed in granite. The limestone is white with bluish and greenish tints. On the south side it is mostly fine-grained, but in the middle

[1] McConnell, R. G.: Geol. Surv., Canada, Sum. Rept. 1909, p. 78.

and on the north side it is comparatively coarse. Sample 20 taken from the fine-grained and Sample 20A from the coarse-grained limestone show that there is little difference in chemical composition between the two types. There is a small development of serpentine in slip planes in the limestone, and along the north edge a zone of siliceous, blue calcium limestone and siliceous dolomite was observed. Occasional thin lenses of white dolomite also occur in other places in the deposit. The chief drawback is the presence of numerous dykes of green trap rock containing pyrite, which traverse the limestone in all directions and have to be removed from the quarried product.

When this deposit was examined in 1929 the quarry was small. It has been much enlarged by subsequent operations and it is reported that a tunnel 7 feet high and 6 feet wide has been driven into the deposit for 120 feet. A pier for loading scows has been constructed out to deep water. Mr. A. Jorgenson of Tacoma, Washington, U.S.A., is the present owner.

Hardy Island

The limestone band seen on Nelson island apparently continues beneath Blind bay to the northern tip of Hardy island where, on the beach facing Blind bay, it has a width of 70 feet. A short distance inland, however, it splits into two bands. This end of Hardy island is low and it would be difficult to quarry the limestone. The following analysis of the limestone on Hardy island was kindly supplied by British Columbia Pulp and Paper Company.

	Per cent
Silica	1·80
Ferric oxide	0·70
Calcium carbonate	96·70
Magnesium carbonate	0·50
Total	99·70

Mainland Opposite East End of Savary Island

A band of white and bluish white limestone enclosed in a granitic rock appears on the shore of a small bay due east of the east end of Savary island, or about ½ mile south of Dinner rock. It is from 15 to 50 feet in width, trends N. 50° W., and dips nearly vertically, and appears to be cut off by the granite a short distance inshore. It consists of a mixture of coarse- to medium-grained calcium limestone and fine- to medium-grained, bluish white dolomite, the two being erraticly mixed. Some dolomite is also disseminated in small grains through what would otherwise be high-calcium limestone. Sample 21 was taken at intervals across the deposit, but it shows only approximately the content of magnesium carbonate because the proportions of dolomite and high-calcium limestone vary widely in different parts of the band.

Homfray Channel

White limestone is reported to occur in the valley of a creek entering the east side of Homfray channel at Lloyd point. The exposures are said to be ½ mile from the mouth of the creek and at an elevation of 500 feet.

Toba Inlet

A large deposit of fine-grained, siliceous, blue limestone is reported to be exposed on both sides of Chusan creek, which enters the east side of Toba inlet.

Cortes Island

Blue, moderately pure, calcium limestone, much intersected by dykes of igneous rock, is exposed along the south shore of Cortes island to the southwest of Blind creek. A small quantity of this limestone was at one time burned in a little pot kiln on the shore. The limestone band trends east and west. It is apparently small, and no sample was taken.

Quadra Island

A belt of limestone over ½ mile in width crosses Quadra island from Granite bay southeasterly to Open bay, a distance of 10 miles. It is known on the Coast as "The Lime Belt". Much of it is mineralized and a number of prospect pits have been dug along its eastern edge in small deposits of pyrrhotite, chalcopyrite, and magnetite, but no producing mine has been developed.

The limestone is of the calcium type. It is fine-grained, dark blue, and only moderately pure at best, and some is very siliceous, especially in streaks. It is traversed by a great number of dykes and sills of igneous rocks. Thick dykes have caused little alteration of the limestone, but adjacent to some only ⅛ to ½ inch wide the limestone is whitened for a distance of 1 inch on either side. Some of the dykes look much like the limestone on fresh fracture, but they are ferruginous and weather rusty, in contrast to the blue of the limestone.

The limestone occupies a valley and is exposed in hummocks. It was followed for some distance inland from Open bay along the bed of an old logging railway, and wherever seen was of the same type. Sample 22 was taken at closely spaced intervals across the band where exposed on the eastern half of Open bay, and Sample 22A was taken at the same place from ridges of siliceous and ferruginous limestone projecting from the weathered surface of the deposit, but which is scarcely distinguishable from the purer limestone on fresh fracture.

Intense folding of the limestone is nearly everywhere apparent (Plate XXVIII A, page 162), and the dip though variable is usually steep. In places the limestone holds fragments of igneous rocks. It smells strongly of sulphur when hit with a hammer.

In the small narrow bay west of Bold point, which is on Quadra island 2 miles northeast of Open bay, similar blue limestone much mixed with other rock is exposed on the east shore. So much foreign rock is intermixed with the limestone, that it is of no value where exposed near the coast, but it is said to contain much less foreign rock about 1 mile inland.

West Redonda Island

A deposit of brucitic limestone similar to that found in Ontario and Quebec[1] occurs on the north shore of West Redonda island about ¾ mile west of George point. The limestone was quarried during the years 1920 to 1926 for use in the acid towers of the sulphite mill of British Columbia Pulp and Paper Company at Woodfibre on Howe Sound, but the brucite was not recognized as such. When the deposit was examined by the writer in 1929 the presence of a soluble, white-weathering mineral similar to that occurring at Bryson,[2] Quebec, was noted, but the mineral was not identified as brucite until the specimens were re-examined during the writing of this report.

The deposit occurs on the side of a mountain rising steeply from the water's edge. It is 125 feet wide and extends up the mountain for an unknown distance. It was examined, where opportunity offered, to a height of 400 feet and it

[1] Goudge, M. F.: Bur. Mines, Dept. of Mines and Resources, Canada, "Prelim. Rept. of Brucite Deposits in Ontario and Quebec", 1939.

[2] Goudge, M. F.: Bur. Mines, Dept. of Mines and Resources, Canada, "Limestones of Canada", Part III, p. 134 (1935).

PLATE XXVIII

A. Intensely folded limestone at Open bay, Quadra island, B.C.

B. Intermixed calcium limestone, dolomite, and trap rock at Phillips arm, B.C. The trap rock is at the left of the photograph and the dolomite stands out in ridges because of its superior resistance to weathering.

possibly connects with what appeared to be cliffs of limestone at a much higher elevation. The limestone is bounded by a green intrusive rock that in turn is enclosed in light-coloured hornblende granitic rocks.

The brucite occurs in granules 1 to 3 mm. in diameter and is especially characteristic of certain zones in the deposit, notably along the east side where it forms about one-third of the rock. Some of the limestone is devoid of it. A narrow zone of white dolomite surrounds most of the brucite granules and the matrix of the rock is calcite. The concentric structure characteristic of the brucite in Ontario and Quebec appears in many of the granules, but not in all. Tiny rounded grains of serpentine constitute the chief impurity, but much of the brucitic limestone is nearly free from it. In other places in the deposit the only magnesian mineral is dolomite that occurs in bladed crystals through the calcite matrix. Most of the limestone has a pale blue tint, but some is white. The grain ranges from fine to coarse with the brucitic portions being for the most part moderately fine-grained. Where exposed on land the brucite has been altered to white hydro-magnesite and much of it has been completely dissolved leaving the typical pitted surface. However, where exposed to seawater the calcite matrix has been dissolved leaving the brucite standing out in relief.

The quarry has been worked across almost the entire width of the deposit and extends 150 feet up the hillside but is only about 20 feet deep. Granite is visible beneath the limestone near the water's edge and the limestone band is narrower at the upper part of the quarry than it is at the base. The heavy growth of trees makes it difficult to examine the rock outside of the quarry and the actual quantity and quality of brucitic limestone available can be ascertained only by considerable work.

Two samples were taken in the quarry: Sample 23 across the entire width of the quarry, including brucitic and non-brucitic limestone; and Sample 23A of the brucitic limestone only, across a width of 20 feet. The analyses of these samples are as follows:—

	Sample 23 Per cent	Sample 23A Per cent
Silica	1·28	0·48
Ferric oxide	0·32	0·18
Alumina	0·22	0·05
Calcium oxide	46·27	37·21
Magnesium oxide	9·22	20·50
Carbon dioxide	39·94	34·60
Water +105°C	2·94	6·48
Total	100·19	99·50
Brucite content	8·3	22·0

As the analysis of Sample 23 shows, the content of brucite across the full width of the deposit as exposed in the quarry is small. But the brucite content of Sample 23A approaches that of the deposits being worked at Wakefield, Quebec.

Frederick Arm

Outcrops of interbanded blue and white, rather siliceous, calcium limestone and dolomite occur at intervals for 1,000 feet along the beach on the west side of Frederick arm, just inside the entrance. Soil, large boulders of granite, and big trees cover the limestone inland, but there are indications that the deposit extends inland to the northwest for about $\frac{1}{2}$ mile to the slopes of Treble mountain. In no place are there continuous exposures of the limestone, but occasional outcrops occur at intervals over a width of 500 feet at right angles to the strike, which is N. 55° W. The dip is vertical. Most of the limestone seen is blue, fine-grained, comparatively soft, and consists predominantly of calcium car-

PLATE XXIX

A. Intense folding and differential weathering in limestone at Phillips arm, B.C.

B. Limestone outcrop and small quarry on property of Coast Calcite Company, Ltd., Smith inlet, B.C.

bonate, but disseminated through it are small crystals of dolomite, and also bands in which dolomite greatly predominates. Most of the limestone contains tiny crystals of pyrite scattered through it. It is also traversed by dykes of fine-grained diabase.

On the western edge of the vertically dipping band, where it is in contact with argillite, is a 12-foot zone of fine- to medium-grained, hard, yellowish white dolomite cut by several igneous dykes. Adjoining this to the east is 18 feet of medium-grained calcium limestone containing dolomite in the form of thin streaks and as scattered grains. From here eastward the outcrops consist of pale blue, fine-grained and very fine-grained, soft, calcium limestone. There are large gaps between the outcrops, but they are fairly plentiful in a zone 100 feet wide near the centre of the band. Some thin streaks of dolomitic limestone and some blebs of silicate minerals occur in this part of the band. Thin veins of yellow dolomite, usually less than $\frac{1}{4}$ inch thick, cut across the bedding of the limestone in places.

The following samples were taken to show the characteristics of the various kinds of limestone composing the band: Sample 24 represents a width of 100 feet of the pale blue limestone that appears to form the major part of the deposit; Sample 24A is from the 12 feet of white dolomite on the western edge of the deposit; Sample 24B was taken from the thin streaks of dolomitic limestone that occur throughout the blue limestone; Sample 24C represents the white, coarse-grained calcium limestone near the western edge of the deposit; and Sample 24D is from streaked, blue limestone adjoining the coarse-grained calcium limestone to the east.

On Owen point, beds of limestone 1 to 6 inches thick are interbedded with argillite.

Cordero Channel

Limestone interbedded with argillite was observed along the shore on the south side of Cordero channel, from Hall point to a place southeast of Denman island. The beds strike parallel to the shore, or northwest-southeast, and dip vertically.

Phillips Arm

A band of very fine-grained, white and light blue, impure calcium limestone much mixed with igneous rock outcrops on the west side of Fanny bay, about midway up the west side of Phillips arm (Plates XXVIII B, page 162, and XXIX A, page 164). The limestone strikes N. 80° W., or parallel to the shore. It also contains much pyrite.

Harbledown Island

Blue, sugary textured, high-calcium limestone cut by igneous dykes forms a ridge along the south coast of Harbledown island at its extreme east end. It strikes N. 50° E. and dips northwest, or inland, at angles ranging from a few degrees to 78 degrees. For 300 yards it is exposed in cliffs 30 to 75 feet high along the coast and then can be traced inland nearly parallel to the coast for some distance. On the south side is igneous rock and on the north is argillite. The limestone band varies in width according to the dip, but in many places it is 300 feet wide. The country underlain by it is heavily forested. In addition to the igneous dykes the limestone contains inclusions of foreign rock and some quartz. Small amounts of pyrite crystals are disseminated through some of the limestone. Sample 25 was taken across the north half of the band at its eastern end, and Sample 25A from the southern half. The extremely low content of magnesium carbonate is notable. Because of the presence of numerous dykes and included masses of other rocks, careful sorting will be necessary in order to obtain a quarry product of the same quality as the samples.

About midway along the south coast of Harbledown island, ⅓ mile west of the small island in Baronet passage, fine-grained, blue high-calcium limestone, containing many dykes and also small fragments of volcanic rock, forms a cliff along the shore for 200 feet. The cliff is 150 feet high in places, but is capped by volcanic rock. Scales of graphite were observed in some of the limestone. Sample 26 was taken here and the sample includes some of the small fragments of volcanic rock which are so plentiful that it is impossible to obtain any quantity of the limestone without including them.

Near the western end of Baronet passage, similar limestone, some of which contains many fossil shells, is exposed on a point. The limestone lies nearly horizontally.

At the extreme west end of Harbledown island, just inside the entrance to Parson bay and on the south side, nearly black, fine-grained siliceous limestone, containing pyrite, is exposed in association with shale and quartzite. The limestone is in thin beds and most of it is filled with tiny quartz grains.

Smith Inlet

A wide band of white limestone, striking N. 70° W. and dipping almost vertically to the northeast, outcrops on both shores of Smith inlet about 3 miles from the head. The part of the band on the south side of the inlet is much cut up by igneous dykes and seems of little value. On the north shore, however, the limestone band is 2,300 feet wide and trends inland along a steeply sloping valley between two mountains for an unknown distance. One-half mile inland the limestone is said to have an elevation of 1,000 feet.

In 1929, the part of the deposit on the north shore of the inlet was under development by *Coast Calcite Company, Limited, Vancouver* (Plate XXIX B, page 164), but operations ceased shortly thereafter and have not been resumed. The company's property consisted of lot 403, which includes all of the deposit fronting on the north shore of the inlet.

The country underlain by the limestone is heavily forested and outcrops are infrequent except along the courses of two small brooks that flow down the valley. The westernmost of these brooks has cut a deep canyon through the limestone for nearly half a mile.

The limestone is mostly snowy white and moderately coarse-grained, but some is fine-grained and has a bluish tint. The bluish limestone generally has some tiny crystals of pyrite scattered through it. The limestone is in part high-calcium and in part dolomitic, the two varieties being interbanded throughout most of the deposit, with the dolomite also occurring, in places, as irregular masses. Small crystals of dolomite are also scattered throughout the high-calcium limestone in varying concentrations. Dykes of green igneous rock intrude the limestone, mostly parallel to the strike, but some cut across the strike. Most of the dykes are from a few inches to 3 feet in thickness, but one 30 feet thick was observed. They are particularly numerous toward the edges of the deposit. Being dark, they are easily distinguished from the limestone in quarry operations.

On both edges of the band, close to the contact with the granitic rock of the coast line, the limestone is siliceous, and dolomite streaks are numerous. In the interior of the band dolomite is less conspicuous, although one large mass of dolomite 25 feet thick occurs just west of the most easterly of the two brooks that flow over the deposit. The dolomite is easily distinguishable from the high-calcium limestone in weathered outcrops, but it is almost impossible to distinguish it in freshly quarried stone. Moreover, most of it has streaks of high-calcium limestone through it.

The quarry from which shipments were made in 1929 is near the western edge of the band and the stone exposed across its 50-foot width is chiefly high-calcium limestone, with only a few narrow streaks in which dolomite is plentiful. Sample 27 was taken across the full width of the quarry. Sample 27A is representative of the dolomite in a small quarry 700 feet east of the main quarry; and Sample 27B is representative of a 50-foot width of high-calcium limestone near the centre of the band.

The water is deep close to the shore where the limestone occurs and scows can be brought up to the shore for loading.

Rivers Inlet

Two deposits of limestone were examined and sampled on the north shore of Rivers inlet; one of these is at False inlet and the other at Kilbella bay.

The deposit at False inlet occurs on the east side of the inlet and consists of a band 300 feet in width of medium-grained, light blue and white, high-calcium limestone striking N. 25° W. or nearly parallel to the shore. Where first seen at its southern end, it is 250 feet wide and is exposed at an elevation of 100 feet above water. As it is traced north it widens and occupies higher ground. It was traced for 500 yards northerly and may extend considerably farther in that direction. On its west side it is in contact with a greenish schistose rock, and on the east with diabase. No dykes were observed in the limestone, but it is unlikely that it is entirely free of them. Visible impurities consist of some very small crystals of pyrite and of a few thin lenticular beds of siliceous limestone. The western half of the band is composed mostly of blue limestone with some white, and the eastern half is composed mostly of white limestone. Much of it is thin-bedded and fractured. In other places it is in massive beds. Sample 28 was taken across the eastern half of the band, which is mostly white limestone; and Sample 28A across the western half, which is mostly blue.

This deposit could be easily quarried and there is deep water up to the shore. As the analyses of the samples show, the limestone is of good quality. Most of the deposit is on lot 1275.

At Kilbella bay the limestone is exposed on the shore just west of the entrance and is in a band 50 to 100 feet wide that trends northerly up a steep slope. The limestone is white and very coarse-grained. It contains inclusions of greenstone and granite, which are the country rocks in this vicinity, and includes veins of magnetite and pyrite. Sample 29 was taken across the band. As the analysis shows, the limestone is comparatively pure, but the presence of included masses of other rocks would complicate quarrying.

Owikeno Lake

On the south shore of Owikeno lake, which drains into Rivers inlet, bands of white limestone are reported to occur ½ mile and 2½ miles east of the fish hatchery. The deposit ½ mile east of the hatchery is said to be very coarse-grained and to consist predominantly of calcite. It is exposed on the shore of the lake and extends southerly up the steep mountainside. Some dykes of green rock are present in the limestone, and samples seen contained some brown mica. The deposit 2½ miles east of the hatchery is reported to be very large and to be of the high-calcium type.

Koeye River

On the north bank of Koeye river, where it empties into Fitzhugh sound about 6 miles south of Namu, is a wide belt of white and light blue limestone, striking N. 60° E. and dipping nearly vertically. It is being quarried by *Koeye*

Limestone Company, Namu, to supply the lime kiln of Pacific Mills at Ocean Falls. The quarry was opened after field work in this district had been completed and is not described herein.

Where the deposit is first seen near the mouth of the river, it consists of siliceous calcium limestone intermixed with dolomite and intersected by igneous dykes. All is fine-grained and blue in colour. One-half mile up the river the limestone is of much better quality. About 200 yards downstream from where the river swings south the limestone composes a hill 150 feet or more in height and having steep slopes. On the beach at the base of the hill the limestone is siliceous and contains irregular streaks of dolomite, but up the hillside, a short distance, it is much purer, although it contains numerous small grains and seams of silicate minerals. It is mostly medium-grained, white and pale blue, and contains considerable dolomite in the form of individual grains scattered through it. A number of igneous dykes also traverse the limestone on this hill. Sample 30 was taken here across a width of 250 feet of the limestone. North of this is granitic country rock.

A short distance farther up the river on the east shore of the cove formed by the bend in the river, the best grade of limestone in the deposit is exposed across a width of 400 feet. The limestone is medium- to coarse-grained and most is pale blue, though some of it is white. Siliceous impurities and bands of dolomite are not noticeable, though the deposit is traversed by some dykes of igneous rock. The limestone rises to a height of 80 feet a short distance inland. On the northern edge of this band of pure limestone is siliceous limestone. Sample 30A was taken across the 400-foot band of pure limestone. The output of the quarry is shipped by scow to Ocean Falls, 42 miles to the north.

One-half to three-quarters of a mile north of the mouth of Koeye river, a band of blue calcium limestone much intersected by igneous dykes was observed on the exposed shore of Fitzhugh sound. The band is 150 feet wide and strikes N. 40° E.

One mile south of Koeye river an outcrop of siliceous dolomite associated with quartzite and some calcium limestone was observed on the shore.

King Island

Pale blue and blue-and-white striped, medium-grained limestone, cut by many diabase dykes and striking N. 15° W. and dipping vertically, is exposed on a small point about $\frac{3}{4}$ mile east of the southern tip of King island. The band is 500 feet wide, but on both flanks the limestone is interbedded with argillite and schist and is impure. On the point, however, which rises about 25 feet above the water, the limestone is of much better quality, although here also the igneous dykes are numerous. They range from a few inches to many feet in thickness, and there is scarcely more than 10 feet between them. Two samples were taken from the centre of the band at the point on the shore. Sample 31 represents a 50-foot width of light grey limestone, and Sample 31A a similar width of blue-and-white striped limestone to the east of Sample 31. The limestone was traced inland for over 600 yards to much higher land, but outcrops were not sufficiently large or numerous to show the character of the deposit away from the shore.

Cunningham Island

A large deposit of white high-calcium limestone on the southern part of this island was quarried during the years 1923 to 1934 by F. J. Beale of Vancouver to supply the lime kiln operated by Pacific Mills in connection with its pulp mill at Ocean Falls, 22 miles northeast. The quarries are on lot 1333 at the head of a lagoon opening off Gunboat passage.

PLATE XXX

A. White high-calcium limestone, much invaded by trap rock, in quarry formerly worked by F. J. Beale on Cunningham island, B.C.

B. Weathered surface of vertically dipping deposit of white high-calcium limestone, Cunningham island, B.C.

From the head of this lagoon a vertically dipping band of white and bluish white high-calcium limestone, 600 to 1,000 feet wide, extends inland to the north for at least a mile and possibly for several miles. One mile north of the lagoon it is visible in high cliffs on the mountainside. The limestone is enclosed in a dark green trap rock, which in turn is enclosed in granite. Dykes and sills of the trap and an occasional tongue of granite penetrate the limestone. These intrusions seem most numerous near the south end and are not so noticeable inland. The limestone is coarse-grained, white, and is apparently free from streaks and masses of dolomite so common in many of the limestone deposits of the coast. In places, however, the limestone is siliceous and contains serpentine, and near some of the dykes it is mineralized with pyrite. Crystals of pyrite are also present in streaks through much of the limestone on the eastern side of the band.

Three quarries and an underground chamber were worked near the head of the lagoon. The several openings were made in order to avoid, as far as possible, quarrying parts of the band containing much pyrite and many igneous dykes. The openings were made at the corners of a rectangle 400 feet east and west and 200 feet north and south, astride the limestone band. A tunnel through the ridge connects the two quarries on the east side of the band with the shipping dock. The underground chamber is at the southwest tip of the band, and was opened to mine a mass of white, pure limestone that was for the most part deeply covered with soil. The quarries are all of the hillside type (Plate XXX A, page 169), have faces 35 to 40 feet high, and are each about 120 feet in diameter. The floors are about 15 feet above high water. They are opened along the flanks of the limestone band and are worked toward the centre. Much pyrite is visible in streaks in the rock on the eastern sides of the two quarries opened on the eastern side of the limestone band, and, in addition to numerous dykes of diabase, sills 10 to 20 feet thick of granitic rock overlie the limestone. In the quarry to the northwest the sills of igneous rock and streaks of pyrite are absent, but there are many dykes. The limestone in the underground chamber is nearly free from dykes and visible impurities. Sample 32 was taken from a 100-foot width of limestone, exclusive of dykes, exposed in the northwest quarry; and Sample 32A is representative of the limestone exposed in the underground chamber.

When the quarries were in operation the limestone was trucked to the shore of the lagoon and there loaded on small scows for towing to Ocean Falls. Small scows had to be used because the entrance to the lagoon is shallow and narrow.

Judging from a brief examination it seems probable that high-grade limestone containing less igneous intrusions and pyrite will be found in this deposit farther north. The deposit widens as it is followed in that direction.

Ocean Falls

Two and one-half miles below Ocean Falls on the northwest side of Cousins inlet, a small deposit of coarse-grained, white calcium limestone, containing many small nodules of greenish rock and enclosed in schist, is seen on the trail to the first Twin lake, about 200 feet from the salt water. The limestone contains flakes of white mica and is obviously impure.

Lime plant of Pacific Mills, Ocean Falls. This company operates a rotary kiln at Ocean Falls for the production of lime required for making sulphite and sulphate pulp. The limestone used is obtained from Koeye river (*see* page 167), but was formerly obtained from Cunningham island (*see* page 168). It is brought to the plant on scows, crushed to minus $1\frac{1}{4}$ inch in two jaw crushers working in series, and elevated to the kiln-feed bins, from which it is fed to the kiln without further sizing. The kiln is 80 feet long and 6 feet in inside diameter and has a capacity of 25 tons of lime a day. Crude oil is used for fuel. The lime is cooled on a steel drag conveyer and is stored in concrete bins.

Aristazabal Island

A large deposit of white high-calcium limestone occurs midway along the eastern shore of Aristazabal island on lot 299, opposite a small cove in which there is a small island. This deposit was not seen by the writer. The following information concerning it was supplied by Mr. F. J. Beale, Vancouver, who has been engaged in the quarrying of limestone on the Pacific coast for many years.

The limestone is exposed in cliffs up to 40 feet high for a considerable distance along the shore on both sides of a small stream that enters at the head of the cove. It has been traced back along the course of the stream for a distance of 3 miles and is apparently free from dykes of igneous rock. There is only a thin covering of soil and moss over most of the limestone. A sample submitted by Mr. Beale was snowy white, coarse-grained, and had the following analysis:—

	Per cent
Insoluble	0·34
Oxides of iron and alumina	0·16
Calcium carbonate	98·37
Magnesium carbonate	1·10
Total	99·97

The cove affords good shelter for small vessels, and the water is deep up to the limestone cliffs.

Princess Royal Island

A nearly flat band of white calcium limestone is exposed for 1,000 feet along the east shore of Princess Royal island on lots 146 and 147, which are 7 miles south of Swanson Bay village. The limestone band is 40 to 50 feet thick and forms a slight projection on the shore. It dips inland at a low angle and is overlain by schist and granitic rock. The limestone is coarse-grained and, in addition to the ever-present dykes of igneous rock, contains much siliceous impurities, but is relatively free from interbeds of magnesian limestone.

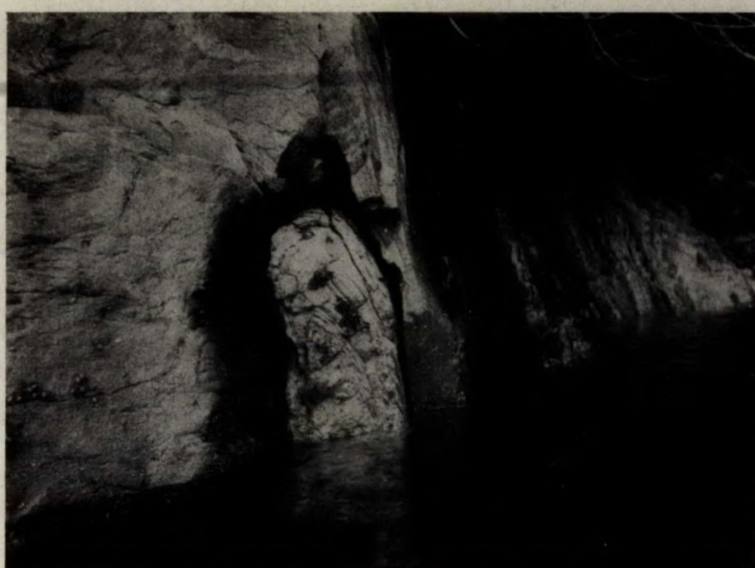
Two quarries were opened in this band to obtain rock for the Swanson Bay pulp mill, but they have not been worked for many years. The most northerly of the quarries is small and is in very impure limestone. The other quarry, 200 yards south, has a face 30 feet in height and 100 feet long and was worked 75 feet into the limestone, which is of better quality than farther north. Inclusions of schist and quartzite occur parallel to the bedding, however, and there are streaks in which golden mica and pyrite are plentiful, in addition to dykes of igneous rock and veins of quartz. There are also streaks of pale blue limestone in which tiny crystals of pyrite are very numerous. It is difficult to find an area 2 feet square free from visible impurities of some kind, and a great deal of cobbing would be necessary before material suitable for use in a pulp mill can be obtained. Sample 33 was taken from the purest limestone visible in the quarry face and does not represent rock that can be obtained in quantity for shipment.

Banks Island

Bands of white, coarsely crystalline limestone (Plate XXXI, page 172). consisting in part of high-calcium limestone and in part of dolomite, occur at a number of places along the east coast of Banks island. In most instances, however, they are in low land where quarrying would be difficult. The southernmost of these bands is on lot 797, between Deer point and Gale point. It is

PLATE XXXI

A. White high-calcium limestone on east shore of Banks island, B.C.



B. Sharply folded bed of limestone enclosed in gneiss on east shore of Banks island, B.C.

600 feet wide, strikes N. 55° W. and dips very steeply northeast, in places being vertical. The limestone is in thin beds and lenticular masses and much of the dolomite present is veined with white quartz. On the northeast edge of the band, particularly, there is much admixture of country rock.

A small exposure of impure, drab-grey limestone occurs on the shore 3½ miles to the north at the mouth of a brook.

Eight miles farther north, on lot 2224, is a steeply dipping band of white high-calcium limestone and dolomite, striking N. 35° W. to N. 50° W. It has a width of 600 feet. Interbedded with the limestone, especially near the edges of the band, is some schistose rock, but there are widths of limestone up to 100 feet in which there is no other rock. The intermingling of the high-calcium limestone and dolomite is erratic. The latter occurs as large lenses and as thin interbeds and is plainly distinguishable only on the weathered surface. It is most common on the edges of the band in contact with the granitic rock of the district. Sample 34 was taken across a 100-foot width of high-calcium limestone, and Sample 34A from a lens of dolomite 30 feet in maximum width. As the analyses show, the rock is very pure, but it would be difficult to separate the dolomite from the high-calcium limestone. The land underlain by the limestone is low. A short distance south of this band, a narrow band of white limestone outcrops on the south side of the cove.

Three and one-half miles farther north from where Sample 34 was taken, another band of limestone outcrops at Despair point on lot 2223. The band strikes N. 80° W. and extends southeasterly from Despair point for ¾ mile, being seen on both shores of a small cove south of the point, but it does not appear at the head of the cove. It has a width of 800 to 1,000 feet and dips vertically. In places it is separated into two bands by quartzite and schist. As in the band to the south, masses of dolomite and interbeds of dolomite occur irregularly through the band. Most of the limestone is coarse-grained and is white, but some is grey and medium-grained. Sample 35 was taken from a width of 50 feet of light grey limestone on the northeastern side of the band; Sample 35A from a width of 50 feet of coarse-grained, white limestone near the centre of the band; and Sample 35B from a 15-foot band of coarse-grained, white dolomite near the southwestern edge of the band. These samples represent the best grades of limestone obtainable. The land underlain by the limestone is low.

Five miles north of Colby bay and near the north end of Banks island is a band of intermixed white and pale blue high-calcium limestone and dolomite, at least 300 yards wide, that strikes N. 60° W. and dips steeply southwest. It forms a low point on the coast of the island and extends for some distance inshore beneath low land. The two types of limestone are much intermixed and most of the land underlain by the limestone is less than 10 feet above high water. Igneous intrusions are few, but much of the dolomite is siliceous.

One and one-half miles northwest of the above, a 100-foot band of intermingled white high-calcium limestone and dolomite outcrops on the shore for 500 feet. It strikes N. 67° W. and dips vertically. The northwestern end of the band runs out under the water of Principe channel, and inshore the band thins out and terminates before high ground is reached. The limestone is medium-grained to fine-grained and appears nearly free from impurities. The dolomite and high-calcium limestone are interbedded, however, throughout the deposit.

Gurd Island

Bands of white limestone 3 to 10 feet wide were observed on the low land at the northwest end of Gurd island.

Kumealon Inlet

A band of blue and of white limestone 500 feet thick is exposed on the low land at the head of Kumealon inlet, which is on the mainland off Grenville channel near the north end of Pitt island. The band strikes N. 60° W. and dips southwest at angles ranging from 55 degrees to nearly vertical. A typical section across the band from north to south in a cove in the inlet is as follows:

100 feet—Intermixed blue and white dolomite and high-calcium limestone.
90 feet—White, coarse-grained limestone.
60 feet—Blue, fine-grained calcium limestone.
15 feet—Igneous rock.
175 feet—Blue limestone of variable quality, some being very impure.
30 feet—Mica schist.
15 feet—White, coarse-grained high-calcium limestone.
30 feet—Blue limestone containing considerable pyrite and interbedded schist.

The several belts in this section vary in thickness from place to place. For instance, on the east shore of the inlet just north of where a small brook enters, there is a width of 200 feet of white, coarse-grained limestone, and in other places there are lenticular masses of white dolomite in the centre of the band. Sample 36 was taken from the blue, fine-grained limestone over a width of 60 feet, and Sample 36A from the white, coarse-grained limestone over a width of 90 feet. The dolomite was not sampled as it is available only in thin beds or in small lenticular masses with calcium limestone intervening.

Lewis Island

White, coarse-grained calcium limestone forms a series of lenticular masses 30 to 50 feet thick separated by schist, along the beach on the east side of and near the south end of Lewis island. Sample 37 represents the best of the limestone in the deposit. Much of the limestone is siliceous and much of it contains interbeds of schist.

Whitecliff Island

On the southern tip of this small island off the northeast coast of Porcher island, a band of pinkish, medium-grained calcium limestone forms a cliff 100 feet high. On either side is a schistose rock, and dykes of igneous rock intrude the limestone, which is much folded. In places white quartz occurs in shapeless masses of various size in the limestone and there are some siliceous streaks parallel to the bedding. Sample 38 was taken across the band, but some of the obviously impure limestone that could be cobbed out in any quarry operation was excluded.

Porcher Island

Narrow bands of impure, laminated, white calcium limestone occur along the northeast shore of Porcher island southeast of Mason point. They trend parallel to the coast line or northwest-southeast and dip at from 45 to 60 degrees out from the shore. It is reported that very impure limestone is exposed on high ground on the north end of this island.

Smith Island

Bluish white, coarsely crystalline high-calcium limestone striking N. 50° E. and dipping northwest at an angle of 53 degrees is exposed in a band at least 100 feet wide for 1 mile along the north shore of the lagoon on the west side of Smith island. The limestone band is enclosed in schist and near its edges schist is interbedded with it. Some brown mica, white tremolite, and crystals of pyrite are also noticeable in the limestone, but the worst impurity consists of thin beds of highly siliceous limestone that occur at frequent intervals in the deposit. Sample 39 represents the pure limestone between the siliceous streaks, and Sample 39A the siliceous streaks. Near the entrance to the lagoon the limestone contains much more schist than elsewhere. Thirty-five years ago limestone from this deposit was burned in a pot kiln to supply a local demand in Prince Rupert.

Digby Island

Blue and white, siliceous calcium limestone, striking N. 65° W. and dipping northeast at 65 degrees, is exposed on the low islet that lies off the southeast corner of Digby island and is connected with it at low tide. The band is several hundred feet wide, but this includes a band of black amphibolite schist. The limestone is enclosed in schist. It is in part fine-grained, and in part coarse-grained and is laminated in most places. Thin bands of siliceous material are plentiful, especially towards the edges of the deposit.

Swamp Point

South of the small creek entering Portland canal at Swamp point a band of limestone 200 feet thick, striking true north and dipping inland at a steep angle, is exposed along the shore, where it was quarried for flux for the Anyox smelter for a number of years prior to 1927, when operations were discontinued. The limestone is medium to coarse in grain and is from white to dark blue in colour, some of it being banded blue and white. Siliceous streaks occur through much of the limestone and as a rule these contain pyrite, actinolite, and some golden mica. The limestone is much folded and contorted and is cut by a few thin igneous dykes. Two quarries were opened in the band and the same type of limestone occurs in each. Two samples were taken from the last quarry worked on the south bank of the creek. Sample A represents the limestone free from siliceous bands; and Sample B is a channel sample taken across the band including the siliceous streaks, and represents the grade of material that would be obtained if no cobbing were done.

	A. Per cent	B. Per cent
Silica	0·95	4·06
Ferric oxide	0·27	0·92
Alumina	0·19	0·54
Calcium phosphate	0·15	0·15
Calcium carbonate	97·77	93·12
Magnesium carbonate	0·53	0·94
Total	99·86	99·73

Analyses of Limestones on the Coastal Mainland and Adjacent Islands

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
20	1·80	0·20	0·21	0·02	95·59	1·91	99·41	Nil	53·56	0·91	59 : 1
20A	1·68	0·27	0·26	0·02	95·18	2·56	99·97	Tr.	53·33	1·22	44 : 1
21	0·94	0·18	0·12	0·04	90·12	8·58	99·98	0·03	50·49	4·10	12 : 1
22	4·86	0·30	0·61	0·20	92·16	1·22	99·35	0·08	51·72	0·58	89 : 1
22A	28·96	1·25	2·43	0·35	64·66	1·16	98·81	0·52	36·40	0·55	66 : 1
23	(*See* page 163)		....	....	....	....	....	....	....	....	....
24	5·92	0·50	1·16	Tr.	86·59	5·80	99·97	0·46	48·52	2·77	17 : 1
24A	2·60	0·46	0·55	0·02	58·50	37·51	99·64	0·38	32·78	17·94	1·82 : 1
24B	5·32	0·33	0·61	0·04	66·66	26·34	99·30	0·51	37·35	12·60	30 : 1
24C	5·66	0·29	0·87	0·04	84·55	8·52	99·93	0·20	47·38	4·07	11··1
24D	7·52	0·51	1·80	0·07	82·57	7·40	99·87	0·42	46·26	3·54	13 : 1
25	1·90	0·15	0·25	0·07	96·89	0·29	99·55	Tr.	54·30	0·14	388 : 1
25A	1·36	0·30	0·44	0·04	96·87	0·27	99·28	0·10	54·27	0·13	417 : 1
26	3·14	0·30	0·37	0·11	94·68	0·80	99·40	Tr.	53·08	0·38	140 : 1
27	0·72	0·13	0·14	0·02	95·02	3·80	99·85	Nil	53·22	1·82	29 : 1
27A	0·58	0·09	0·19	0·04	57·96	41·02	99·88	Nil	32·48	19·61	1·65 : 1
27B	1·08	0·08	0·02	0·09	95·25	2·38	98·90	Nil	53·39	1·14	47 : 1
28	0·38	0·23	0·08	0·07	98·25	0·63	99·64	Nil	55·06	0·30	184 : 1
28A	1·04	0·24	0·19	0·11	96·52	1·17	99·27	Nil	54·11	0·56	97 : 1
29	1·00	0·10	0·10	0·04	97·09	1·19	99·52	Nil	54·39	0·57	95 : 1

Analyses of Limestones on the Coastal Mainland and Adjacent Islands—*Concluded*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
30.......	4·68	0·46	0·42	0·04	80·30	15·18	101·08	0·02	44·99	7·26	6 : 1
30A.....	0·74	0·12	0·23	0·07	96·62	1·94	99·72	Nil	54·15	0·93	58 : 1
31.......	2·80	0·23	0·46	0·02	91·46	4·31	99·28	Tr.	51·23	2·06	25 : 1
31A.....	0·82	0·18	0·14	0·02	96·50	0·80	98·46	0·02	54·05	0·38	142 : 1
32.......	1·00	0·22	0·18	0·04	97·45	0·48	99·37	0·02	54·59	0·23	237 : 1
32A.....	0·48	0·12	0·18	0·04	98·28	0·29	99·29	Nil	55·06	0·14	393 : 1
33.......	1·56	0·18	0·25	0·02	96·20	1·50	99·71	0·02	53·88	0·72	75 : 1
34.......	0·24	0·07	0·18	0·02	97·41	1·51	99·43	Nil	54·56	0·72	76 : 1
34A.....	0·24	0·23	0·08	0·02	56·84	43·44	100·85	Tr.	31·84	20·77	1·53 : 1
35.......	1·66	0·20	0·53	0·02	94·27	1·78	98·46	0·03	52·80	0·85	62 : 1
35A.....	3·10	0·06	0·15	0·11	92·73	3·34	99·49	Nil	51·99	1·60	32 : 1
35B.....	0·78	0·08	0·15	0·07	56·57	43·12	100·77	Nil	31·72	20·62	1·53 : 1
36.......	7·12	0·26	0·30	0·17	85·57	5·08	98·50	0·07	48·01	2·43	20 : 1
36A.....	1·04	0·14	0·18	0·09	93·39	4·34	99·18	0·04	52·35	2·07	25 : 1
37.......	2·52	0·42	0·39	0·02	94·61	0·36	98·32	0·04	52·99	0·17	312 : 1
38.......	6·12	0·49	0·51	0·04	91·14	1·07	99·37	0·03	51·06	0·51	100 : 1
39.......	0·98	0·08	0·11	0·02	97·55	0·80	99·54	Nil	54·64	0·38	144 : 1
39A.....	47·70	0·67	0·22	0·02	45·30	6·34	100·25	0·04	25·38	3·03	8 : 1

20.	Nelson island.	Fine-grained limestone in band on northwest side of the island.
20A.	" "	Coarse-grained part of the same deposit.
21.	Dinner rock.	White and bluish white limestone on mainland ½ mile south of Dinner rock, or opposite the east end of Savary island.
22.	Quadra island.	Dark blue limestone on the eastern half of Open bay.
22A.	" "	Ridges of siliceous limestone in the same deposit.
23.	West Redonda island	Light blue limestone formerly quarried by British Columbia Pulp and Paper Company.
24.	Frederick arm.	One hundred feet of pale blue limestone on west side of Frederick arm just inside the entrance.
24A.	" "	Same deposit; 12 feet of white dolomite on west edge.
24B.	" "	Same deposit; thin streaks of dolomitic limestone occurring in the blue limestone.
24C.	" "	Same deposit; white, coarse-grained limestone near the west edge.
24D.	" "	Same deposit; streaked, blue limestone adjoining the coarse-grained limestone to the east.
25.	Harbledown island.	North half of limestone band on south coast at east end of the island.
25A.	" "	South half of same band.
26.	" "	Blue high-calcium limestone midway along south coast of the island.
27.	Smith inlet.	White limestone in the larger of two quarries formerly worked by Coast Calcite Company.
27A.	" "	White dolomite in small quarry 700 feet east of the above quarry.
27B.	" "	Fifty-foot width of high-calcium limestone in the centre of the deposit.
28.	Rivers inlet.	Easterly half of the limestone band on the north shore of Rivers inlet at False inlet.
28A.	" "	Western half of same band.
29.	" "	Deposit of white coarse-grained limestone at Kilbella bay on the north side of the inlet.
30.	Koeye river.	White and light blue limestone composing a hill ½ mile up the river from its mouth.
30A.	" "	Pale blue and white limestone in cove on east shore of the river upstream from where No. 30 was taken.
31.	King island.	Fifty feet of light grey limestone near centre of deposit on point ¾ mile east of the southern tip of the island.
31A.	" "	Fifty feet of blue-and-white striped limestone adjoining No. 31 to the east.
32.	Cunningham island.	One hundred feet of white limestone in quarry formerly worked by F. J. Beale.
32A.	" "	White limestone in underground chamber on the same property.
33.	Princess Royal island.	Purest limestone exposed in old quarry on east shore of the island from which limestone was formerly obtained for the pulp mill at Swanson Bay.
34.	Banks island.	One hundred feet of white limestone on lot 2224 on the east coast of the island.
34A.	" "	Lens of white dolomite on the same deposit.
35.	" "	Fifty feet of light grey limestone on northeastern side of deposit at Despair point on the east side of the island.
35A.	" "	Fifty feet of white limestone near the centre of the same deposit.
35B.	" "	Fifteen feet of dolomite near the southwestern edge of the same deposit.
36.	Kumealon inlet.	Sixty feet of fine-grained, blue limestone near north edge of the deposit.
36A.	" "	Ninety feet of coarse-grained, white limestone north of No. 36.
37.	Lewis island.	White limestone on east side of and near the south end of the island.
38.	Whitecliff island.	Pink, medium-grained limestone from cliff on south tip of the island.
39.	Smith island.	Pure, bluish, coarse-grained limestone on north shore of lagoon on west side of the island.
39A.	" "	Siliceous streaks in same deposit.

Fraser River Valley between Vancouver and Lytton

The limestones of the Fraser valley west of Lytton are of Carboniferous age, with the possible exception of those in the vicinities of Yale and Saddle Rock which are surrounded by intrusive rock (believed to be of Jurassic age) that has metamorphosed the limestone to such an extent that all fossils have been destroyed. The Carboniferous limestone occurs associated with quartzite and argillite in steeply dipping deposits, two of the largest being in the vicinities of Rosedale and Popkum. All of the limestone sampled contained over 3 per cent of silica, some had over 10 per cent. The magnesium carbonate content, however, is low, as, except in one deposit, it ranged from 1·13 to 2·52 per cent. The deposits would therefore be suitable for making Portland cement. All deposits examined were close either to the Canadian National or the Canadian Pacific railway. At Popkum there is a large deposit of marl.

A deposit of limestone at Agassiz and the deposit of marl at Popkum are being worked to supply material for use in correcting the acidity of the soil in the Fraser valley. Agricultural limestone was also made at Popkum, but the plant has been idle for a number of years. Small amounts of lime were produced in the past at several of the deposits.

Agassiz

Bluish grey, fine-grained, hard, calcium limestone of Carboniferous age, occurring on the southwest end of a hill on the north bank of the Fraser river, 2½ miles southwest of Agassiz, is being quarried and pulverized for agricultural use by Maurice Tuyttens, who operates under the name of *The Agassiz Lime Quarry*.

The quarry is opened in a knoll of limestone and quartzite, 40 feet high, at the base of the main hill (Plate XXXII A, page 178). It is 30 feet wide and has been worked 60 feet into the knoll. On either side is quartzite and this is the predominant rock in the outcrops behind the quarry face. Sample 40 was taken across the quarry face, and Sample 40A from the pulverized material being bagged for shipment. Other outcrops of similar limestone are exposed on the hill adjoining the knoll in which the quarry is worked.

A jackhammer is used for drilling the limestone. Broken stone is loaded by hand on a small car which is pushed by hand out of the quarry and is hauled by cable to the adjacent crushing and grinding plant.

This plant has a capacity of 1 ton an hour of ground material and is run by electric power. The rock is crushed in a small jaw crusher and is then passed to a ball mill, the discharge from which is screened on a rotary screen. Coarse material is marketed for poultry grit and the fine material, all of which passes a 20-mesh screen, is bagged for shipment for use in correcting soil acidity.

Other deposits of limestone are reported to occur in the vicinity of Agassiz. Bowen[1] states that there is a thick limestone band "on the low mountain northwest of Agassiz", but no further information concerning it is given.

Rosedale

At Bretts mill near Rosedale, fine-grained to medium-grained, blue-grey calcium limestone of Carboniferous age is exposed in the valley of a small creek and was at one time utilized for making lime. Thin wavy films of brown-weathering calcareous shale are present in much of the limestone, as are also patches and veins of white calcite. Bedding is indistinct, but the deposit apparently strikes east and west and dips north at an angle of 45 degrees. Sample 41 is representative of a 10-foot thickness of limestone exposed.

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[1] Bowen, N. L.: Geol. Surv., Canada, Sum. Rept. 1912, p. 113.

PLATE XXXII

A. Quarry in small lens of Carboniferous limestone at Agassiz, B.C. The rock on either side of the opening is quartzite.

B. Steeply dipping, heavily bedded Carboniferous limestone formerly quarried for agricultural use at Popkum, B.C.

Similar limestone is exposed on the heavily wooded mountainside at intervals from Rosedale to Popkum, the largest exposures being 1 mile from Bretts mill, and from them Sample 42 was taken. Gravelly soil covers the limestone in most places, but the deposit may be continuous from here to Popkum. Films of brown-weathering shale are prominent in all the outcrops seen, and veins and masses of white calcite are more numerous than in the exposures at the foot of the mountain. British Columbia Cement Company owns part of this limestone deposit.

Popkum

Bluish grey, fine-grained to medium-grained, Carboniferous calcium limestone that weathers brown is exposed adjacent to the highway at the base of Cheam mountain, 1 mile southeast of Popkum, where it has been quarried and ground for agricultural use. Successive operators have been Western Canada Lime Company, Chilliwack Lime and Fertilizer Company, and Popkum Lime Products Company. There has been no production in the past few years. The limestone forms a wide belt striking along the steep mountainside and dipping downhill at an angle of 30 degrees (Plate XXXII B, page 178). In most places it is covered by from 5 to 8 feet of soil that supports a dense forest growth, but occasional outcrops indicate that the belt continues far to the southwest, possibly as far as Rosedale. Two small quarries of the side-hill type have been opened in the deposit at Popkum. In the lower of the two quarries, which is connected by a narrow-gauge tramway with the grinding plant, a thickness of 25 feet of limestone is exposed. Two types are apparent, a medium-grained, comparatively pure limestone consisting almost entirely of calcium carbonate, and a very fine-grained, impure variety containing much fine silica and other siliceous matter, including blue chert. The siliceous limestone is present as lenses and thin beds throughout the pure limestone. It is probable that this highly siliceous matter is characteristic of only certain zones in the large limestone belt, because in the small quarry opened farther up the mountainside and south of the other quarry these lenses are not apparent, nor were they observed in an outcrop several hundred feet above the main quarry. Sample 43 was taken from the 25 feet of strata exposed in the lower of the two quarries; Sample 43A from pulverized material in the bins in the grinding plant; and Sample 43B in the small, long-disused quarry south of and above the other quarry.

The grinding plant was operated by steam and the equipment, in addition to a steam boiler and engine, consists of a small gyratory crusher, a ball mill, and rotary screens. The plant was formerly connected with the Canadian National railway by a spur track, but the rails were removed long ago.

One-third mile south of where the spur track formerly crossed the highway a mass of siliceous, dark blue magnesian limestone is exposed on the southeast side of the highway. It is veined with calcite and with some white quartz. Beneath the magnesian limestone is impure calcium limestone.

A large deposit of brown marl having a high content of organic matter occurs in Popkum lake, north of the highway and 1 mile southwest of Popkum station on the Canadian National railway. *Fraser Valley Chemical Company, Limited,* with head office at 414 Credit Foncier Building, Vancouver, is pumping the marl from the lake and selling it for agricultural use. The slurry from the lake is delivered by a centrifugal pump to large wooden vats where the water is allowed to drain off. The drying of the marl is completed by spreading it on platforms exposed to the sun. It is marketed in bulk in the lump form and also, after having been passed through a hammer mill, in powdered form packed in bags. The analysis of a sample taken from the bagging bin is as follows:—

	Per cent
Silica	5·84
Ferric oxide	0·88
Alumina	1·96
Calcium phosphate	0·92
Calcium carbonate	78·34
Magnesium carbonate	1·46
Organic matter	10·90
Total	100·30

Ruby Creek

Several thin bands of siliceous limestone interbedded with schist are reported to occur at the mouth of Ruby creek near the station of the same name on the Canadian Pacific railway.

Hope

On the east side of the Fraser river, 1 mile above Hope and 1 mile back from the river, is a thin band of Carboniferous limestone that in the early days of settlement of the district provided lime for local use. Another thin band occurs on the east side of the river, 4 miles above Hope. Both deposits are small and the limestone is of poor quality and variable in composition.

Yale

Siliceous, rusty-weathering, grey dolomite occurs in a narrow band in the valley of Gordon creek, 1 mile south of Yale.

Saddle Rock

A short distance south of Saddle Rock siding on the Canadian Pacific railway a vertically dipping band of siliceous, bluish white, fine-grained, calcium limestone extends from the west bank of the Fraser river northwestward up the steep side of the mountain. At the river bank the limestone band is 50 feet thick and contains much interbedded quartzite and many veins of milky quartz. Where it crosses the highway, 50 feet above the river, it is 60 feet wide, and at the railway, 50 feet higher, the band is 80 feet wide, but this latter width includes a 15-foot band of quartzite that occurs in the centre of the limestone band. One hundred and fifty yards northwest of the siding are the ruins of a pot kiln in which the limestone was burnt. At this place the limestone is pale brownish grey and is exposed in a cliff 50 feet high. It contains stringers and platy masses of white quartz and some flakes of golden mica, but is of better quality than was seen elsewhere in the part of the deposit examined. To the east a fine-grained granitic rock is in contact with the limestone. Sample 44 is representative only of a hand specimen of the limestone free from quartz and quartzite. Stone of this quality cannot be obtained in quantity from the deposit. A number of years ago part of this deposit was optioned by *H. Reynolds, 2475 Charles St., Vancouver*, who produced a small quantity of agricultural limestone and poultry grit therefrom.

Analyses of Limestones in Fraser River Valley between Vancouver and Lytton

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
40.......	9·10	0·80	2·60	0·09	83·00	5·14	100·73	0·22	46·50	2·46	19 : 1
40A.....	8·52	0·57	2·16	0·09	86·87	4·60	100·81	0·20	48·68	2·20	22 : 1
41.......	3·92	0·37	0·86	0·07	93·16	2·22	100·60	Tr.	52·21	1·06	49 : 1
42.......	3·28	0·33	0·67	0·11	94·84	1·13	100·36	Tr.	53·17	0·54	98 : 1
43.......	12·66	0·37	0·12	0·07	85·62	1·32	100·16	0·05	48·02	0·63	76 : 1
43A.....	10·48	0·26	0·16	0·11	87·09	2·09	100·19	0·06	48·83	1·00	49 : 1
43B.....	3·46	0·24	0·14	0·10	95·20	1·13	100·27	0·02	53·33	0·54	99 : 1
44.......	1·51	0·32	0·21	n.d.	95·38	2·52	99·94	Tr.	53·44	1·21	44 : 1

40.	Agassiz.	Carboniferous limestone in quarry of Agassiz Lime Quarry.
40A.	"	Pulverized limestone from bin in grinding plant of Agassiz Lime Quarry.
41.	Rosedale.	Ten feet of Carboniferous limestone in valley of small creek at Bretts mill.
42.	"	Carboniferous limestone on mountainside 1 mile northeast of Bretts mill.
43.	Popkum.	Carboniferous limestone in quarry 1 mile southeast of Popkum station formerly worked for agricultural limestone.
43A.	"	Pulverized limestone from bin in grinding plant at Popkum.
43B.	"	Carboniferous limestone in small disused quarry south of where Sample 43 was obtained.
44.	Saddle Rock.	Limestone free from quartz veins and quartzite beds.

Thompson River Valley between Lytton and Kamloops

In this district, which is served by the Canadian National and Canadian Pacific railways, the principal known deposits of limestone are of Carboniferous age and are found at Martel, Ashcroft, and Kamloops. They are all of good size and are of the high-calcium type, the only magnesian limestone observed consisting of small patches of impure dolomitic material scattered sparingly throughout parts of a large deposit of high-calcium limestone 3 miles west of Ashcroft. The purest limestone is that on the Harper ranch, 12 miles east of Kamloops, much of which contains less than 0·5 per cent of silica and less than 1 per cent of magnesium carbonate. It was included in this section because at present the only place from which it can be shipped by rail is Kamloops.

There is no production from any of the deposits. In the early days of settlement of the country a number of the deposits were quarried for making lime for local use.

Martel

Just north of Martel station on the Canadian National railway, 7 miles north of Spences Bridge, a triangular-shaped mass of Carboniferous high-calcium limestone forms a barren ridge on the steep west bank of the Thompson river immediately above the highway. The railway is 200 feet below. The base of the limestone deposit is hidden by a gravel bench on which the highway is built, but a width of 260 feet of limestone is exposed above the gravel. The apex of the triangular-shaped limestone mass is 200 feet higher up and 400 feet west. The limestone is very fine-grained, is dark blue on fresh fracture, and weathers to a very light grey. It is much fractured and bedding is indistinct (Plate XXXIII A, page 182), but the apparent strike is nearly east and west. The limestone is nearly free from visible impurities except along the northern edge where, for a short distance from the contact, a green argillite is interbedded with it. Sample 45 was taken across a width of 120 feet of limestone strata beginning at the north edge of the deposit near where it emerges from the gravel bench. Sample 45A was taken across a width of 120 feet of strata beginning at the south edge, just above the gravel bench.

The same kind of limestone occurs across the river in a cutting and in a tunnel on the Canadian Pacific railway, where it is not in a quarriable position.

Beginning 300 yards north of where Sample 45 was taken, a very large limestone mass forms the west bank of the Thompson river for about a mile and rises in a ridge 1,200 to 1,500 feet high. Wherever examined the limestone seemed the same, being fine-grained, dark blue on fresh fracture, and weathering to a

PLATE XXXIII

A. Weathered surface of Carboniferous limestone near Martel station, 7 miles north of Spences Bridge, B.C.

B. Extremely cherty Carboniferous limestone, Harper ranch, 12 miles east of Kamloops, B.C.

light grey. It is veined with white calcite and is much fractured. Near the highway the limestone is traversed by numerous dykes of igneous rock, but higher up these dykes are not numerous. Occasional nodules and stringers of blue chert project from the weathered surface. The limestone mass strikes west of north and dips southwest. It extends down to the railway and a tunnel has been cut through it. Sample 46 was taken along the top of the ridge.

Northerly along the road, the limestone becomes progressively less pure and finally is underlain by slate. For 2 miles along the highway toward Ashcroft, bands of highly altered limestone alternate with bands of igneous rock and argillite. Many of these limestone bands are siliceous and none is in a position favourable for quarrying. The southwestern half of the main limestone mass, however, would provide an enormous tonnage of high-calcium limestone of a composition similar to that of Sample 46.

Ashcroft

Just north of where Cornwall creek crosses the highway about 3 miles west of Ashcroft, a bare hill composed mostly of Carboniferous high-calcium limestone rises west of the highway to a height of 300 feet. The hill is oval-shaped in plan, being about 600 yards in length from east to west and 400 yards wide. Running through the centre of the hill in an east-west direction is a band of shale, quartzite, and argillite about 200 feet in width and dipping north at an angle of 60 degrees. This band occupies a slight depression and the limestone rises on either side of it in two small peaks.

The limestone is medium-grained, light grey, and weathers to a dirty white, though in places it is rusty. All through it are thin films of rusty, calcareous shale that give it a rather poor appearance. The weathered surface is very rough. Here and there in the high-calcium limestone are small patches of very fine-grained, grey-blue, siliceous, highly magnesian limestone that weathers brown. These patches are not numerous except at the north side of the deposit and do not greatly affect the quality of the limestone. Sample 47 was taken here and there over the whole deposit, excluding the magnesian patches. Sample 47A was taken from a number of patches of the highly magnesian limestone. The content of calcium phosphate in these samples is far above the average.

On the eastern slope of and near the top of Rattlesnake hill, 4 miles northeast of Ashcroft, are some patches of siliceous calcium limestone of the Nicola group (Triassic). The limestone has a sugary texture, is mostly light grey to nearly white, and contains small masses and grains of white quartz and of blue chert. In some places it has mauve and green tints, and coarse crystals of mauve calcite are sparingly distributed through it. Sample 48 was taken at irregular intervals over the main outcrop. The limestone is surrounded by argillite and quartzite and is cut by several dykes of green igneous rock.

Savona

Four miles west of Savona on the east bank of Deadman river, which empties into the Thompson river from the north, very fine-grained, dark blue calcium limestone of the Nicola group protrudes through a river terrace, just above the highway bridge. The limestone in some places is fairly pure, but in most places it is so intermixed with argillite and igneous rock as to be of no value for industrial purposes.

One and three-quarter miles east of Savona, fine-grained, brownish grey calcium limestone of the Nicola group is exposed north of the highway to Kamloops just east of Threemile creek. The limestone has many veins of calcite and weathers to a rusty grey. Much of it is impure. The deposit dips steeply south and is underlain by a limestone conglomerate containing a great number of small pebbles of quartzite.

Kamloops

On the Harper ranch, 12 miles east of Kamloops, on the north side of the South Thompson river, are extensive exposures of very fine-grained, dark blue and grey, high-calcium limestone of Carboniferous age. Some of this limesone is of excellent quality and some is very siliceous. The limestone is exposed on the southern faces of two adjoining hills (separated only by a gully) that rise out of the river plain and form foothills to the mountains at the rear. For the most part the hills consist of a highly siliceous limestone in which the siliceous material is distributed in parallel rows, as along bedding planes, and shows on the weathered outcrops as pale brown, irregularly shaped projections (Plate XXXIII B, page 182). On each hill, however, there is a wide, steeply dipping band, or large lens, several hundred feet thick of exceptionally pure high-calcium limestone that trends up the slope and is well exposed in a series of benches. The best grade of limestone is found well up on the hillsides. Sample 49 was obtained across a thickness of 300 feet of pure limestone from the band on the easternmost of the twin hills about one-third of the way up to the summit. Sample 49A was obtained from a thickness of 200 feet of pure limestone exposed lower down the hill and west of where Sample 49 was taken. Sample 49B was obtained on the hill to the west and represents a thickness of 100 feet of pure limestone present in a steeply dipping lenticular band. Though the siliceous limestone is readily recognizable in weathered outcrops, it is almost indistinguishable from much of the pure limestone in a freshly broken piece because the siliceous material is of the same colour on fresh fracture and also is somewhat calcareous. Some of the pure limestone is coarser in grain than is the siliceous material and this would serve as a distinguishing feature in quarry operations.

To the east the siliceous limestone is in contact with highly altered eruptive rocks and near the eastern edge some thin dykes of diabase intrude the limestone. The actual contact was not seen. The limestone beds in this vicinity strike N. 55° W. and dip southwest at an angle of 70 degrees. Westward the rocks of the Cache Creek series, to which this limestone apparently belongs, extend along the river front for a distance of several miles, and several other outcrops of limestone, most of which is highly siliceous, are seen within a distance of 2½ miles. The ruins of pot kilns in the neighbourhood show that the limestone was used at one time for making lime.

The nearest rail shipping point is Kamloops, about 13 miles distant by road, but the Canadian Pacific railway on the opposite side of the river is only a little more than 1 mile away.

North of Kamloops, Carboniferous limestone deposits occur in the valley of the North Thompson river. These deposits are described on pages 215 to 217.

Analyses of Limestones in Thompson River Valley between Lytton and Kamloops

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
45.......	2·14	0·20	0·21	0·11	96·66	0·90	100·22	Nil	54·19	0·43	126 : 1
45A.....	1·44	0·27	0·17	0·11	97·68	0·42	100·09	Nil	54·76	0·20	274 : 1
46.......	2·44	0·07	0·14	0·11	95·98	0·46	99·20	Nil	53·81	0·22	245 : 1
47.......	1·98	0·10	0·48	1·27	95·84	0·29	99·96	Nil	54·36	0·14	388 : 1
47A.....	8·20	1·67	2·95	2·01	54·18	32·79	101·80	Tr.	31·43	15·68	2 : 1
48.......	11·56	0·66	1·38	0·22	85·50	0·69	100·01	Tr.	48·00	0·33	145 : 1
49.......	0·42	0·07	0·09	0·09	98·20	0·96	99·83	Nil	55·04	0·46	120 : 1
49A.....	0·42	0·08	0·12	0·09	98·50	0·69	99·90	Nil	55·21	0·33	167 : 1
49B.....	0·30	0·11	0·08	0·04	98·45	0·74	99·72	Nil	55·15	0·35	158 : 1

45.	Martel.	One hundred and twenty feet of Carboniferous limestone from north edge of deposit north of Martel station.
45A.	"	One hundred and twenty feet of Carboniferous limestone from south edge of the same deposit.
46.	"	Carboniferous limestone forming west bank of Thompson river for 1 mile north of Martel.
47.	Ashcroft.	Carboniferous limestone west of the highway 3 miles west of Ashcroft.
47A.	"	Thin patches of magnesian limestone in the same deposit.
48.	"	Triassic limestone on Rattlesnake hill 4 miles northeast of Ashcroft.
49.	Kamloops.	Harper ranch, 300 feet of Carboniferous limestone on the easternmost of the twin hills and one-third way to the summit.
49A.	"	Two hundred feet of Carboniferous limestone strata lower down the same hill.
49B.	"	One hundred feet of Carboniferous limestone on the westernmost of the twin hills.

Main Line of the Canadian Pacific Railway between Kamloops and the Alberta Boundary

Limestones ranging from high-calcium to dolomite, and from comparatively pure to very impure, are available along the main line of the Canadian Pacific railway between Kamloops and the Alberta boundary. Variety in the limestones in this area is to be expected because the deposits range in age from Precambrian to Silurian, though for the most part they are Cambrian and Precambrian.

Between Notch Hill and Sicamous, where the limestones are mostly Cambrian and Precambrian in age, all the deposits examined have a low content of magnesium carbonate and some are sufficiently pure to be classed as high-calcium.

Between Albert Canyon and Beavermouth the railway crosses the Precambrian Selkirk range, which includes little limestone and such that does occur is magnesian and for the most part siliceous.

Eastward from Beavermouth to the Alberta boundary the railway traverses Palæozoic rocks of the Rocky mountains, which include a variety of limestones, mostly magnesian in composition, including some pure dolomite.

Except for some riprap quarried from the Palæozoic limestone near Glenogle for use in protecting the railway bed from erosion by the Kicking Horse river, no use has been made of any of the limestone in recent years. During the construction of the railway, and for some time afterwards, small quantities of lime were made from several of the limestone deposits for local use.

Notch Hill

High-calcium limestone of Precambrian (Sicamous limestone) age is exposed on the south shore of Shuswap lake in the vicinity of Sorrento and Blind bay, which are north and east respectively of Notch Hill station on the Canadian Pacific railway. Where seen on the road 1 mile east of Sorrento, the limestone is fine-grained, dark blue, very impure and of a slaty nature with fine micaceous scales developed along bedding planes. Veins of white calcite and of white quartz cut across the beds.

On the beach at the southwest point of Blind bay the Sicamous limestone is again exposed. Here, it strikes N. 5° E. and dips west at an angle of 15 degrees. It is of a fair degree of purity as shown by the analysis of Sample 50, representative of a thickness of 10 feet of strata. The limestone is dark blue, graphitic, fine-grained, and in thin beds, with tiny flakes of mica developed

A. Patch of dolomite in high-calcium limestone (Sicamous formation) at Notch Hill, B.C.

B. Thinly bedded, impure Sicamous limestone, Sicamous, B.C.

along the bedding planes. It has many veins of white calcite, and some veins of quartz 2 to 4 inches thick cut across the bedding, as do the calcite veins. In one place several thin platy masses of dark blue dolomite occur in the high-calcium limestone. These dolomitic patches weather darker than the rest of the limestone and stand out in relief with a typically scarred surface (Plate XXXIV A, page 186). On a freshly broken surface the distinction is difficult except by testing with acid, as the dolomite and the high-calcium limestone may be almost identical in appearance.

Carlin

Northeast of Carlin station on the Canadian Pacific railway, an extension of the deposit of Sicamous limestone exposed at Notch Hill is exposed in the valley of White creek and on the lower slopes of Bastion mountain. It is very impure, being slaty in nature and containing many veins of white quartz. Considerable dolomite is also visible in these outcrops.

Salmon Arm

A band of white, medium-grained, high-calcium limestone of Precambrian age outcrops on the western end of Larch hill, about 800 feet above the road and just back of the property of W. E. Meek. This is about 3 miles from the Canadian Pacific railway station at Salmon Arm. The limestone forms a small ridge trending N. 70° W. along the face of the hill, which here trends N. 45° W. This ridge is about 250 feet across and 800 feet long. The dip of the limestone is difficult to ascertain because of its fractured condition, but it is apparently into the hillside. The limestone ranges from white to bluish white in colour and is all of the high-calcium variety, except for a few thin seams of brown-weathering, blue dolomite along some fractures. A few quartz veins were observed in the limestone and, near the edge of the band, some quartzite pebbles and small patches of shale are present. The ridge was sampled in two places. Sample 51 was taken across the northwest end, and Sample 51A is representative of the whole ridge, excepting an impure band along its lower side.

Sicamous

Sicamous is the type locality for the Sicamous limestone, and alongside the Canadian Pacific railway this limestone is well exposed. It is dark bluish grey, slaty in appearance (Plate XXXIV B, page 186), and impure. It strikes northwest-southeast and dips northeast. Westward from the railway station it becomes more and more impure and is interbedded with other rocks.

On the west shore of Shuswap lake, opposite Sicamous, the Sicamous limestone is again exposed, and from there westward forms a wide belt along the south side of Bastion mountains for 10 miles. The same kind of limestone is also exposed on the west shore of the lake, opposite Quartzite point.

Albert Canyon

A band of Precambrian magnesian limestone 50 feet thick, striking northwest and dipping northeast at an angle of 40 degrees, crosses the Illecillewaet river and the Canadian Pacific railway about 75 yards west of where the trains stop to allow passengers to see the canyon. The limestone is bluish grey, streaked parallel to the bedding with light grey, and is fine- to medium-grained. Some of the beds consist almost entirely of dolomite and others of calcium carbonate. Thin veins of white calcite cut through both types, and occasional crystals of sphalerite are present. At one time this limestone was used for making lime in a pot kiln, the remains of which are on the south side of the track at the deposit. In recent years it has been investigated as a source of marble, but there has been no production. Sample 52 was taken across the band at right angles to the bedding. The limestone can be traced for several hundred yards after which it is covered with overburden. It is overlain by mica schist and underlain by quartzite.

A short distance west of Albert Canyon station a band of bluish white, magnesian limestone about 150 feet thick is exposed in the bed of Albert creek. It is said that this limestone band can be traced for 2 miles to the south. It, too, is underlain by quartzite and overlain by a micaceous schistose rock.

Ross Peak to Beavermouth

In Glacier Park between Ross Peak and Beavermouth stations on the Canadian Pacific railway, a Precambrian limestone band known as the Nakimu limestone is, because of folding, exposed adjacent to the railway in four places, namely, 1 mile east of Ross Peak, 2 miles west of Connaught, 2 miles east of Six Mile Creek, and 2 miles west of Beavermouth. Daly's[1] description of this limestone is as follows:—

> The Nakimu limestone is the key to the stratigraphy and structure of the Selkirk and Purcell mountains, in the railway belt. It is named from the Caves of Nakimu (Caves of Cheops) which have been opened in the limestone by the erosion of Cougar brook in its subterranean course northeast of Cougar mountain.
>
> The formation has its greatest observed thickness at the Caves of Nakimu, where it appears in the western limb of the summit syncline. Local warping of its easterly-dipping rocks here broadens the outcrop, which reaches a width of about 1,200 feet. The total thickness at this section is at least 350 feet and may be as much as 500 feet. A bluish-grey crystalline limestone is the principal constituent. A few beds are composed wholly of carbonate, ranging from nearly pure calcite to dolomite. The majority are more or less charged with detrital grains of quartz and with shreds of sericite or talc lying in the bedding planes. Near the top the limestone is interrupted by phyllitic and quartzitic laminæ. The limestone generally weathers grey but is often mottled with irregular buff-coloured surfaces. It is usually fine-grained, with diameters of the grains averaging about 0·2 mm. These are characteristically flattened parallel to the plane of bedding.

Glenogle

The northern end of a steeply dipping belt of Palæozoic dolomite (Beaverfoot? formation) that extends lengthwise of the Beaverfoot range along its northeastern side, is exposed along the highway in the canyon of the Kicking Horse river just northwest of Glenogle. One mile west of Glenogle station the railway company has opened a quarry in the dolomite to obtain riprap for use along its track in the valley of the Kicking Horse river. Although it is not in a favourable position for quarrying where seen along the highway, samples were taken to supplement the information obtained elsewhere on the chemical characteristics of this important dolomite formation. The rock is hard, fine-grained, steel-grey, and in uneven beds that dip steeply to the east. Some is massive, some is thin-bedded, and in places much blue chert appears. Sample 53 represents a very fine-grained, light steel-grey dolomite; Sample 53A a dark grey impure variety containing blue chert; and Sample 53B a faintly mottled light grey dolomite.

Tufa deposits are plentiful in this locality. Sample 53C was taken from a deposit along the highway 1 mile southeast of Glenogle.

Leanchoil

One and one-half miles east of Leanchoil station on the Canadian Pacific railway, where the highway and the railway bend sharply to the north, massive, fine-grained, dark bluish grey limestone regarded as being probably of Cambrian

[1] Daly, R. A.: Geol. Surv., Canada, Mem. 68, p. 76 (1915).

age is exposed. The limestone is mainly of the calcium variety, but it is banded, parallel to the bedding, with fine-grained dolomite that shows on the surface as brown streaks in contrast to the grey weathered surface of the calcium limestone.

Three-quarters of a mile north of the above exposure there is exposed a dove-grey, fine-grained limestone consisting of a calcite groundmass irregularly mottled with very ferruginous dolomite. This limestone is thin-bedded and layers of shale occur between the beds. It is veined with calcite and with rusty dolomitic films containing tiny micaceous scales. A short distance farther north it is overlain by a light grey shale.

Field

At Natural Bridge, 2 miles west of Field, a deposit of very impure limestone consisting of alternate bands of calcium limestone and of dolomitic limestone is exposed in the valley of the Kicking Horse river. On fresh fracture the dolomitic and the calcium limestones are almost indistinguishable, both being very fine-grained and dark blue, but on the weathered surface the dolomitic bands become a reddish brown and form ridges, whereas the calcium limestone weathers grey and as it dissolves more rapidly than the dolomite it forms troughs. The bands of both varieties of limestone are each about 2 to 3 inches thick.

At Field, hard, brittle, fine-grained, black, thin-bedded calcium limestone, dipping at low angles, is exposed in the valley of the Kicking Horse river. The beds range from 2 to 8 inches in thickness. In places they are separated by interbeds of shale, in others shale partings are absent and several beds may be tightly joined together. The limestone weathers to a drab grey and usually has a lined surface. Calcite veins are in evidence in places. Sample 54 was taken west of the town and serves as an indication of the chemical composition of this limestone, which is mapped by Allan[1] as being of Cambrian age. Some sections seem more magnesian than the analysis indicates.

Yoho Valley

A band of greyish white and light blue Cambrian dolomite over 300 feet thick and lying almost horizontally is exposed at the switchback on the Yoho Valley road, about 3 miles north of the Canadian Pacific railway. In 1911 it was staked with the intention of working it for marble, but aside from a small amount of diamond-drilling no further work was done. It contains too many cavities and is too variable in grain size to constitute a high-grade marble. The dolomite varies in colour from greyish white to pale blue, the lighter colour being predominant in the upper part of the band. In places it is faintly mottled and is commonly streaked. The grain varies from coarse in the upper beds to fine in the bluish beds near the base. As shown by the analyses of a series of samples taken from top to bottom of the band, it is uniformly pure dolomite with a rather high content of iron. Most of the iron, however, appears to be present as the carbonate and therefore would not adversely affect the use of the rock for marble. On weathering, the dolomite turns brownish grey. In the coarser-grained upper beds, in particular, are many cavities partly filled with white pearl spar in rhombohedral crystals with curved faces. Crystals of white calcite were observed in some cavities and an occasional narrow vein of milky quartz cuts through the dolomite. The bedding is massive in places and quite thin in others. The band dips northeast at angles of 8 to 15 degrees.

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[1] Allan, J. A.: Geol. Surv., Canada, Mem. 55 (1914)

Allan's[1] measurement of the marble band as here exposed is as follows:

25 feet	white and grey dolomitic marble (massive).
35 feet	white and grey dolomitic marble (shattered).
55 feet	best variety of white dolomitic marble.
100 feet	white marble with many grey spots and containing cavities formed as a result of dolomitization.
40 feet	coarsely crystalline, grey to white dolomitic marble.
15 feet	mottled grey marble with white bands.
6 feet	mottled white marble with grey bands.
20 feet	dark grey, badly shattered.
15 feet	dark grey, with white stringers.
4 feet	dark grey, coarse.
5 feet	light grey to white.
7 feet	bluish, siliceous limestone.
13 feet	mottled and banded with white dolomite.
10 feet	arenaceous limestone containing pyrite crystals.
350 feet.	Total thickness measured.

Sample 55 was taken from the upper 100 feet of coarse-grained, greyish white dolomite; Sample 55A from the next 100 feet of grey, medium-grained dolomite; Sample 55B from the next 50 feet of mottled dolomite; and Sample 55C from the finer-grained, bluish dolomite near the base, and represents a thickness of 50 feet.

Apparently a large quantity of the dolomite is available here as it can be followed for a long distance along the mountainside and is also reported by Allan[2] to occur on Cathedral mountain, Mt. Field, and Mt. Odaray.

Between Yoho and Wapta Lake

Beginning one mile east of where the Yoho river joins the Kicking Horse river, Cambrian limestone is exposed continuously along the highway and railway for 1 mile to Sherbrooke creek and is then exposed at intervals to the west end of Wapta lake, 1 mile farther east.

At the western end of this section, which is the base, the limestone is highly metamorphosed but becomes progressively less so higher up in the section. The beds dip northeast at an angle of 50 degrees. The first limestone seen is pale grey, very fine-grained, and is faintly mottled with pale mauve dolomite that stands out in prominent relief on the weathered surface and is brown in contrast to the grey weathered surface of the high-calcium part of the rock. No siliceous impurities were observed. This type of limestone extends for 400 yards along the highway in the vicinity of the bridge over the Kicking Horse river, just west of Wapta. Sample 56 is representative of this limestone.

This is followed to the east by darker mottled limestones of probably similar composition, with which is interbedded an occasional band of blue dolomite.

One-quarter mile east of the bridge a band of greyish white medium-grained dolomite 60 feet thick is exposed dipping to the northeast at an angle of 50 degrees. This dolomite is identical in appearance with that in the Yoho valley just described. Sample 57 was taken from this dolomite band.

Overlying the white dolomite is 70 feet of dark grey, fine-grained, striped limestone, the striped appearance being due to irregular streaks of pale grey dolomite in the darker high-calcium matrix. The streaks are parallel to the bedding. On the weathered surface the dolomite is rusty brown in contrast to the grey of the matrix. This in turn is overlain by about 70 feet of beds, some of which are dolomite and some high-calcium limestone. From there to

[1] Allan, J. A.: Geol. Surv., Canada, Mem. 55, p. 67 (1914).
[2] Allan, J. A.: Op. cit., p. 67.

Sherbrooke creek the limestone as exposed is shaly and thin-bedded, except that at Sherbrooke creek, which is heavily bedded. It is nearly black and contains much less dolomite than does that just described.

Between Sherbrooke creek and the west end of Wapta lake only a few small outcrops of black mottled limestone were observed.

Hector

East of Hector station on the Canadian Pacific railway, massively bedded, dark blue-grey, fine-grained, mottled limestone is extensively exposed dipping west at an angle of 20 degrees. The mottling is not prominent and the magnesia content is probably not over 5 per cent, in contrast to the 9 per cent in beds at a corresponding geological horizon near Yoho. One mile farther east this limestone is underlain by quartzite.

Analyses of Limestones along the Main Line of the Canadian Pacific Railway between Kamloops and the Alberta Boundary

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
50.......	4·04	0·66	0·59	0·28	92·20	1·58	99·35	0·06	51·78	0·75	69 : 1
51.......	1·32	0·14	0·21	0·33	97·59	0·74	100·33	Nil	54·83	0·35	157 : 1
51A.....	2·22	0·27	0·29	0·39	95·73	1·41	100·31	Tr.	53·82	0·67	80 : 1
52.......	2·44	0·44	0·61	0·20	82·80	14·09	100·58	0·01	46·48	6·74	7 : 1
53.......	1·28	0·28	0·41	0·02	55·71	44·96	101·66	0·01	31·21	21·02	1·48 : 1
53A.....	5·02	0·60	0·43	0·02	52·36	42·96	100·39	0·02	29·33	20·06	1·46 : 1
53B.....	1·10	0·46	0·29	0·02	55·50	43·31	100·68	0·01	31·09	20·71	1·50 : 1
53C.....	0·48	0·11	0·30	0·02	96·24	1·62	98·77	Nil	53·90	0·77	70 : 1
54.......	1·56	0·38	1·44	0·07	86·77	9·58	99·80	0·02	48·63	4·58	11 : 1
55.......	0·46	0·61	0·47	Tr.	55·39	43·84	100·77	Tr.	31·02	20·96	1·47 : 1
55A.....	0·40	0·66	0·26	Tr.	55·12	43·90	100·34	Tr.	30·87	20·99	1·47 : 1
55B.....	0·20	0·44	0·16	0·01	54·02	43·72	98·55	Tr.	30·27	20·92	1·45 : 1
55C.....	0·36	0·95	0·35	0·02	55·00	43·10	99·78	0·03	30·81	20·61	1·49 : 1
56.......	0·26	0·26	0·14	Tr.	91·11	8·74	100·51	Tr.	51·02	4·18	12 : 1
57.......	0·36	0·78	0·35	0·02	55·55	43·71	100·77	Tr.	31·12	20·90	1·49 : 1

50.	Notch Hill.	Ten feet of Sicamous (Precambrian) limestone on the beach at Blind bay.
51.	Salmon Arm.	White and bluish white Precambrian limestone in northwest end of ridge on property of W.E. Meek.
51A.	"	Sample representing the whole ridge at the same place.
52.	Albert Canyon.	Fifty-foot band of Precambrian limestone.
53.	Glenogle.	Light grey Palæozoic dolomite.
53A.	"	Dark grey Palæozoic dolomite containing chert.
53B.	"	Faintly mottled, light grey Palæozoic dolomite.
53C.	"	Calcareous tufa on highway 1 mile southeast of the station.
54.	Field.	Black calcium limestone of Cambrian age in valley of Kicking Horse river west of the town.
55.	Yoho Valley.	Top 100-foot thickness of greyish white Cambrian dolomite on Yoho Valley road 3 miles north of Canadian Pacific railway.
55A.	"	Next 100 feet of grey dolomite.
55B.	"	Next 50 feet of mottled dolomite.
55C.	"	Fifty feet of bluish dolomite near the base of the exposure.
56.	Wapta.	Grey mottled Cambrian limestone near bridge over Kicking Horse river, just west of Wapta.
57.	"	Greyish white Cambrian dolomite ¼ mile east of the bridge over the Kicking Horse river.

Kettle Valley Branch of the Canadian Pacific Railway

In crossing the province from Hope to the Alberta boundary this railway traverses a complete cross-section of the main rock formations of the province. Limestone deposits are relatively common from Princeton eastward. They are predominantly of the calcium type and for the most part are only moderately pure. No true dolomite is found in the area tributary to the line, except for certain narrow bands in Precambrian limestone deposits near Procter and in a siliceous deposit on the east side of Kootenay lake, opposite Procter. The latter deposit is dealt with in the section treating of Kootenay Lake limestones. All the deposits examined, except those in the vicinity of Kootenay lake and Moyie lake, are probably of Carboniferous age although many of the limestones are so metamorphosed that they have no resemblance to the normal Carboniferous limestone, and all fossils have been obliterated, thus rendering positive identification difficult. Certain lithological and chemical characteristics indicate, however, that they are of Carboniferous age.

At present only one quarry is in operation along this line and that is at Fife, where the limestone is being quarried for flux for use in the Trail smelter. In the past, lime was produced from a number of the deposits and quarries were opened to obtain material for Portland cement and for building stone and marble.

Princeton

Lenses of siliceous, bluish grey, Carboniferous limestone associated with argillite, quartzite, and volcanic rocks occur 2½ miles southeast of Princeton. In 1912 a cement plant was built near Princeton to use this limestone together with local clay. However, the lenticular occurrence of the limestone necessitated the quarrying of several tons of rock to obtain one ton of limestone and the venture was abandoned in 1914. An analysis of what was reported to be the best grade of limestone is as follows:

	Per cent
Insoluble	9·5
Oxides of iron and alumina	1·4
Calcium carbonate	88·0
Magnesium carbonate	1·3
Total	100·2

Three samples from small deposits in this neighbourhood, analysed for calcium carbonate only, contained 89·8, 77·6, and 53·8 per cent of that constituent.

Hedley

Nickel Plate mountain at Hedley is composed largely of Carboniferous limestone resting on a base of granodiorite. All through the limestone are numerous sills of igneous rock, many of which follow bedding planes. The limestone is of varying degrees of purity. Most of it is light blue, medium-grained. and massively bedded. Much of it is cherty and otherwise siliceous, but there are bands that are fairly pure. A number of years ago lime for use in the mill of Hedley Gold Mining Company, Limited was made from the purer limestone available. The quarry was 500 feet up on the west face of Nickel Plate mountain, just above the contact between the granodiorite and the limestone. It was worked mostly in a 30-foot band, underlying which is an impure, light blue limestone containing numerous interbeds of a ferruginous igneous rock. The 30-foot band is overlain by 10 feet of siliceous limestone, which in turn is overlain by a thickness of 35 feet of rather impure limestone containing nodules of hard blue chert and narrow seams of ferruginous igneous rock. All the strata dip diagonally down the mountain at an angle of 25 degrees. The mountain is composed of a similar succession of limestone beds, sandwiched in between which are sills of igneous rock. Some vertical dykes of a different type of igneous rock to that composing the sills also cut the limestone. Two samples were taken: Sample 58 from the 30-foot band formerly quarried; and Sample 58A from the 35-foot band of cherty limestone overlying it.

Across the Similkameen river from Nickel Plate mountain, at a place opposite the mining company's dam, similar limestone having an almost vertical dip is exposed on the mountainside. Bands of highly altered siliceous limestone alternate with bands of moderately pure limestone up to 30 feet thick, and dykes of igneous rock cut through both types, although these dykes are not so numerous as on Nickel Plate mountain.

Bradshaw

At Shoemaker creek, 3 miles south of Bradshaw, a band of fine-grained, light blue calcium limestone, in places filled with blue chert and in other places free from chert, occurs far up on the mountain.

Keremeos

Impure limestone bands occur in a number of places in the mountains in the vicinity of Keremeos and between there and Hedley. Seven miles north of Keremeos and on the east side of the road to Penticton, a prominent band of greyish white limestone is reported to occur on the mountain about 1,000 feet above the road. On the west side of the road opposite this deposit a dark blue siliceous limestone is exposed and was formerly used for making lime. Another band of bluish white, impure calcium limestone occurs on the north side of Winters creek not far from the highway.

Bridesville

Lime was made at one time at Bridesville from a deposit of siliceous grey limestone on the mountainside. The rock is covered deeply with soil and very little is visible.

Rock Creek

One and three-quarter miles east of Rock Creek bluish white calcium limestone carrying a network of thin silica veins is exposed on the property of Owen Wheeler. Apparently it is only a small deposit.

Midway

Four miles west of Midway, outcrops of Palæozoic siliceous and argillaceous calcium limestone extend from the Kettle river to near the top of a hill north of the Canadian Pacific railway. At the top of the hill, which is about 400 feet high, the limestone is capped by igneous rock. Along the railway the limestone is exposed at intervals for a distance of 600 yards. Most of the outcrops consist of fine-grained, blue, cherty, calcium limestone much intersected by dykes of igneous rock. The limestone is also divided by numerous cracks and for $\frac{1}{4}$ to $\frac{1}{2}$ inch on either side of many of the cracks it is white. On the hillside most of the limestone is pale blue to greyish white and is of better grade than near the railway, the chert not being so noticeable, but it is cut by a number of igneous dykes. Sample 59 was taken from the better grade limestone exposed on the hillside.

Boundary Falls

A small deposit of bluish white calcium limestone, $\frac{1}{2}$ mile northeast of Boundary Falls, was at one time used for making lime. The deposit is almost worked out.

Along the Canadian Pacific railway, $\frac{1}{3}$ mile north of the old smelter site at Boundary Falls, is a mass of pale blue, hard, fine-grained dolomite, 200 feet long by 75 feet wide, enclosed in igneous rock. It was quarried at one time on a small scale for making lime in a nearby pot kiln. The deposit appeared so small that no sample was taken.

Eholt

Limestone deposits of many degrees of purity are numerous in the vicinity of the old mining camp of Summit City, south of Eholt station.

Fine-grained, brittle, light grey, siliceous, Palæozoic, calcium limestone that tends to break into small angular fragments and contains streaks in which crystals of pyrite are very numerous is exposed in cuttings along the old railroad, about ½ mile south of the Oro Denoro mine. It strikes north and south and dips east at a steep angle. Sample 60 represents the average grade of limestone. Other outcrops of this band appear at intervals for more than a mile south of where the sample was taken. One-half mile west of this is another large area of limestone.

North of Summit City and about 1¼ miles due south of Eholt station, comparatively pure limestone forms a hill about 400 feet high. The limestone is coarse-grained, massively bedded, mostly white, and is of the high-calcium type. It strikes nearly north and south and dips almost vertically. On both the eastern and western flanks of the hill the limestone is siliceous and cherty, but in the central part it is of a good grade of purity, except for some occasional thin siliceous streaks. It is intersected by a few igneous dykes. Toward the western side the limestone is pale blue, but elsewhere it is white. A measured section from west to east across the deposit, near the top of the hill, is as follows:

60 feet—Blue, coarse-grained limestone.
3 feet—Fine-grained siliceous limestone.
47 feet—White, coarse-grained limestone with an igneous dyke 6 inches wide on the east side.
4 feet—Fine-grained, cherty, white limestone.
100 feet—White, coarse-grained limestone.
4 feet—Fine-grained siliceous limestone.
35 feet—White, coarse-grained limestone that is cut by an igneous dyke. Then, siliceous limestone.

This section would be different if measured elsewhere, but it gives a general idea of the deposit. Sample 61 was taken across the band of pure limestone on the southern face of the hill. The soil covering is thin and the deposit is in a favourable position for quarrying.

Four miles east of Eholt, and about 1 mile south of where the Kettle Valley branch of the Canadian Pacific railway turns south along the Granby river, is a large area of blue calcium limestone, most of which is siliceous. At Mileage 104 on the railway the limestone is exposed in twisted, broken beds. It is fine-grained, dark blue in colour, and is intruded by a number of igneous dykes. As shown by the analysis of Sample 62 taken here from 40 feet of beds, the limestone is highly siliceous. Similar limestone is seen along the track for a considerable distance.

Downhill, towards the highway and the river, is a small quarry once worked for marble. This is about 300 feet below the railway and 200 yards south of Lime creek. The limestone in the vicinity of the quarry is pinkish white and has a sugary texture. It contains inclusions of other rock, nodules of chert, and igneous dykes, and in places has a brecciated appearance. The light colour is possibly due to a large intrusion of granodiorite nearby. Sample 63 was taken in the quarry and vicinity, but none of the inclusions or chert nodules were included.

South, along the railway, the limestone is very siliceous. Sample 64 was taken from dove-grey and blue-grey, fine-grained limestone containing rusty streaks, as exposed at Mileage 103¼ where it ends.

Grand Forks

A number of deposits of Palæozoic limestone, some of them large and comparatively pure, occur in the neighbourhood of Smelter lake northwest of Grand Forks. One of these is exposed in a cut at Mileage 99 on the Canadian Pacific railway, about 1 mile northwest of Smelter lake. At this place a fine-grained, blue limestone veined with white calcite occurs along the railway for 500 feet. It is cut by igneous dykes and contains numerous small particles of silica or silicates and nodules of chert. No sample was taken.

Less than 1 mile southwest of Smelter lake, or about 2 miles northwest of Grand Forks, blue, fine-grained calcium limestone veined with white calcite is exposed extensively in the vicinity of Hardy creek, where it was quarried on a small scale for making lime many years ago. Small angular lumps of silica are distributed throughout the limestone and large nodules of hard, blue chert are common in certain bands throughout the deposit. North of the creek, dykes of green igneous rock are plentiful in the limestone, but are less in evidence south of the creek. North of the creek, the limestone can be traced due north along the side of the mountain for more than a mile, and is said to continue on to the top of Hardy mountain. South of the creek, the limestone extends almost due west for 2 miles and then turns northerly along the side of Eagle mountain for 1 mile. Two samples were taken at Hardy creek, Sample 65 in the small quarry and from neighbouring outcrops, and Sample 65A across 800 feet of limestone exposed north of the creek. In neither case were the chert nodules included. It is difficult to ascertain the dip and strike of this metamorphosed limestone, but in the quarry it apparently dips east, or down the mountainside at an angle of 60 degrees. The distance from the quarry to the railway is $\frac{3}{4}$ mile, but the railway passes within $\frac{1}{4}$ mile of and below the limestone north of Hardy creek.

The western extension of this band, where seen on Eagle mountain, consists of very similar limestone to that to the east but it is less pure and is lighter in colour, some being white. The limestone is thin-bedded and a thick sill of diabase intrudes it about midway up the mountain. The strike is N. 60° W. and the dip is into the mountainside, or to the northeast, at angles of from 30 to 60 degrees. The limestone undoubtedly covers a large area, but its boundaries could not be determined on account of the overburden. Sample 66 was taken from numerous outcrops on the southwest side of Eagle mountain.

Three miles east of Grand Forks a deposit of interbanded dolomite and calcium limestone occurs just north of the highway and railway. The deposit is on the south slope of a mountain and the exposures extend for more than $\frac{1}{2}$ mile. The strike and dip of the strata are extremely variable. Most of the calcium limestone is white and medium-grained, whereas the dolomite, though white, is coarse-grained. On the weathered surface the dolomite is brown and the calcium limestone is grey. The dolomite and the calcium limestone contain numerous grains of a yellow mineral, flakes of yellow mica, and fragments and veins of quartz. Interbanded throughout the deposit are masses of schist, such as composes the country rock, and the entire mass is cut by dykes of igneous rock. The dykes apparently have not caused the dolomitization of parts of the deposit, because they cut across the banding and in many places are in contact with the calcium limestone, without causing any change in the composition of the latter unless it be a slight silicification in some places. There is more dolomite in the western than in the eastern end of the deposit. Two small quarries were at one time worked in this most unpromising deposit, one for building stone and the other for stone for making lime in two pot kilns. Both quarries are in the sides of a gully cutting across the deposit.

PLATE XXXV

A. Quarries formerly worked for flux near Fife, B.C. Christina lake is in the background.

B. Carboniferous limestone cut by dykes of igneous rock in old quarry near Fife, B.C.

Fife

Consolidated Mining and Smelting Company of Canada, Limited obtains flux for its smelter at Trail from a band of Carboniferous limestone that extends northerly for 2½ miles from a point about ½ mile north of Fife station on the Canadian Pacific railway. The band is from 400 to 800 feet thick and dips vertically. It begins on top of the cliff above Christina lake and extends northerly from there. The railway passes over the band about 400 yards from its southern end and most of the band lies east of the track. There are few outcrops and the limestone is best examined in the old quarries opened at the extreme south end of the band, west of the railway. Two of these quarries are opened nearly parallel to each other and separated by 150 to 250 feet of highly siliceous limestone. The larger quarry is on the west and is 1,000 feet long, 200 feet wide, and has a face 175 feet high at the highest point. The limestone exposed is grey to pale blue, and medium- to fine-grained. Bedding is indistinct, and the limestone tends to break into small pieces because of the folding and faulting. On both edges of the band the limestone in contact with the enclosing volcanic rock is highly siliceous and there are zones throughout the band in which are lenses of siliceous limestone and nodules of hard blue chert. Contorted dykes of green igneous rock intrude the deposit. Plate XXXV A, page 196, shows the quarries with Christina lake in the background, and Plate XXXV B, page 196, shows the nature of the limestone and some of the contorted dykes of igneous rock that occur in it.

The limestone is being won by the "glory hole" method and is produced under contract by Messrs. M. Agostinelli and F. Vannuchi. Present workings are ½ mile north of Fife station and on the east side of the railway. Cars holding about 3 tons of rock are loaded from the chutes at the end of a tunnel beneath the glory hole and are pushed through the tunnel and dumped into a loading bin adjacent to and above a siding. The rock is loaded into gondola cars from the loading bin for shipment to Trail. There is no crusher at the deposit. The limestone tends to break into relatively small fragments on blasting.

Until 1943 the limestone was obtained from several glory holes on the same band, 1 mile north of Fife station. These glory holes were 200 feet in diameter and 200 feet deep. They were all connected by a tunnel 900 feet in length, driven into the hillside 600 feet above the track. An inclined railway with cable cars was used to take the rock down to the Canadian Pacific railway from the rock bins at the tunnel entrance. The limestone band at this place is 800 feet wide. Sample 67 was obtained from limestone on the sides of the glory holes and from outcrops between them. It represents much purer rock than is shipped from the property, because the glory-hole system offers no opportunity for sorting, and siliceous bands as well as stone from igneous dykes are included in the shipments. An anaylsis supplied by the company as being representative of the shipments is as follows:

	Per cent
Silica	6·5
Ferric oxide	0·3
Alumina	0·1
Calcium oxide	51·0
Magnesium oxide	0·3
Loss on ignition	41·5
Total	99·7

Another band of blue limestone containing much chert and other siliceous matter parallels the main band to the northwest. It is very impure and is apparently small.

Coryell

Siliceous, blue limestone enclosed in volcanic rock and penetrated by many volcanic dykes is exposed in a number of places along the "Molly Gibson" road on the mountainside west of Coryell. It is apparently all of the calcium type, with a very low content of magnesium carbonate.

Procter

On the west shore of Kootenay lake, a few hundred yards southeast of Procter, a steeply dipping band of white Precambrian limestone much intermingled with schists and other rocks is exposed and was quarried many years ago for flux. The limestone consists in part of the calcium variety and in part of dolomite, the two types being interbanded. On the weathered surface of the deposit the dolomite stands up in ridges ¼ to 4 inches wide (Plate XXXVI A, page 199). Flakes of light brown mica and graphite occur in places in the calcium limestone.

On the same side of the lake, 1½ miles southeast of Procter, another band of white and bluish white Precambrian limestone, 30 to 50 feet wide, enclosed in schist, is exposed along the railway at the shore of the lake and can be traced up the steep side of the mountain. The band strikes S. 25° W. and dips northwest at an angle of 30 degrees. It is composed in part of calcium limestone and in part of dolomite, the two types of limestone being interbanded as in the deposit near Procter. Veins of white quartz cut across the limestone in places and some silicate minerals are also developed.

In 1937, Consolidated Mining and Smelting Company of Canada, Limited drove a tunnel 1,000 feet into this band with the intention of working it by shrinkage stoping as a source of flux for its Trail smelter, but there has been no production to date, aside from the limestone obtained during development work. Sample 68 was taken at various places along the tunnel.

Three hundred feet south, another and thinner band of Precambrian limestone is exposed.

Four miles southwest of Procter a band of very impure Precambrian dolomite is exposed on the lake shore. It is possibly the extension of the band of similar dolomite exposed at Pilot point on the east shore of the lake and described on page 212.

Jerome

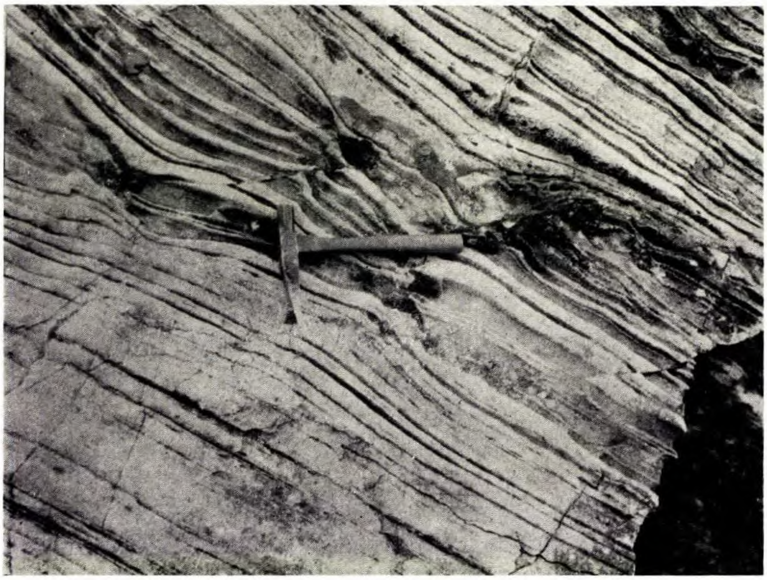
Impure, brown-weathering, grey Cambrian limestone in beds 6 to 12 inches thick, associated with quartzite and argillite, is exposed at the railway tunnel at Jerome at the head of Upper Moyie lake.

Wardner

Carboniferous limestone, ranging in composition from the pure high-calcium variety to a highly magnesian type, is available over a large area on both sides of the Kootenay river, from 4 miles southeast of Wardner to 4 miles northeast of the town. The area is traversed by the Kettle Valley branch of the Canadian Pacific railway and by the Cranbrook-Lake Windermere branch of the same railway. Numerous good exposures occur along the railway lines and on the hillsides above the old river terraces of gravel that are present in the valley. Some of the limestone is of a good grade but much of it is cherty and contains interbedded shale.

Four miles north of the town a ridge of pure, coarse-grained, light grey limestone only lightly covered with soil occurs on the southwest side of the river and the railway. Sample 69 was taken here from a series of outcrops. Possibly some chert occurs in the covered places between the outcrops.

PLATE XXXVI



A. Interbedded high-calcium limestone and dolomite of Precambrian age, near Procter, B.C. The dolomite bands stand out in relief.

B. Thinly bedded Carboniferous limestone in railway cut at Wardner, B.C.

The limestone is well exposed in the railway cuttings on the Kettle Valley railway north of the town. In the next to the last cutting, 4 miles north of Wardner, it strikes N. 45° W. and dips northeast at an angle of 20 degrees. At the northern end of the cut is coarse-grained, soft, grey magnesian limestone in a band 24 feet thick and exposed for a horizontal distance of 180 feet. This is underlain by an earthy, crumbly, brown limestone having a much higher content of magnesium carbonate than the overlying rock. It has a thickness of 17 feet and is seen for a distance of 100 feet along the track. The crumbly earthy appearance may be due to weathering, as in places the crumbly stone passes into solid rock. Beneath this is 12 feet of solid, grey, medium- to coarse-grained high-calcium limestone showing for 75 feet, which in turn is underlain by brown magnesian limestone to the end of the cut, or a distance of 60 feet. Samples were taken from each band in the cut as follows: Sample 70 from the 24 feet of grey magnesian limestone; Sample 70A from the crumbly magnesian limestone; Sample 70B from the 11 feet of coarse-grained, grey high-calcium limestone; and Sample 70C from the magnesian limestone at the southern end of the cut. As the analyses show, most of the limestone is low in silica, but with the exception of one band it is sufficiently high in magnesium carbonate to put it into the magnesian limestone class. This is due to the presence of minute crystals of dolomite scattered throughout the calcite matrix.

Most of the limestone exposed in the other cuttings north of Wardner contains much hard, blue chert. Interbedded with the cherty stone are bands of relatively pure limestone, much of which is lower in magnesium carbonate than is the limestone described above. Sample 70D was taken from a 12-foot band of limestone overlain and underlain by extremely cherty limestone.

Two miles north of Wardner, two lime kilns have been cut out of the solid limestone that forms a cliff adjacent to the railway track, but they have not been in use for many years. The limestone for burning was obtained from a small quarry back of the kilns. The limestone in this immediate vicinity contains much chert. It strikes N. 40° E. and dips vertically. Farther north, it is free from chert and is of good quality, as shown by the analysis of Sample 71, taken along the face of a hill about 200 feet high near the railway. This limestone is brownish grey, fine-grained, and is in indistinct, broken beds.

One-half mile north of the kilns is a mass of yellowish brown, sugary textured, impure magnesian limestone mixed with white calcite, the extent of which cannot be determined. Sample 72 was taken from this limestone.

In the town of Wardner, the limestone, as seen at the end of the highway bridge, is studded with chert and interbedded with shale.

On the east side of Kootenay river, 1½ miles upstream from the highway bridge, is a hill of Carboniferous limestone 300 feet high. On the southeast side of the hill most of the outcrops are coarse-grained, light brownish grey high-calcium limestone. On the opposite side of the hill the limestone exposed is finer grained and darker and contains some silicified fossils and blue chert. The limestone is much broken and this, together with the absence of large continuous exposures, makes it difficult to ascertain with certainty the strike and dip of the strata, but apparently the dip is south. Three samples were taken: Sample 73 from the coarse-grained limestone at the bottom of the hill on the southeast side; Sample 73A from about midway up the hill also on the southeast side; and Sample 73B from the fine-grained, dark grey limestone on the northwest slope, but excluding any chert nodules.

Outcrops of Carboniferous limestone occur all along the east side of the Kootenay river to beyond Bull river. In general it is very similar to that on the west side of the Kootenay river, but it is much broken and is not so well situated for quarrying, largely because the overburden is much heavier.

South of Wardner most of the limestone adjacent to the railway is very fine-grained, dark blue, and consists in part of bands with fine mottlings of brown-weathering magnesian material. Much of the limestone is thin-bedded (Plate XXXVI B, page 199) and much fractured, but the mottled variety, as seen in the railway cut nearest the bridge, is almost massive. Sample 74 was taken from the mottled limestone exposed in the cutting. This stone is overlain and underlain by the unmottled variety. The upper beds of the thin-bedded limestone have very thin partings of shale, but these are absent in the lower beds.

On the east side of the river and south of Wardner, the same fine-grained, dark grey, high-calcium limestone is exposed, striking east and west and dipping south at angles between 30 and 40 degrees. The beds are 2 to 6 inches in thickness and are somewhat uneven.

Elko

Three miles east of Elko, fine-grained, bluish grey and brownish grey calcium limestone of Carboniferous age, thickly studded with chert, is exposed at intervals for a mile adjacent to the railway. The dip and strike of the strata vary from place to place.

Morrissey

One-half mile south of Morrissey the railway passes close to a mountain largely composed of Carboniferous limestone. Near the base of this mountain is a band of fine-grained, dark bluish grey high-calcium limestone 100 feet thick. The band dips into the mountain and is overlain by very cherty, impure limestone and thus can be won only by underground mining. Judging from the talus along the foot of the mountain, there are other bands of pure limestone higher up, but as they alternate with bands of impure limestone, and as all dip into the mountain, large-scale quarrying of limestone of uniform composition would be impossible.

Fernie

South of Fernie the Rocky mountains are largely composed of Carboniferous limestone, but little if any of it is in a favourable position for quarrying.

Loop

Beginning 1 mile east of Loop station on the Canadian Pacific railway, medium- and fine-grained, grey calcium limestone of Carboniferous age is exposed along the railway for $\frac{3}{4}$ mile. It dips westward at various angles. At the western end of the outcrops the limestone appears to be of the high-calcium type, with only an occasional magnesian band and an occasional cherty streak. Toward the east, however, the magnesian and the cherty bands become increasingly plentiful and beds of shale appear. Conditions are not favourable for quarrying, and no samples were taken.

Analyses of Limestones along the Kettle Valley Branch of the Canadian Pacific Railway, from Hope to the Alberta Boundary

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
58.......	2·90	0·29	0·29	0·20	93·43	2·83	99·97	0·01	52·43	1·37	39 : 1
58A.....	5·70	0·26	0·54	0·24	92·75	0·68	100·17	0·05	52·07	0·23	226 : 1
59.......	7·45	0·64	7·80	0·31	82·04	1·39	99·63	0·04	46·11	0·66	70 : 1
60.......	5·70	0·39	0·42	0·20	91·57	1·41	99·69	0·04	51·39	0·67	77 : 1
61.......	2·58	0·38	0·04	0·15	96·77	0·38	100·30	0·01	54·27	0·18	302 : 1
62.......	16·38	0·46	0·97	0·02	80·45	1·51	99·79	0·22	45·06	0·72	63 : 1
63.......	4·80	0·35	0·52	0·20	92·82	1·68	100·37	Tr.	52·09	0·80	65 : 1
64.......	13·68	0·51	0·67	0·13	83·57	1·47	100·03	Tr.	46·87	0·70	67 : 1
65.......	2·12	0·12	0·18	0·13	96·36	1·22	100·13	Tr.	54·03	0·58	93 : 1
65A.....	3·70	0·16	0·17	0·11	94·70	1·34	100·18	Tr.	53·09	0·64	83 : 1
66.......	8·60	0·48	0·87	0·20	88·04	1·41	99·60	Tr.	49·41	0·67	74 : 1
67.......	2·72	0·16	0·08	0·07	96·11	0·53	99·67	Tr.	53·86	0·25	215 : 1
68.......	5·61	0·26	0·20	0·04	78·85	15·35	100·31	0·02	44·18	7·34	6·0 : 1
69.......	0·14	0·07	0·09	0·09	93·59	5·80	99·78	Tr.	52·46	2·77	19 : 1
70.......	0·54	0·16	0·20	0·09	83·61	16·02	100·62	Tr.	46·87	7·66	6·1 : 1
70A.....	1·92	0·26	0·24	0·13	68·89	28·67	100·11	Tr.	38·65	13·71	2·8 : 1
70B.....	0·48	0·18	0·02	0·13	98·06	1·00	99·87	Tr.	54·98	0·48	115 : 1
70C.....	1·28	0·12	0·16	0·13	84·00	14·79	100·48	Tr.	47·11	7·07	6·7 : 1
70D.....	0·88	0·08	0·17	0·15	91·73	6·69	99·70	Nil	51·45	3·20	16 : 1
71.......	0·94	0·33	0·23	0·04	97·14	1·11	99·79	0·02	54·41	0·53	103 : 1
72.......	7·48	0·55	0·55	0·35	53·89	37·70	100·52	Tr.	30·37	18·03	1·68 : 1
73.......	1·04	0·06	0·24	0·13	95·71	3·12	100·30	Nil	53·67	1·49	36 : 1
73A.....	0·38	0·06	0·12	0·11	98·53	0·61	99·81	Nil	55·24	0·29	190 : 1
73B.....	1·50	0·07	0·37	Tr.	97·09	0·92	99·95	Nil	54·37	0·44	124 : 1
74.......	2·04	0·16	0·40	0·13	84·25	13·21	100·19	Tr.	47·25	6·32	7·5 : 1

58.	Hedley.	Thirty-foot band of Carboniferous limestone formerly quarried for lime.
58A.	"	Thirty-five foot band of cherty limestone overlying the above.
59.	Midway.	Better grade of Palæozoic limestone exposed on the hillside 4 miles west of Midway.
60.	Eholt.	Palæozoic limestone ½ mile south of the old Oro Denoro mine.
61.	"	Best grade of Palæozoic limestone 1¼ miles due south of Eholt station.
62.	"	Siliceous, blue Palæozoic limestone in cutting at Mile 104 on the railway.
63.	"	Palæozoic limestone in small quarry below the railway and 200 yards south of Lime creek.
64.	"	Palæozoic limestone exposed at Mile 103¼.
65.	Grand Forks.	Palæozoic limestone in small quarry at Hardy creek, 2 miles northwest of Grand Forks.
65A.	"	Eight hundred feet of Palæozoic limestone strata north of Hardy creek.
66.	"	Palæozoic limestone on southwest side of Eagle mountain.
67.	Fife.	Carboniferous limestone quarried by Consolidated Mining and Smelting Company of Canada, Limited, 1 mile north of Fife station.
68.	Procter.	Precambrian limestone from property owned by Consolidated Mining and Smelting Company of Canada, Limited, on the west shore of Kootenay lake, 1½ miles southeast of Procter.
69.	Wardner.	Ridge of pure, coarse-grained Carboniferous limestone, 4 miles north of the town.
70.	"	Twenty-four feet of grey magnesian Carboniferous limestone at northern end of railway cutting, 4 miles north of the town.
70A.	"	Crumbly magnesian Carboniferous limestone underlying the grey magnesian limestone.
70B.	"	Eleven-foot thickness of high-calcium Carboniferous limestone underlying the magnesian limestone.
70C.	"	Magnesian Carboniferous limestone at the southern end of the cutting.
70D.	"	Twelve-foot band of pure Carboniferous limestone overlain and underlain by cherty limestone in railway cut 3½ miles north of Wardner.
71.	"	Face of hill of Carboniferous limestone 2 miles north of Wardner.
72.	"	Magnesian Carboniferous limestone exposed ½ mile north of old lime kilns to the north of the town.
73.	"	East side of Kootenay river, 1½ miles north of the town; coarse-grained limestone at base of hill.
73A.	"	Same locality; midway up the hill.
73B.	"	Same locality; fine-grained limestone on northwest slope of the hill.
74.	"	Mottled Carboniferous limestone just south of the town.

PLATE XXXVII

A. Much fractured Carboniferous limestone in railway cut at Wardner, B.C.

B. Palæozoic limestone exposed near Armstrong, B.C.

Okanagan Valley

Palæozoic limestone deposits occur in a number of localities in the Okanagan valley, the principal deposits being in the northern part of the valley in the vicinity of Armstrong. They are somewhat siliceous, but contain little magnesium carbonate. They occur as bands dipping at various angles, are much metamorphosed, and some are intersected by igneous dykes. Several of the deposits were worked in the past to obtain stone for making lime, and between Armstrong and Enderby a plant was in operation a number of years ago grinding limestone for use on farmland. In addition to the limestone a number of deposits of marl are reported to occur in the district.

Armstrong

Several deposits of Palæozoic calcium limestone with a very low content of magnesium carbonate occur in the vicinity of Armstrong and have been worked on a small scale at various times to supply lime and agricultural limestone.

On what is known as the Mason property at Knob Hill, 4 miles northwest of Armstrong, a band of white and pinkish, fine- to medium-grained high-calcium limestone is exposed. The band strikes N. 65° W. and dips southwest at an average angle of 30 degrees. Outcrops occur across a width of 180 feet at right angles to the strike. The limestone is in beds 2 to 6 inches thick, between many of which are thin sheets of a schistose rock. Several vertical dykes of igneous rock were also observed in the deposit. A small quarry to obtain stone for making lime in a pot kiln, now in ruins, has been opened at the base of a low hill on the property. Sample 75 was taken from the limestone exposed in the quarry and in adjacent outcrops. None of the intercalated schist was included and the sample represents the purest rock that can be obtained.

One mile west of the Mason property, on the property of Gordon Maw, blue-and-white, medium-grained calcium limestone of Palæozoic age is exposed in nearly horizontal beds to a thickness of 50 feet. It can be traced west for ½ mile and outcrops are visible on top of the hill on the property for 300 yards north and south. On the eastern face of the hill, and just south of Mr. Maw's house, the limestone is exposed in a 12-foot cliff part way up the hill and just above the road. There is little overburden on the hill. The limestone is thin-bedded and has schistose material between some of the beds, many of which are so tightly joined that the limestone has a massive appearance in the outcrop. Sample 76 is representative of the limestone exposed on the property. Both of these deposits northwest of Armstrong are not far from the branch of the Canadian National railway running between Armstrong and Ducks (near Kamloops).

Three and one-half miles northeast of Armstrong, on lot 989, on the back road from Armstrong to Enderby, a moderately coarse-grained, grey Palæozoic limestone streaked with blue is exposed on the west slope of a hill, where it was quarried a number of years ago for agricultural use by *Land Limes, Limited,* and prior to that it was utilized on a small scale for making lime. The limestone band strikes N. 75° E. and dips northwest at an angle of 75 degrees. As seen in the small quarry that is opened on the bank of Christian creek, the limestone band is at least 25 and may be 50 feet thick. It is in sharp contact with slate on the southern side, but the northern edge is not visible. The limestone is in beds up to 18 inches thick and between some, particularly those near the slate contact, is a development of silicate minerals. There is an abundance of tiny crystals of pyrite in some of the limestone and such beds weather to a rusty colour. Most of the deposit is covered with soil that supports a thick growth of bushes, and there are few outcrops. The analysis of a sample taken from the pulverized limestone in the bins is given as No. 77 in the table on page 205.

The small plant in which poultry grit and limestone flour for use in correcting soil acidity were made is 200 feet from the quarry and is connected with it by a narrow-gauge tramway. The equipment used consisted of a 20 h.p. semi-diesel engine, a small jaw crusher, and a rod mill.

Grindrod

An apparently large deposit of crumbly calcareous tufa occurs 1¾ miles from Grindrod along the Salmon Arm road and just north of the Enderby road. No sample was taken.

Between Grindrod and Mara, and also southeast of Mara, siliceous limestone containing much quartz and numerous veins of intrusive granite is exposed along the road.

Oliver

Several small deposits of limestone are reported to occur near Oliver. One of these at Fairview was quarried on a small scale to obtain stone for making lime for use in the Joe Dandy mine when it was in operation.

Vernon

Calcium limestone is reported to occur on the shore of Okanagan lake near Vernon, and several other deposits of limestone and of marl are reported to occur near the town.

Long Lake

White to grey, high-calcium limestone is reported to be available in quantity around the head of Long lake and between it and Okanagan lake.

Mission

On the west side of Okanagan lake, several miles above the Mission, several beds of relatively impure, grey, fine-grained limestone are exposed along the road.

Peachland

Several small deposits of calcium limestone are reported to occur in this vicinity.

Analyses of Okanagan Valley Limestones

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
75.......	1·10	0·10	0·23	0·02	98·27	0·50	100·22	Nil	55·04	0·24	229 : 1
76.......	4·26	0·27	0·39	0·04	94·23	0·59	99·78	Nil	52·79	0·28	189 : 1
77.......	3·74	0·93	0·27	0·13	94·20	0·63	99·90	0·10	52·84	0·30	176 : 1

75. Armstrong. Palæozoic limestone in small quarry on the Mason property.
76. " Palæozoic limestone on property of Gordon Maw.
77. " Pulverized Palæozoic limestone from the bins of a mill formerly operated by Land Limes, Limited.

Arrow Lakes and Columbia River

Only a few limestone deposits have been reported as occurring close to the Arrow lakes and in the valley of the Columbia river near where it enters and leaves the lakes. Among them are the deposits near Sidmouth, just above Upper Arrow lake; on the west shore of Upper Arrow lake, 2 miles below Pingston creek; near Deer Park mountain, on Lower Arrow lake; and in the vicinity of Waneta on the Columbia river just north of the International Boundary.

Sidmouth

Pure, coarse-grained high-calcium limestone, most of it white and some with a bluish tinge, is exposed on the side of the mountain immediately northeast of the village of Sidmouth, north of Arrowhead on the Columbia river, just above Upper Arrow lake. The limestone is probably of Carboniferous age and comprises a band at least 100 feet thick that strikes north and south and dips east at angles ranging from 35 to 50 degrees. It is overlain by a dark green amphibolitic schist, but the lower contact was not seen. Wallace creek cuts through the limestone band and exposes a good section. With the exception of a 4-foot band of fine-grained, yellowish, magnesian limestone about the centre of the exposed part of the deposit, all the limestone is of the high-calcium type, as is shown by the analysis of Sample 78, taken across the band but omitting the magnesian streak. The band forms the lower face of the mountain for a distance of ¼ mile and thus is in a good position for quarrying. Along the top of the limestone cliff, however, there is rarely more than 50 feet of limestone before the schist is reached, as it has been eroded away.

Another deposit of limestone is reported to occur 3 miles up the Columbia river and on the west side just east of where the Begbie trail crosses the mountain. The limestone is reported to be not far from the river, but there are no transportation facilities.

Broadwater

A band of siliceous limestone low in magnesium carbonate, and much cut by volcanic rock, outcrops in a cove at Broadwater on the east side of Lower Arrow lake, on the north side of Deer Park mountain. The band varies in width, but where measured it was 500 feet across, following the contour of the ground. It strikes N. 65° E. and dips southeast at an angle of 55 degrees. It can be followed to the east up the mountainside and is reported to extend for 5 miles in that direction and to become much wider. The limestone was quarried on a small scale many years ago for making lime. It is blue and blue-and-white striped, and medium to coarse in grain. Throughout most of it is a considerable development of silicate minerals and of pyrite. The silicates are particularly noticeable in the southern part of the deposit. Dykes of igneous rock are numerous and cut through the limestone in all directions. Two samples of the better grade of limestone available in the deposit were taken, Sample 79 from a 25-foot width between igneous rocks on the northern side of the band, and Sample 79A from a 20-foot width in the small quarry 150 feet from the southern edge of the band. The remainder of the limestone is more siliceous than that sampled.

Waneta

A short distance north of the Canadian customs house at Waneta, beds of dark blue, fine-grained, grey-weathering Precambrian limestone, alternating with beds of light grey shale or schist having a micaceous sheen, are exposed along the road to Salmo and also form a cliff 150 feet in height on the west side of the road. The strata strike N. 15° W. and dip west at an angle of 45 degrees, and consist of individual beds 2 to 8 inches thick, many of which may be tightly joined, giving the appearance of heavy bedding. In other places there are shale partings between the limestone beds. The nature of the deposit is illustrated in the following section measured from the southernmost exposure towards the north, the measurements being at right angles to the dip:

17 feet—Dark blue, fine-grained limestone.
12 feet—Calcareous, grey shale or schist.
17 feet—Shaly limestone breaking into long slabs.
15 feet—Mixed shale and limestone with shale predominating.
12 feet—Dark blue, fine-grained limestone, underlain by shale or schist.

This series of alternate beds of limestone and shale or schist continues for a mile. Two samples were taken, Sample 80 from the 17 feet of limestone at the south end of the exposures, and Sample 80A from the 12 feet of limestone at the northern end of the measured section.

In places the limestone contains round nodules, about ½ inch in diameter, of black calcite much coarser in grain than the remainder of the rock. Veins of calcite also occur in places in the bedded limestone.

Salmo

Deposits of limestone similar to those at Waneta are reported to be plentiful in the area east of Salmo, but for the most part they are in mountainous country at considerable distances from rail transportation. A number of years ago, siliceous magnesian limestone, occurring at the Hunter V mine 6 miles northeast of Salmo, was shipped to Consolidated Mining and Smelting Company at Trail for flux. A partial analysis of the limestone shipped is as follows:

	Per cent
Silica	10
Calcium oxide	39
Magnesium oxide	12

Analyses of Limestones on the Arrow Lakes and the Columbia River

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
78	0·36	0·12	0·24	0·02	97·34	2·07	100·15	Tr.	54·52	0·99	55 : 1
79	6·04	0·23	0·29	0·07	92·59	1·18	100·40	0·06	51·89	0·56	93 : 1
79A	11·58	0·30	0·46	0·09	86·25	0·99	99·67	0·08	48·35	0·47	103 : 1
80	2·20	0·40	0·92	0·02	93·37	3·09	100·00	Tr.	52·30	1·48	35 : 1
80A	1·44	0·23	0·61	0·02	96·34	0·92	99·56	Tr.	53·96	0·44	123 : 1

78.	Sidmouth.	One-hundred-foot band of white Carboniferous (?) limestone on mountain immediately northeast of the village.
79.	Broadwater.	Twenty-five-foot section of Carboniferous (?) limestone band on side of mountain.
79A.	"	Twenty-foot section in small quarry near south edge of same band.
80.	Waneta.	Seventeen feet of Precambrian limestone at south end of outcrops.
80A.	"	Twelve feet of strata at northern end of outcrops.

Kootenay Lake Area

On both shores of Kootenay lake and north thereof are a number of deposits of highly crystalline, only moderately pure Precambrian limestone that contains from 6 to 13 per cent of magnesium carbonate. There is some high-calcium limestone and some dolomite. The limestone was formerly quarried for marble at Marble Head and opposite Kaslo. It has also been quarried for flux and for making lime for local use. Except for those on the west shore of the lake south of Procter, the deposits are without rail transportation and quarried stone for shipment to present centres of consumption would have to be transported to the railway either by trucks or on barges. The deposits south of Procter are described on page 198 with other deposits along the Kettle Valley branch of the Canadian Pacific railway.

Marble Head

Heavily bedded, very fine-grained, light blue, white, and blue-and-white striped calcium limestone of Precambrian age is exposed in a cutting on the now unused branch of the Canadian Pacific railway 450 yards north of Marble Head. A short distance farther north is a quarry once worked for marble, and ½ mile still farther north is an underground working from which marble was obtained until recently by *Canadian Granite and Marble Company, Limited, Edmonton, Alberta.* The limestone, or marble, in the cutting strikes N. 55° W. and dips

A. Massively bedded Precambrian limestone at Marble Head, B.C., formerly quarried for marble by Canadian Granite and Marble Company, Ltd.

B. Old marble quarry in Precambrian limestone on east side of Kootenay lake, opposite Kaslo, B.C.

northeast at an angle of 40 degrees. Beginning at the southern end of the cutting, the following succession of strata is exposed:

6 feet—Fine-grained, pale blue limestone, faintly striped with white and containing considerable graphite and also some films of brown shaly material.
7 feet—Blue and white, fine-grained limestone.
10 feet—Fine-grained, light blue limestone.
5 feet—Medium-grained, blue-and-white and white limestone.
15 feet—Very fine-grained, white limestone containing streaks of hard siliceous material. This is overlain by fine-grained, blue limestone.

Sample 81 was taken from 28 feet of the blue and the blue-and-white limestone at the southern end of the cutting.

Seventy-five yards north of the cutting is a small quarry from which marble was at one time quarried with a channelling machine (Plate XXXVIII A, page 208). The quarry is 90 feet long and 50 feet wide and has a face 24 feet high next to the mountain. The limestone is mostly white and contains many hard siliceous streaks. Below this, as shown by diamond drilling, is 40 feet of light blue limestone, and above is at least 50 feet of blue-and-white limestone, giving a band of marble somewhat more than 100 feet in exposed thickness. It is said that the full thickness of the marble band is in excess of 500 feet. This quarry was abandoned because of unsoundness in the marble and because of the prevalence of hard siliceous streaks around which the marble tended to crack after being sawn into slabs, and which are generally undesirable in marble for sawn stock.

The underground chamber from which marble was obtained until 1930 by *Canadian Granite and Marble Company, Limited, Edmonton, Alberta,* is about ½ mile north of the above-mentioned quarry. It is opened in the steep side of a ridge of marble that rises to a height of 150 feet on the west side of the railway and that is composed of strata striking N. 60° W. and dipping northeast at an angle of 40 degrees. The floor of the chamber is level and is only a few feet above the railway. Outside, as seen on the steep face of the hill, the limestone, or marble, is much fractured, but inside the chamber the fracturing is not greatly in evidence. When seen in 1929 this chamber was 100 feet long parallel to the ridge, 20 feet high, and 60 feet wide. The entrance was 36 feet long, 30 feet wide, and 18 feet high. The marble in the floor is light blue. Above this is a 10-foot thickness of very fine-grained, white marble with siliceous streaks, overlain by 6 feet of bluish white, medium-grained high-calcium limestone, which in turn is overlain by blue-and-white, medium-grained marble of unknown thickness. The following samples were taken: Sample 81A from the fine-grained, white marble with siliceous streaks; Sample 81B from the 6 feet of bluish white, medium-grained marble overlying the white, fine-grained marble; Sample 81C from the blue-and-white, medium-grained marble above this. As the analyses show, this marble, with the exception of the band containing the siliceous streaks, is remarkably pure. The only other visible impurity is golden mica, present in small amount in some beds.

Above this, on the hillside, interbanded blue and blue-and-white marble containing a few thin veins of white quartz is seen for about 75 feet above the opening to the underground chamber. Marble produced here was known as "Kootenay" marble. It was at first used for building and decorative purposes, but in later years was used solely for monuments. The Great West Life Assurance Building in Winnipeg and the Canadian Bank of Commerce Building in Nelson are examples of its use as an exterior building material. For a time a mill for sawing and finishing the marble was in operation at the property, but later the marble was shipped in the form of blocks to the company's marble working plant at Edmonton.

One mile north of the Marble Head quarries a broad band of similar marble is visible high up on the mountain west of the track. Blocks of it seen on the talus are of the same types as those just described and the band is probably a continuation of that at Marble Head.

It is reported that light-coloured limestone of good purity is available on the mountain on the east side of the Lardeau and Duncan rivers and that a wide band of highly crystalline limestone can be traced along the height of land from Duncan lake for many miles northwest.

Lardeau

On the mountainside ½ mile north of Lardeau is a large band of blue and of blue-and-white Precambrian limestone, from which part of the flux requirements were obtained for the smelter at Nelson, which operated from 1896 until 1907. Lime in small quantity was also made at one time from this limestone. The quarry is opened in a cliff of medium-grained, dark blue, and blue-and-white striped calcium limestone, the beds of which dip at a slight angle into the mountain. Interbeds of highly siliceous limestone from a few inches to 2 feet or more in thickness are present, as are mineralized veins and stringers of quartz and thin streaks of brown-weathering slate. The face of the mountain rises steeply and the quarry face, which is 125 feet high, has been worked into the mountain for a distance of only 100 feet. Impure, partly calcareous, schistose rock occurs at the top of the quarry face. Sample 82 was taken as opportunity offered from such beds as could be reached in the cliff face. It represents better stone than could be obtained in quarrying, as a number of the quartzite or highly siliceous beds were intentionally omitted. The limestone here is exposed at the track level.

A short distance south the limestone is seen only at a height of 400 feet or more above the track level. It is similar to that just described and has a slight dip into the mountain. The lowest rock seen consists of a 100-foot thickness of light blue and dark blue calcium limestone containing interbeds of highly siliceous material. This is overlain by 100 feet of slaty or schistose limestone, which in turn is overlain by an undetermined thickness of light blue, medium-grained calcium limestone. Sample 82A taken here consisted of chips taken at intervals of 2 feet across a thickness of 50 feet of the lowest beds exposed, excluding the siliceous interbeds.

Kaslo

A number of deposits of Precambrian limestone occur in the vicinity of Kaslo, most of which are of little importance since they are impure or are difficult to quarry, or both. The principal deposit is on the east side of Kootenay lake, directly opposite Kaslo. It was worked at one time on a small scale for marble and the property is known as the Kaslo Marble Quarry (Plate XXXVIII B, page 208). The limestone occurs in a band 50 feet thick, overlain and underlain by schist, and is exposed on the north side of a point that juts out into the lake. It consists of interbanded, coarse-grained, nearly white high-calcium limestone, and of fine-grained bluish and yellowish dolomite. The line of division between the two is sharp but irregular, and much twisting of the beds is in evidence in places. The general strike is N. 50° W. and the prevailing dip is southwest at an angle of 28 degrees. Pale yellow mica is characteristic of the bedding planes and is more common in the dolomite than in the high-calcium limestone. Tremolite is common along bedding planes and in the dolomite, and there are occasional short veins of white quartz in the deposit. Near the beach an aplite dyke 3 feet thick cuts the limestone, and granitic dykes as much as 15 feet thick occur elsewhere. Where the covering of schist is absent, the limestone is exposed for several hundred feet from the water and can be seen for 500 feet along the shore. It was quarried for lime and for marble. The marble quarry is 60 feet long, 45 feet wide, and has a face of 25 feet. The marble exposed in it is heavily bedded, but jointing is frequent. Sample 83 taken in the quarry is representative of 20 feet of strata. Marble from this quarry was used in building the court house and the post office in Nelson.

One and one-quarter miles north of Kaslo, white calcium limestone, interbedded with quartzite and veined with quartz, is exposed on the hillside near the lake. The band dips into the hillside and is overlain by schist. Many years ago it was quarried for making lime.

One mile south of Kaslo, thin-bedded, medium-grained, white calcium limestone, interbanded with schist, is exposed on the west shore of Kootenay lake, where it has been quarried in small amounts. The band is not extensive and dips into the hillside.

A little more than $3\frac{1}{4}$ miles west of Kaslo, dark blue, fine-grained, slaty, calcium limestone is exposed in quantity along the Kaslo Creek road just east of where the road forks. The deposit is at least 300 feet wide and dips vertically. Much of the limestone is soft and it contains a great deal of pyrite and siliceous bands. Stringers of white quartz are numerous.

Parks[1] reports a deposit of marble as occurring 5 miles from Kaslo on the south fork of Kaslo creek.

> Marble is exposed near the level of the creek and on the mountainside at an elevation of 500 feet above the stream. . . . Down stream the stone is a fine blue limestone imperfectly marmorized, and excessively shattered by sharp diagonal dries. . . . Up stream the stone is blue and white mottled, and passes into a fine white crystallized type for a distance of 10 feet, and probably farther as the formation is covered.
>
> The upper exposure bears N. 25° W. on the outcrop described above. Here a face of marble is presented for at least 150 yards in an east and west direction along the mountainsides. . . . The western part of the outcrop, for more than half the distance of its total length is of fine-grained, white stone. The central part presents a mottled type, which gradually passes into the blue variety at the east end.

Ainsworth

Bands of siliceous limestone, containing much pyrite and mica, are exposed at intervals along the west shore of Kootenay lake both north and south of Ainsworth. One band is at the Kootenay-Florence mine and another is near Coffee creek. They dip into the hillside at low angles and as the limestone is overlain by other rocks it would not be available by quarry methods.

At the Bluebell mine on the east shore of Kootenay lake, about 2 miles above Ainsworth, a belt of rather siliceous calcium limestone, possibly 200 feet thick, is exposed for a length of $\frac{1}{2}$ mile on the small promontory jutting into the lake. The belt strikes north and south and dips at an angle of 35 degrees west. It is overlain by mica schist and underlain by hornblende schist. The deposit consists of interbedded calcium limestone and dolomite, with the former predominating. In the vicinity of the Bluebell mine, which is opened in the northern end of this belt, the limestone is mineralized with galena and pyrite and there is a considerable development of silicate minerals and graphite. At the southern end of the promontory, however, where the limestone is exposed in a cliff, there is little mineralization and the limestone is of better grade than elsewhere. Sample 84 was taken across the central 50 feet of the belt and is representative of the best grade of limestone available here, for toward the top and the bottom of the belt the limestone is more siliceous, tremolite and quartz being especially abundant. Above this belt and separated from it by 65 feet of schist is a band of similar limestone 6 to 15 feet thick, in which dolomite is more prevalent than in the wide belt. A small quantity of this limestone has been quarried in the past for making lime.

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[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, Rept. No. 452, p. 138 (1917).

Pilot Point

A belt of siliceous, white dolomite of Precambrian age crosses Pilot point in a northeasterly direction from 2 miles north of the tip to Crawford bay. What is probably the continuation of this belt is reported to outcrop on the east shore of Crawford bay near its head.

Where seen on the shore of Kootenay lake, 2 miles north of the tip of Pilot point, the dolomite band is 500 feet wide. It is medium-grained, white or yellowish white, and contains golden mica, quartz veins, and patches of various silicates. Interbeds of schistose rock occur, particularly near the north edge, and there are numerous intrusive dykes. Thus the belt shows no promise of yielding pure dolomite. Two samples were taken: Sample 85 from near the northern edge of the belt; and Sample 85A from the southern edge; interbeds of other rock being omitted in each case. Across the lake on the west shore, near Procter, are other deposits of limestone. They are described on page 198.

Analyses of Limestones in Kootenay Lake Area

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
81.......	0·36	0·45	0·01	0·02	90·75	8·39	99·98	0·01	50·83	4·01	13 : 1
81A.....	10·20	0·14	0·02	0·04	86·04	1·41	99·85	0·01	49·41	0·67	74 : 1
81B.....	0·24	0·16	Tr.	Tr.	99·07	0·71	100·18	0·02	55·48	0·34	163 : 1
81C.....	0·14	0·05	0·03	0·17	98·98	1·24	100·61	0·01	55·52	0·59	94 : 1
82.......	2·40	0·33	0·19	0·13	89·77	7·30	100·12	0·01	50·34	3·49	14 : 1
82A.....	1·96	0·21	0·27	0·07	91·20	6·71	100·42	0·01	51·11	3·21	16 : 1
83.......	3·22	0·11	0·27	0·07	83·84	13·21	100·72	Tr.	46·99	6·32	7·4 : 1
84.......	4·96	0·16	0·22	0·13	86·86	8·22	100·55	0·02	48·71	3·93	12 : 1
85.......	3·94	0·49	0·71	0·22	53·93	42·20	101·49	0·02	30·32	20·18	1·50 : 1
85A.....	5·76	0·90	0·36	0·13	52·27	41·47	100·89	0·02	29·34	19·83	1·48 : 1

81.	Marble Head.	Twenty-eight feet of blue and blue-and-white Precambrian limestone in railway cutting.
81A.	"	Underground workings of Canadian Granite and Marble Company; 10 feet of siliceous white Precambrian marble.
81B.	"	Same place; 6 feet of bluish-white, medium-grained marble.
81C.	"	Same place; blue-and white, medium-grained marble above 81B.
82.	Lardeau.	Old Nelson smelter quarry; best grade of limestone available.
82A.	"	Lowest beds of marble on mountainside to the south of the old smelter quarry.
83.	Kaslo.	Old marble quarry on opposite side of Kootenay lake from the village.
84.	Ainsworth.	Central 50 feet of Precambrian limestone in cliff face on east shore of Kootenay lake, south of the Bluebell mine.
85.	Pilot Point.	Northern edge of belt of Precambrian limestone on shore of Kootenay lake, 2 miles north of Pilot point.
85A.	"	Southern edge of same belt.

Windermere Valley

The Windermere valley is bounded on the east by the Beaverfoot-Brisco-Stanford range of mountains, the western flank of which is composed in large part of limestone ranging from Cambrian to Silurian in age, and in composition from an impure calcium limestone to very pure dolomite. This territory has been geologically mapped by J. F. Walker[1]. The various limestone formations as shown on the map accompanying this report are Ottertail (Cambrian), Goodsir (Cambrian and Ordovician), Beaverfoot and Brisco (Ordovician and Silurian). The Kootenay Central branch of the Canadian Pacific railway serves this district.

The limestone occurs in a steeply dipping belt that in places is vertical, and the mountains have a steep western face. In the Beaverfoot section of the

[1] Walker, J. F.: Geol. Surv., Canada, Mem. 148 (1926).

range, which is the northern part, the limestone is exposed only high up on the slopes, and the base of the mountains is faced with other rocks, whereas in the central (Brisco) and southern sections (Stanford), the limestone is available on the lower slopes. It is in the southern range that the pure dolomite occurs. Much of the limestone along this mountain range is shaly and siliceous and some of it is probably suitable for use in the manufacture of rock wool.

Harrogate

From Golden to Harrogate no limestone was observed on the lowest slopes of the mountain in the several places where an examination was made, but opposite Harrogate station, a siliceous, grey, very fine-grained calcium limestone, much mottled with brown-weathering siliceous bands, is exposed in beds that strike along the face of the mountain and dip southwest at steep angles. Sample 86 was taken at a point about 2 miles from the railway.

Spillimacheen

Two miles north of Spillimacheen, massively bedded, brownish grey, fine-grained dolomite, of which the weathered surface is deeply scarred and nearly white, is exposed in steeply dipping beds along the base of the mountain. Sample 87 is representative of this dolomite, which is comparatively pure. In the same locality are beds of brown-weathering brecciated dolomite of which the cementing material is, in part, white calcite. The dolomite fragments are mostly less than one-quarter inch in diameter. In addition to the beds of relatively pure dolomite exposed along the mountainside, there are also interbeds of highly siliceous dolomite and quartzite; such are to be seen opposite Brisco station and for some distance south.

Athalmer

Five miles directly north of the village of Athalmer, limestones of the Ottertail, Goodsir, and Beaverfoot-Brisco formations are exposed in the valley of a small creek, just east of the highway, and $1\frac{1}{2}$ miles east of the Canadian Pacific railway. Because of intense folding the succession of strata is inverted and the lowest beds encountered are those of the Beaverfoot-Brisco formation. These consist of medium- to fine-grained, grey calcium limestone, mottled and streaked with siliceous material, which weathers to a reddish brown in contrast to the blue-weathered surface of the purer limestone. Occasional bands contain nodules of brown-weathering chert, and narrow veins of white calcite appear in some places. The bedding varies from thin to massive. The strike is northwest-southeast and the dip is steep to the southwest. Two samples were taken along the north side of the valley of the creek: Sample 88 represents beds having little of the brown-weathering siliceous material; and Sample 88A is of beds containing much of the siliceous material.

A short distance farther up the creek valley thin-bedded, shaly, grey calcium limestone, streaked with brown-weathering siliceous material and interbedded with shale, is exposed for a distance of about half a mile up the mountainside. Sample 89, taken here and there from the more calcareous beds, shows that this type of limestone has almost the composition required in a raw material for making rock wool, and the addition of a small quantity of sandy dolomite found in the locality would render it suitable.

Higher on the mountainside, approximately 1,000 feet above where Sample 88 was taken, is a vertical cliff of grey, fine-grained Ottertail dolomite. White and blue chert nodules appear in places in this dolomite, but most of it is of good grade. Sample 90 was taken from such beds as were accessible.

Fairmont Springs

Southeast of the village of Fairmont Springs and 2 miles due east of Radium station on the Canadian Pacific railway, dolomite of a high degree of purity forms an entire spur of the mountain, 2,000 feet in height, just south of Fairmont creek. The Ottertail and Beaverfoot-Brisco formations are exposed, the former on the western slope of the ridge that rises south of Fairmont creek, the latter on the northeastern slope of the same ridge, and also forming another mountain spur just north of Columbia lake. In all places the dolomite can be easily quarried, but the lowest outcrops are about 1,000 feet above the railway. Similar dolomite is available at other places in this vicinity.

The Ottertail dolomite as exposed on the west slope of the spur just south of Fairmont creek is dark blue and fine-grained where first seen, but as it is traced up the side of the ridge across the strike it becomes much lighter in colour and coarser in grain, and near the top of the ridge it is pale bluish grey and pinkish grey and medium-grained. The bedding is heavy but indistinct, with an east and west strike and an apparent dip down the slope at an angle of 25 degrees. All of the rock weathers to a rough, dark brownish grey surface. Three samples were taken at numerous places as being representative of the dolomite exposed on the flank of the ridge: Sample 91 was from the lowest exposures of fine-grained, dark blue and medium-grained, light pinkish grey dolomite; Sample 91A was from the beds exposed about halfway up the ridge; and Sample 91B from the uppermost beds of the Ottertail formation near the top of the ridge.

The saddle of the ridge and the slope facing Fairmont creek are composed of the Beaverfoot-Brisco dolomite, which is fine-grained, pale blue, faintly mottled with light grey, and in massive beds. It weathers to a dark grey in contrast to the dark brownish grey of the Ottertail. Sample 92 was taken here and there over a large area on the saddle and north flank of the ridge.

The spur that juts out to the west from just south of the spur abovementioned is composed of very fine-grained, dark blue, hard Beaverfoot-Brisco dolomite in massive beds, as shown by the analysis of Sample 93 taken at various places.

Analyses of Windermere Valley Limestones

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
86.......	15·34	0·74	1·96	0·70	75·95	3·59	98·28	0·03	42·91	1·72	25 : 1
87.......	0·74	0·50	0·25	0·02	55·18	45·04	101·73	0·02	30·91	21·54	1·44 : 1
88.......	4·16	0·25	0·25	0·48	91·87	1·39	98·40	Tr.	51·71	0·66	78 : 1
88A.....	13·94	0·78	2·31	0·46	77·07	3·70	98·28	0·01	43·41	1·77	25 : 1
89.......	28·10	0·72	2·44	1·31	65·70	1·03	99·30	0·01	37·50	0·49	77 : 1
90.......	1·88	0·28	0·68	0·04	54·59	42·95	100·42	Tr.	30·59	20·54	1·49 : 1
91.......	0·18	0·26	0·20	0·02	55·59	44·15	100·40	Tr.	31·14	21·11	1·47 : 1
91A.....	0·24	0·50	0·12	0·02	55·66	43·77	100·31	Tr.	31·18	20·93	1·48 : 1
91B.....	0·06	0·29	0·14	0·02	55·30	44·75	100·56	Tr.	30·98	21·40	1·45 : 1
92.......	0·70	0·43	0·20	0·02	55·70	43·40	100·45	Tr.	31·20	20·75	1·50 : 1
93.......	1·40	0·30	0·40	0·02	54·25	44·46	101·83	Tr.	30·39	21·26	1·43 : 1

86.	Harrogate.	Palæozoic limestone at base of mountain 2 miles from Canadian Pacific railway.
87.	Spillimacheen.	Massively bedded Palæozoic dolomite at base of mountain, 2 miles north of Spillimacheen.
88.	Athalmer.	Beaverfoot-Brisco calcium limestone exposed at base of mountain in the valley of a small creek, 5 miles north of the village.
88A.	"	Limestone from the same locality containing streaks of the same material.
89.	"	Shaly limestone farther up the mountain.
90.	"	Ottertail dolomite exposed 1,000 feet still farther up the mountain.

91.	Fairmont Springs.	Ottertail dolomite in lowest exposures on a ridge south of Fairmont creek.
91A.	"	Ottertail dolomite halfway to the top of the same ridge.
91B.	"	Ottertail dolomite from near the top of the same ridge.
92.	"	Beaverfoot-Brisco dolomite from top of the ridge and on the slope facing Fairmont creek.
93.	"	Beaverfoot-Brisco dolomite on hill that juts out of the west from south of the above-mentioned ridge.

Banff-Windermere Highway

Near where it crosses the Banff-Windermere highway, Tokumm creek has cut a canyon up to 150 feet deep for more than $\frac{1}{4}$ mile through a deposit of highly metamorphosed limestone. The marble strikes northeast-southwest and dips southeast at an angle of 10 degrees. It is free from visible impurities but is a mixture of dolomite and high-calcium limestone. The original rock appears to have been a grey, fine-grained high-calcium limestone, but it has undergone intense metamorphism in most places and has become nearly white, much coarser in grain, and dolomitic. The process of dolomitization has gone on very irregularly and the same bed may be high-calcium in composition in one place and dolomitic in another, or it may be half dolomite and half high-calcium limestone. Much of the dolomite is tinted and mottled with pink, yellow, and blue.

Sinclair Pass

Fine-grained, dark blue dolomite in heavy beds is exposed along the highway opposite Olive lake at the summit of Sinclair pass. Three and one-quarter miles farther south, black, calcium limestone with interbeds of brown, calcareous shale forms a cliff along the east side of the highway. One-half mile still farther south, very fine-grained, dark grey limestone, mottled in places with brown-weathering magnesian limestone and containing some chert, forms a high cliff along the highway. At the southern end of this outcrop, vermilion-coloured crystals of realgar occur in veins of white calcite which traverse the limestone in a vertical zone 10 to 15 feet wide. One mile north of Radium Hot Springs, the road is cut through a cliff of dark grey, fine-grained limestone, mottled with brown-weathering magnesian limestone.

Main Line of the Canadian National Railway between Kamloops and the Alberta Boundary

From Kamloops northward the main line of the Canadian National railway follows the valley of the North Thompson river to its head and then crosses the height of land into the valley of the Fraser, which it follows nearly to the provincial boundary.

In the valley of the North Thompson are a number of deposits of Carboniferous limestone that occur as large masses in the lavas, argillites, and greenstones of the Cache Creek series of rocks which prevail throughout much of the valley. Except for small dolomitized areas these limestones are low in magnesium carbonate and some are of a high degree of purity. Several of the deposits were utilized for making lime, but no use is being made of them at present.

Near the Alberta boundary the railway runs close to a wide band of Cambrian dolomite that at one time was worked on a small scale for marble.

At Valemont, on the height of land between the North Thompson, Fraser, and Columbia watersheds, a deposit of marl is being worked for agricultural use.

Rayleigh

A small mass of Carboniferous limestone enclosed in argillite occurs on the mountainside on the east side of North Thompson river, about 2 miles south of Rayleigh station on the Canadian National railway, or $8\frac{3}{4}$ miles north of Kamloops. The limestone is first seen at a height of 100 to 150 feet up the mountain, where it is in sharp contact with argillite on its lower edge. The limestone mass is 100 feet wide and extends about 200 feet up the mountain. It consists of very fine-grained, blue and white, brittle high-calcium limestone that tends to break into small angular fragments along calcite veins or along incipient fissures. Small, irregular patches or spots of fine-grained, pale blue, brown-weathering dolomite appear in places as projections on the weathered surface. At the foot of the mountain are the remains of an old pot kiln in which this limestone was burned. Sample 94X was taken from this deposit.

Black Pines

A large mass of Carboniferous limestone forms a spur at the foot of the mountain on the west bank of the North Thompson river at Black Pines, $18\frac{3}{4}$ miles north of the bridge at North Kamloops. This is nearly opposite the station of Vinsulla on the Canadian National railway on the east side of the river. The road going up the west bank of the river bends around this limestone spur for a distance of 500 yards. The limestone is mostly massive, but it appears to strike nearly north and south. On the property of Mrs. K. I. Hardy, it rises precipitously for 50 to 75 feet from the road to form a grass-covered spur jutting out toward the river for several hundred feet. This spur steadily rises in height toward the mountain and the limestone continues on up the mountainside. The limestone is rather soft and brittle and although the outcrops are massive it is difficult to obtain a large piece free from cracks. It is high-calcium in composition and white to pale blue, with the latter colour predominating, and weathers to a light grey-blue. The texture is sugary and veins of white calcite are numerous. At the south end where the road first meets it, the limestone has a slaty appearance and much of it is reddish and weathers to a brown shade. Some streaks of this type appear elsewhere in the deposit, but in minor quantity. The most uniform parts of the deposit appear to be the central and northern parts as exposed adjacent to the road, and Sample 94 was taken there. Sample 94A represents the reddish limestone at the south end; and Sample 94B was taken on the main mountain at the base of the spur. Between the road and the base of the spur most of the rock is covered with soil. This limestone was used for making lime many years ago in a pot kiln at the river bank.

Four miles farther north along the road another mass of Carboniferous limestone is visible on the mountainside west of the river. It is high-calcium in composition and similar in most respects to that just described, but it occurs in a steep cliff high up on the mountain, and thus is not so readily available.

Vavenby

Carboniferous limestone forms a small mountain on the north side of the North Thompson river, 1 mile northwest of Vavenby station on the Canadian National railway, and the same type of limestone is extensively exposed on the mountainside to the southeast, on the south side of the river. The occurrence on the north side of the river is referred to locally as the Lime Bluff. The road and railroad pass near its base. The lower slopes to a height of about 300 feet consist of soil-covered talus rising at 45 degrees, but above this the limestone rises precipitously for several hundred feet. The easternmost knob of the mountain consists of pale blue, brown-weathering dolomite that is filled with milky quartz in the form of veins and irregular masses. The contact between the dolomite and the high-calcium limestone is irregular. Elsewhere the mountain consists mostly of sugary-textured, soft, pale blue to nearly white, high-calcium limestone in massive formation. It all weathers to a pale grey-blue. Despite its massive appearance the limestone tends to break into small angular fragments.

A number of years ago Wm. Elliot of Vavenby made lime from the blue-and-white high-calcium limestone on this mountain. The kiln was hewn out of the solid limestone where it formed a bench about 300 feet up on the mountain, and two tunnels, one for firing and one for drawing, were driven to the kiln from the bottom of the bench. The small quarry was above the kiln, and from this quarry Sample 95 was taken as being representative of much of the limestone that is available. No lime has been made here since 1933.

Grant Brook

One mile east of Grant Brook station on the Canadian National railway, a band of pink, white, blue, and brown, impure, Cambrian dolomite occurs on the mountainside to the north of the railway. The band is at least 400 feet wide and is exposed in a series of steps rising to a height of 600 feet for a mile or more parallel to the railway. At the western end, where it is exposed in the walls of a brook, beds of light green talcose slate from one-eighth inch to several feet in thickness are interbedded with the dolomite, and the entire band itself is enclosed in similar slate. The strike is nearly east and west (magnetic) and the dip is vertical. At the eastern end the dolomite is heavily bedded and free from shale, except for some irregular films.

Many years ago a small amount of the dolomite was quarried for marble and an inclined tramway was built from the railway up to where the dolomite is exposed, at a height of 350 feet or more. A deposit of gravel hides all rock below this level. Opposite the end of the tramway the following section is exposed:

40 feet—Hard, fine-grained, heavily bedded pink dolomite faintly mottled with white and containing green chloritic streaks and also some crystals and veins of white quartz. Sample 96 was taken across a width of 25 feet of the pink dolomite.
100 feet—White and bluish white, fine-grained dolomite with yellow streaks in some places. Also contains crystals and thin veins of quartz. Sample 96A is representative of this section.
100 feet—Covered interval.
50 feet—Fine-grained, white dolomite containing many brown patches due to stains from pyrite. Sample 96B was taken from this part.
50 feet—Deep pink, fine-grained, mottled dolomite containing streaks of blue and purple shale. Sample 96C was taken from this 50-foot band.

The section varies from place to place and also toward the west the deposit becomes more siliceous. The samples represent the purest stone available.

It is reported that more pink dolomite occurs on Grant brook 7 miles north of the railway.

Analyses of Limestones along the Main Line of the Canadian National Railway between Kamloops and the Alberta Boundary

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
94X*....	2·98	0·21	0·37	0·04	96·18	0·29	100·07	0·01	53·89	0·14	385 : 1
94*......	3·44	0·37	0·59	0·04	94·86	1·13	100·43	0·01	53·15	0·54	98 : 1
94A*....	36·26	0·88	2·92	0·06	56·97	0·84	97·93	0·01	31·92	0·40	80 : 1
94B*....	1·48	0·37	0·43	0·04	96·55	1·67	100·54	0·01	54·10	0·80	68 : 1
95*......	0·68	0·14	0·18	0·06	98·08	0·63	99·77	0·01	54·95	0·30	183 : 1
96........	5·42	0·62	1·66	0·22	52·62	40·12	100·56	0·01	29·59	19·14	1·54 : 1
96A.....	1·54	0·44	0·51	0·15	55·09	43·25	100·98	0·01	30·93	20·68	1·49 : 1
96B.....	3·80	0·65	0·29	0·17	53·68	42·04	100·63	0·02	30·15	20·10	1·50 : 1
96C.....	4·06	0·61	0·81	0·17	53·43	41·77	100·85	0·01	30·01	19·97	1·50 : 1

*Analysed by A. Sadler, Bureau of Mines, Ottawa.

94X. Rayleigh. Carboniferous limestone 2 miles south of the station.

94.	Black Pines.	Carboniferous limestone from central and northern parts of deposit on property of Mrs. K. I. Hardy.
94A.	"	Same deposit; red slaty limestone at south end.
94B.	"	Same deposit; back, on mountain.
95.	Vavenby.	Carboniferous limestone on north side of North Thompson river, 1 mile northwest of Vavenby station.
96.	Grant Brook.	Cambrian dolomite on mountain north of the railway; 25 feet of pink marble.
96A.	"	Same deposit; 100 feet of white and bluish white marble.
96B.	"	Same deposit; 50 feet of white marble.
96C.	"	Same deposit; 50 feet of deep pink mottled marble.

Canadian National Railway between Prince Rupert and Red Pass Junction

There are a number of large limestone deposits in the territory served by the Canadian National railway between Prince Rupert and Red Pass junction, among them being those near Shames, Lindup, Hansard, and Urling. The deposits include high-calcium limestone and magnesian limestone. None of the limestones is being utilized. There are also several deposits of marl.

Shames

Near Shames flag station on the Canadian National railway a large deposit of limestone is reported to occur on the mountainside to the north between Mileage 78½ and Mileage 82½ (west of Prince Rupert). In 1912 and 1913 it was investigated by *Prince Rupert Portland Cement Company*, which was formed to manufacture Portland cement at Shames but which did not get into operation. The following information is taken from reports prepared for that company.

The deposit consists of white and light-coloured limestone. It is in the form of a band, variously reported to be from 400 feet to 2,600 feet in width, dipping vertically and trending southeasterly from the Shames river for 3½ miles. It is cut by a few igneous dykes. At its western end the limestone band is 1 mile north of the railway and has an elevation of 300 feet. To the east it rises steadily until opposite Mileage 80 it attains an elevation of 3,000 feet, but from there on the elevation decreases and at its eastern end it is only 100 feet above the railway and about 800 feet distant. Overburden is reported to be very light and in places the limestone is exposed in high, vertical cliffs. The following analyses are of samples taken by various persons:

	1	2	3	4	5	6	7
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Silica	2·4	7·9	0·60	1·10	9·0	2·0	7·2
Ferric oxide	0·3	0·9	....	} 1·60	2·0	1·0	1·6
Alumina	Tr.	0·1	0·60				
Calcium carbonate	97·1	91·1	97·62	96·93	88·9	97·0	90·2
Magnesium carbonate	Tr.	Tr.	0·84	1·68	0·2	Tr.	Tr.
Total	99·8	100·0	99·66	101·31	100·1	100·0	99·0

1. Light-coloured limestone.
2. Dark-coloured limestone.
3. No description.
4. No description.
5. Grey limestone near east end of the deposit.
6. White limestone ½ mile west of the east end of the deposit.
7. No description.

Judging from the above analyses the deposit differs considerably in purity from place to place, but is uniformly low in its content of magnesium carbonate.

PLATE XXXIX

A. Ridge of Carboniferous limestone south of Canadian National railway, west of Hansard, B.C.

B. Pavilion mountains, composed largely of pure high-calcium limestone, near Pavilion, B.C.

Moricetown

Leach[1] reports the presence of high-calcium limestone near the headwaters of Zymoetz river west of Moricetown. He says:

As limestone suitable for smelting purposes has not before been noted from this district, the discovery of a bed of good quality may be of interest. This limestone occurs on the north side of the pass followed by the old trail from Moricetown to Hankin's Camp, on the Zymoetz river, and not far from the summit. As the only outcrop seen was in heavy timber it was impossible to ascertain the thickness of the bed, but it would appear to be of good size. The following analysis was made in this office:—

Insoluble matter	1·31	per cent
Fe_2O_3, Al_2O_3	1·30	" "
$CaCO_3$	92·41	" "
$MgCO_3$	3·63	" "
Total	98·65	

Hansard

One mile west of Hansard is a ridge, in places 200 feet high, of fine-grained, pale blue and dark blue high-calcium limestone of Carboniferous age that runs parallel to and south of the highway and the Canadian National railway for more than half a mile (Plate XXXIX A, page 219). The limestone is massive, but is very brittle and has been much fractured. Many of the fracture planes are filled with thin calcite veins and the rock tends to break into small angular fragments. The limestone has a light soil covering that supports a dense growth of trees. Outcrops are infrequent, except in the area from 1 to 1½ miles west of Hansard. The deposit probably extends considerably farther south and west of the area where it was examined. Three samples were taken: Sample 97 across the west end of the cliff at the west end of the main outcrops; Sample 97A at the eastern end of the same cliff; and Sample 97B from outcrops opposite a saw mill. These samples, representative of a large tonnage of limestone, all show a uniformly low content of magnesium carbonate.

Other deposits of limestone similar in appearance to that just described are reported to occur 6 miles south of Hansard and also in the vicinity of Hansard lake.

Urling

On the east bank of Ptarmigan creek, 2 miles west of Urling, the Canadian National Railways Company opened a quarry for riprap in a deposit of pale blue, fine-grained limestone that consists in part of high-calcium limestone and in part of pink and light brown magnesian limestone, the latter being distributed throughout the deposit in zones and lenticular areas. No beds having the composition of dolomite occur since the magnesian zones are made up of grains of dolomite in a calcite matrix and these have the analyses of magnesian limestone. There may, or may not, be a distinct line of parting between the magnesian limestone and the high-calcium, but commonly there is a thin film of iron oxide at the contact. Most of the magnesian zones are horizontal and the deposit as a whole has the appearance of being in a horizontal position. The limestone is nearly free from siliceous impurities. Three samples were taken in the quarry: Sample 98 represents the high-calcium limestone between the magnesian bands; Sample 98A the brown magnesian limestone; and Sample 98B the pink magnesian limestone. Owing to the uneven distribution of the dolomite crystals it is difficult to estimate the magnesium carbonate content of material that could be quarried, but probably it is in excess of 8 per cent.

[1] Leach, W. W.: Geol. Surv., Canada, Sum. Rept. 1908, p. 45.

The quarry is opened on the bank of the creek, just below a high falls, and is 600 feet long with a face 250 feet high. When in operation it was connected with the main line of the railway by a spur track. Outside of the quarry the rock in the vicinity is hidden by soil and dense undergrowth and it is impossible to estimate the size of the deposit without digging trenches and test pits.

Analyses of Limestones along the Canadian National Railway Between Prince Rupert and Red Pass Junction

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
97.......	2·58	0·34	0·66	0·02	94·78	0·63	99·01	Tr.	53·09	0·30	177 : 1
97A.....	1·68	0·33	0·35	0·07	95·41	0·90	98·74	Tr.	53·47	0·43	124 : 1
97B.....	1·20	0·32	0·22	0·20	96·12	1·39	99·45	Tr.	53·94	0·66	82 : 1
98.......	0·20	0·07	0·02	0·02	97·41	1·89	99·61	Tr.	54·58	0·87	63 : 1
98A.....	0·32	0·38	0·11	0·02	76·15	23·74	100·72	Tr.	42·67	11·35	3·7 : 1
98B.....	0·38	0·17	0·06	0·02	87·01	12·60	100·24	Tr.	48·77	6·03	8 : 1

97. Hansard. West end of limestone cliff 1 mile west of Hansard.
97A. " East end of same cliff.
97B. " Limestone exposed opposite a saw mill 1¼ miles west of Hansard.
98. Urling. High-calcium bands in deposit on Ptarmigan creek.
98A. " Brown magnesian limestone in same deposit.
98B. " Pink magnesian limestone in same deposit.

Pacific Great Eastern Railway

The only limestone deposits examined and sampled adjacent to this railway were those of the Marble Canyon district and in the neighbourhood of Clinton. In these districts Carboniferous high-calcium limestone of great purity forms the major parts of the Pavilion and Marble mountains. Although, in places, there are bands of cherty and otherwise siliceous limestone, most of that sampled contained less than 0·5 per cent silica and less than 1 per cent magnesium carbonate. The iron content is also very low. The principal drawback to its utilization is its distance from consuming centres. There is a deposit of pure calcareous tufa on the railway southwest of Clinton and another in a lake adjoining the railway.

Carquile–Pavilion Road

This road goes southwesterly along the valley of Hat creek for 12 miles from Carquile on the Clinton-Ashcroft road and then turns northwesterly through the Marble canyon to Pavilion. The canyon is a deep defile between towering mountains of Carboniferous limestone, much of which is as pure as any found in British Columbia.

The first outcrops observed adjacent to the road were highly inclined beds of cherty, high-calcium limestone exposed ¼ mile northeast of where the road forks, one branch going south to Upper Hat Creek and the other northwest through the Marble canyon to Pavilion. The limestone is bluish grey, fine-grained, strikes east and west (magnetic) and dips south at an angle of 45 degrees. Dark blue chert occurs as interbeds in the limestone. At the road-forks and to the northwest are massive outcrops of light grey and pale blue, high-calcium limestone containing only a little chert. Sample 99 was taken across a width of 100 feet of this limestone. Similar limestone occurs in enormous quantity in the mountains that rise on either side of the canyon, but it is interbanded with siliceous limestone and except in a few localities it would have to be mined rather than quarried. Some of the siliceous limestone is exposed 1 mile beyond where the road forks, where it forms the side of a knoll. It is fine-grained, bluish grey, and hard, and has siliceous matter distributed all through it. The beds strike N. 80° W. and dip south at an angle of 60 degrees.

One and three-quarter miles northwest of the road-forks, very fine-grained, dark grey, faintly mottled limestone is exposed near the road. In places it appears highly siliceous but in others it is pure and free from visible silicates. Sample 100 was taken from the pure limestone. The faint mottling is due to magnesian material. A little farther along the road a band of fine-grained, blue, highly magnesian limestone containing much chert is exposed, and adjoining it is cherty calcium limestone.

Two and one-quarter miles from the forks, white, fine-grained, high-calcium limestone, striking N. 60° W. and dipping steeply southwest, is extensively exposed in a hill at the foot of the mountains. An occasional siliceous streak was observed but, as shown by the analysis of Sample 101, which represents this white limestone, it is for the most part very pure.

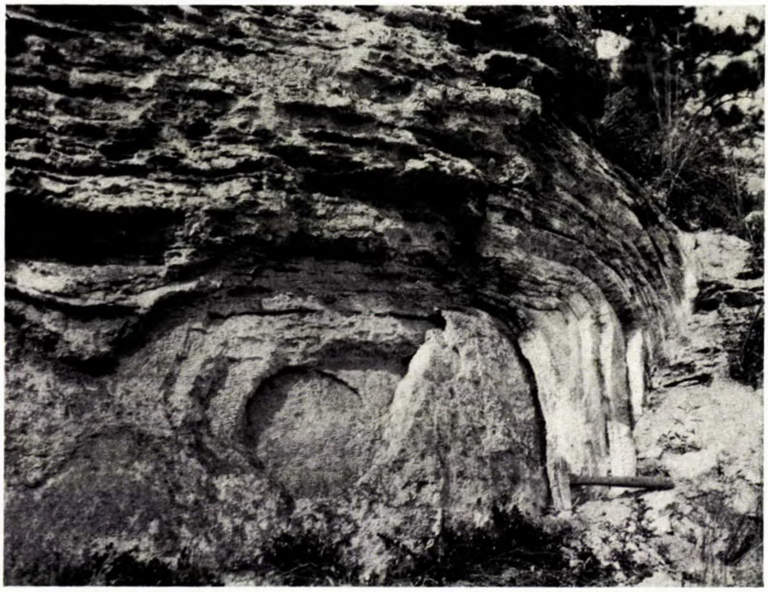
Three and one-half miles northwest of the road-forks, tan-coloured, fine-grained, faintly mottled limestone rises in high cliffs along the road. It is very pure as shown by Sample 102, taken along the cliff face, but the sample does not represent a very great thickness of strata. Similar limestone, some of it nearly white, is exposed along the road for a mile to the northwest, and Samples 103 and 104 were taken within this distance. Sample 103 represents about 100 feet of strata, and Sample 104 a thickness of 150 feet. The average strike is N. 60° W. and the dip is southwest at an angle of 80 degrees.

Limestone of good quality composes the canyon walls for another 3 miles, but it is not so readily accessible and the outcrops are farther from the road. At 7½ miles from the forks other rocks are exposed along the road. The distance from the northwest end of the canyon to Pavilion station on the Pacific Great Eastern railway, the nearest rail shipping point, is 7 miles.

Kelly Lake

Calcium carbonate in the form of sand and small rounded pebbles up to nearly 1 inch in diameter occurs in fan-shaped deposits along the west side of Kelly lake, which lies between the highway and the Pacific Great Eastern railway 11 miles southwest of Clinton. The calcium carbonate is apparently deposited from solution and many of the little nodules have a sand grain for a nucleus. One of the deposits extends for 600 feet along the shore and for 100 feet out into the lake. It has a depth of at least 3 feet in places. Deposits occur along the shore at intervals for more than ¼ mile and calcium carbonate sand is mixed with ordinary beach sand for a considerable distance on either side of the area wherein the main deposits occur. In places the calcium carbonate is intimately mixed with other sand and gravel, but in other places such admixture is not evident. Organic matter in the form of decayed wood and leaves is always present and when dug the deposits give off a sulphurous odour. Samples were taken of the coarse, intermediate, and fine sizes of material in the largest deposit and the analyses are as follows:—

A. Calcareous tufa exposed in railway cutting near Clinton, B.C.



B. Characteristic appearance of calcareous tufa at the edge of a deposit.

—	Coarse	Medium	Fine
	Per cent	Per cent	Per cent
Silica	2·66	3·74	2·46
Ferric oxide	0·20	0·09	0·16
Alumina	0·32	0·65	0·44
Calcium phosphate	0·04	0·04	0·02
Calcium carbonate	92·39	89·84	92·50
Magnesium carbonate	1·27	0·61	1·10
Water and organic matter	3·18	4·22	2·74
Total	100·06	99·19	99·42
Sulphur	0·11	0·09	0·09

Clinton

White-weathering Carboniferous limestone, in bands of various degrees of purity, composes the upper parts of the Pavilion mountains to the southeast (Plate XXXIX B, page 219), and the Marble mountains to the northwest of the highway to Clinton. The lower slopes appear to be underlain by argillite though most of this rock is covered by gravel and talus. Some of the limestone is very pure but much is impure, and the angle of dip of the interbanded limestone is such that limestone of uniform quality could be made available in quantity only by underground mining methods. To determine the purity of some of the best-appearing limestone, Sample 105 was taken of a 150-foot band of fine-grained, light grey high-calcium limestone on the Marble mountains, at a point 5 miles southwest of Clinton. The analysis of this sample shows that the limestone is of a high degree of purity.

Two and three-quarter miles southwest of Clinton, fine-grained, dove-grey high-calcium limestone is exposed in massive outcrops on the side of the Marble mountains at a height of about 800 feet above the highway. The band is about 250 feet thick and is underlain by argillite. Along the upper edge of the exposures some bands of steel-blue, fine-grained dolomite occur in the high-calcium limestone, but the overlying rock is hidden by drift. Sample 106 was taken from the 250-foot band that appears to strike nearly north and south along the face of a foothill of the mountains and to dip east at an angle of 70 degrees.

Two miles southwest of Clinton the Pacific Great Eastern railway passes over a deposit of buff, calcareous tufa about 700 feet in diameter and having a maximum depth of at least 25 feet. It is lightly covered with calcareous soil that supports a thick growth of small trees. A railway cutting, 600 feet long, made through the tufa exposes a section 23 feet thick. As shown in Plates XL A and B, page 223, the tufa is roughly bedded. Some of the beds are dense, but most are cellular. The dense beds are steeply inclined, whereas the cellular beds are horizontal. The slope of the beds is not due to movement in the deposit but to the mode of formation. Towards the rim of the deposit, twigs and branches of trees as well as lenses of mud and sand occur, but elsewhere the tufa is very pure, except for a content of 1 to 1·5 per cent of magnesium carbonate. Three samples were taken: Sample 107A from the top 12 feet in the centre of the cutting; Sample 107B from the bottom 11 feet at the same place; and Sample 107C from 18 feet of tufa near the southwest end of the cutting.

About 400 feet west of the tufa deposit very fine-grained, grey high-calcium limestone is exposed along the foot of the mountain and has been quarried in small quantity for making lime in a pot kiln, now in ruins. Adjacent to the pure limestone are outcrops of siliceous, grey and blue calcium limestone and some that are highly magnesian.

Analyses of Limestones Along the Pacific Great Eastern Railway

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO	Ratio of CaO to MgO
99......	0·14	0·06	0·05	0·07	98·91	1·03	100·26	Nil	55·43	0·49	113 : 1
100......	0·64	0·26	0·16	0·09	96·36	2·76	100·28	Tr.	54·01	1·32	41 : 1
101......	0·38	0·04	0·13	0·07	98·48	0·78	99·88	Nil	55·19	0·37	149 : 1
102......	0·12	0·08	0·15	0·02	99·05	0·67	100·09	Nil	55·48	0·32	173 : 1
103......	0·78	0·05	Tr.	0·61	96·48	0·69	98·61	Nil	54·36	0·33	165 : 1
104......	0·24	0·06	0·10	0·13	98·18	0·44	99·15	Nil	55·06	0·21	262 : 1
105......	0·48	0·07	0·14	0·24	99·11	0·40	100·44	Nil	55·63	0·19	293 : 1
106......	0·82	0·07	0·10	0·15	96·98	2·22	100·34	Nil	54·39	1·06	51 : 1
107A....	0·20	0·04	0·11	0·02	98·34	1·37	100·08	0·01	55·08	0·65	85 : 1
107B....	0·80	0·12	0·25	0·02	96·84	1·51	99·54	0·10	54·24	0·72	75 : 1
107C....	0·17	0·05	0·16	0·02	98·21	1·09	99·70	0·10	55·00	0·52	106 : 1

99. Marble Canyon. One hundred feet of Carboniferous limestone by the roadside at the eastern end of the canyon.
100. " Dark grey Carboniferous limestone 2 miles west of where Sample 99 was taken.
101. " White Carboniferous limestone ½ mile farther west in the canyon.
102. " Tan Carboniferous limestone 1¼ miles farther west in the canyon.
103. " One hundred feet of Carboniferous limestone exposed ½ mile farther west.
104. " One hundred and fifty feet of Carboniferous limestone exposed ½ mile still farther west.
105. Clinton. Carboniferous limestone on the side of the Marble mountains 5 miles southwest of the village.
106. " Two hundred and fifty feet of Carboniferous limestone 2¾ miles southwest of the village.
107A. " Top 12 feet of calcareous tufa in railway cut 2 miles southwest of Clinton.
107B. " Bottom 11 feet exposed of same deposit.
107C. " Eighteen feet of tufa near southwest end of the cutting.

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CANADA
DEPARTMENT OF MINES AND RESOURCES
MINES AND GEOLOGY BRANCH
BUREAU OF MINES
DISTRIBUTION OF LIMESTONE
SOUTHERN BRITISH COLUMBIA
AND
SOUTHWESTERN ALBERTA
Scale, 1/1,520,640 or 1 Inch to 24 Miles
Miles
24 0 24 48 72
LEGEND
CRETACEOUS AND TERTIARY (mainly)
KT Sedimentary rocks, mainly sandstones and shales
PALÆOZOIC TO TERTIARY
P-T Mixed rocks, mainly Mesozoic and Tertiary intrusives and volcanics. Limestone deposits occur in rocks of late Palæozoic and Triassic age
PALÆOZOIC (mainly)
P Cambrian to Carboniferous formations, largely limestones
PRECAMBRIAN
P€ Sedimentary and metamorphic rocks with occasional limestone beds
20 Sample number
Outcrop or inactive quarry
Operating quarry
Commercial lime plant
Lime plant operated in connection with another industry
Portland cement plant
Calcium and high-calcium limestone
Dolomite
Magnesian limestone
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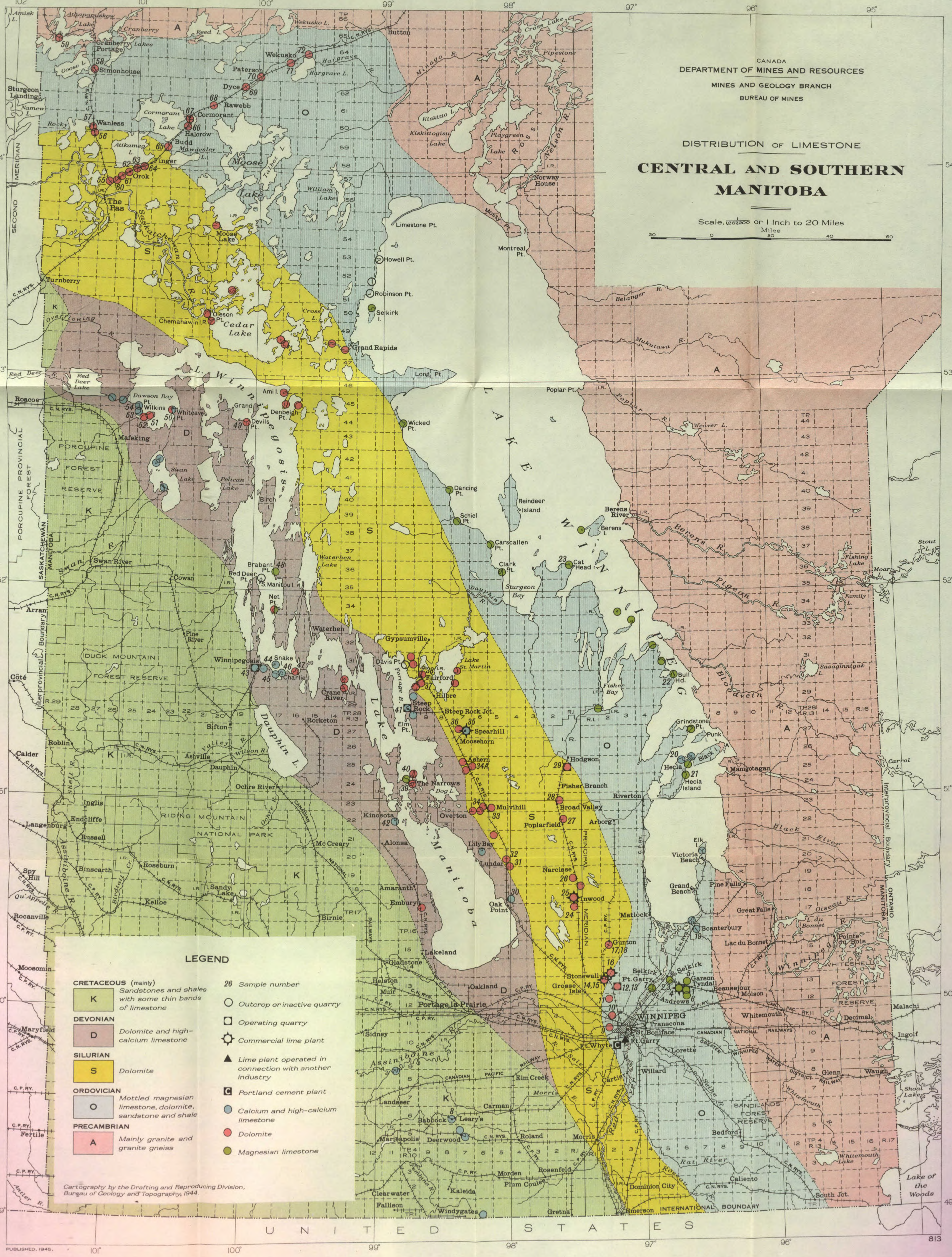
ALBERTA
PACIFIC OCEAN
UNITED STATES
Queen Charlotte Sound
Strait of Georgia
Vancouver Island
VANCOUVER
VICTORIA
CALGARY
Prince Rupert
Prince George
Kamloops
Revelstoke
Banff
Nelson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DISTRIBUTION OF LIMESTONE
CENTRAL AND SOUTHERN MANITOBA
Scale, 1:1,267,200 or 1 Inch to 20 Miles
Miles
LEGEND
CRETACEOUS (mainly)
K Sandstones and shales with some thin bands of limestone
DEVONIAN
D Dolomite and high-calcium limestone
SILURIAN
S Dolomite
ORDOVICIAN
O Mottled magnesian limestone, dolomite, sandstone and shale
PRECAMBRIAN
A Mainly granite and granite gneiss
26 Sample number
Outcrop or inactive quarry
Operating quarry
Commercial lime plant
Lime plant operated in connection with another industry
Portland cement plant
Calcium and high-calcium limestone
Dolomite
Magnesian limestone
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