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Haddington Island andesite and Jervis Inlet granite. Buildings of the Legislative Assembly of British Columbia, and sea-wall, Victoria, B.C.

CANADA

DEPARTMENT OF MINES

HON. ES. L. PATENAUDE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER;

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

REPORT

ON THE

Building and Ornamental Stones

OF

CANADA

VOL. V

PROVINCE OF BRITISH COLUMBIA

BY

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

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LETTER OF TRANSMITTAL.

EUGENE HAANEL, PH.D.,

Director Mines Branch,

Department of Mines,

Canada.

SIR,—I have the honour to submit herewith the fifth volume of a Report on the Building and Ornamental Stones of Canada. The earlier volumes of the series, already published, deal successively with the Building and Ornamental Stones of Ontario, the Maritime Provinces, Quebec, and the Prairie Provinces. The present volume is devoted to an account of the Building and Ornamental Stones occurring in the Province of British Columbia.

I have the honour to be, Sir,

Your obedient servant,

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

University of Toronto,
April 23, 1917.

AUTHOR'S PREFACE.

Under instructions from the Director of the Mines Branch (Dr. Eugene Haanel), I spent the field season of 1916—from May 27 to August 31—in making an examination of the quarries and of reported occurrences of stone suitable for structural purposes in the Province of British Columbia.

All quarries which have produced structural stone in commercial quantity were visited, and in addition, a number of others which have been worked for crushed stone, lime-making, etc. It was thought advisable to include quarries of this type in order to ascertain if they offer any encouragement from the present point of view. The information thus gained is chiefly of a negative character, but it has been included in the report, as practically any sort of stone is of possible value as building material. Quarries of building stone in the narrower sense are those which are operated solely or primarily for the production of structural stone; it is thought that all such quarries are included in the report. While most of the quarries operated for other purposes were visited, the report does not pretend to be complete in this respect. In addition to actual quarries, a large number of outcrops were examined, to which attention was drawn by the existing literature on the subject, or by information obtained from private sources. It is manifest that considerable discretion had to be used in selecting the localities of this type to be visited, as some of the reported occurrences are too remote or inaccessible to make a visit possible in the time available for the investigation.

In accordance with the plan followed in the earlier volumes of this report, a geological basis of classification has been adopted, although it is freely admitted that this method is less satisfactory in the case of British Columbia. The reason for this lies in the great number of formations, and in the lack of definite correlation of the formations of different districts. A strict adherence to the geological method of classification, or an attempt to present the subject to the satisfaction of the purely scientific reader, would obscure the economic essentials under a mass of detail quite foreign to the purpose of this report. In the chapter dealing with the geology of the province, certain geological tables are used: these are intentionally incomplete, and are not intended for the use of scientists, but merely to give the average reader a rough idea of the position in the time-scale of certain strata capable of yielding building stone.

Critical readers will doubtless find many instances of scientific inaccuracy: many of these are due to the necessity for brevity, and are justified by the fact that the report is primarily intended for the use of non-scientific readers. Other inaccuracies are due to a desire to avoid ultra-technical terms; for instance, a stone may be called "granite" in the general description, but "granodiorite" in the more detailed account. In the chapters on granites and black granites the grouping of the various stones is quite indefensible on scientific grounds, and is determined entirely by those superficial resemblances in building stone which strike the eye of the average operator. Numerous examples might be referred to: they are not due to carelessness in preparation, but to the desire to preserve a reasonable mean between the scientific and the popular.

While the report is thought to be fairly complete with respect to known occurrences of valuable stone, it is to be remembered that British Columbia contains vast tracts of rocky country, of which, practically, nothing is known. It is manifest, therefore, that the general conclusion drawn from this report as to the resources of the province in building stone is not to be construed as expressing in any way the possible, or even probable, limits of production. This observation is made necessary by the fact that the earlier volumes are more or less expressive of the total probabilities of production; in the fourth volume particularly, an attempt is made to point out the possibilities of all the rock formations of Manitoba, Saskatchewan, and Alberta. An effort to apply this method to British Columbia, in one season's operations, would be ludicrous.

The first chapter of the report is devoted to a general account of the stone industry in the province, to a synopsis of the method of testing, and to a summary of results. The descriptions of the tests are given only in sufficient detail to render intelligible the body of the report. For further information readers are referred to the corresponding parts of the earlier volumes. Experience has shown that crushing strength determinations at high pressures are too inaccurate to serve as a satisfactory means of comparing dry, wet, and frozen cubes of stone, like granite. In consequence, this comparison has been omitted in the case of these stones, and the cubes have all been crushed dry with a view to ascertaining the range of variation, and of calculating the "probable error" of the experiment.

As pointed out in the fourth volume, the application of a uniform chiselling test to all kinds of stone is inappropriate; consequently two methods of chiselling have been devised. The softer stones have been tested by both methods.

The systematic portion of the report is divided into chapters, each of which is devoted to a particular class of stone. Within the chapters the descriptions are arranged, first, on a geological basis, second, on a geographical basis. The minor arrangement of matter is effected by establishing certain more or less indefinite districts termed "areas." The individual properties are described as far as possible under the name of the owner which is conspicuously printed in italics. In a general way the subject matter of each description is arranged as follows:—

Location.

Description of quarry.

General description of the stone.

Physical tests.
Chemical analysis.
Quarrying methods.
Prices, statistics, and economic remarks.
Buildings constructed of the stone.

At convenient points short summaries are introduced for the benefit of readers desirous of general rather than of detailed information. These summaries necessarily involve a certain amount of repetition, which, however, seems to be justified by the purpose of their insertion, as stated above.

The material for testing was prepared in the laboratory of the Royal Ontario Museum of Geology, Toronto. The transverse and shearing strength tests were made by Mr. Robert Marshall, on an Olson wire testing machine in the strength-of-materials laboratory of the University of Toronto. The crushing strength determinations were made on the 100-ton Wicksteed machine at McGill University, Montreal, by Mr. S. D. McNab. Mr. Alexander MacLean of the University of Toronto conducted all the experiments, and made the numerous weighings in connexion with the determination of porosity, specific gravity, corrosion, etc. The analyses were made in the laboratory of the Department of Mines at Ottawa.

In carrying on the field work, assistance and information was received from numerous gentlemen to whom I desire to express sincere thanks. Mr. W. Fleet Robertson, Provincial Mineralogist, Victoria, greatly assisted with information as to localities of occurrence, and with advice as to itinerary; hospitality, and assistance in transportation was received from Mr. Hugh Keefer of the Vancouver Granite Co., the Sechelt Granite Co., the Malaspina Marble Co., Mr. W. S. McDonald of Vancouver, Major Hull of Prince Rupert, and many others. I am again indebted to Dean Adams and Professor MacKay of McGill University for permission to use the large Wicksteed machine for determinations of crushing strength.

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CHAPTER I.

INTRODUCTORY.

VARIETIES OF BUILDING AND ORNAMENTAL STONE OCCURRING IN THE PROVINCE OF BRITISH COLUMBIA. OUTLINE OF THE PROCEDURE IN TESTING WITH A SUMMARY OF RESULTS.

The commercial production of building and ornamental stone in British Columbia is confined to the sandstones of the Gulf islands; the granites of the Coast range, Okanagan lake, and the Nelson district; and the marbles of Kootenay lake, Texada island, and Nootka sound.

The sandstones have been quarried near Nanaimo and at Koksilah on Vancouver island, and on Denman, Hornby, Newcastle, Gabriola, Saltspring, Mayne, Pender, and Saturna islands. The stone is normally of a greyish-blue colour, but it alters rapidly to buff, and is quarried in that condition to some depth from the surface in certain of the quarries.

The granites of the Coast range vary greatly in mineral composition, colour, and grain. The most important quarries, in a medium-grained grey type of stone, are on the islands off the mouth of Jervis inlet. Stones of darker colour have been quarried in small quantity near Prince Rupert, and also at Agassiz and Cathmar on the line of the Canadian Pacific railway.

The Nelson granites are of the same general type as the Coast range stones, but they are lighter in colour, and usually coarser in grain. The Okanagan granites are of medium grain and pinkish colour; they have been quarried to a very small extent for local use only.

A white and blue-banded marble is quarried north of Kootenay lake and a very similar stone has been procured from Nootka sound on the west coast of Vancouver island. In the interior and at many points along the coast occurrences of marble of this same general type have been reported, but all that have been investigated seem to be too shattered for commercial exploitation. A very handsome red marble has been worked to a small extent near the southern extremity of Texada island, and fine-grained red and white varieties occur in abundance in the mountain above Grant Brook on the line of the Grand Trunk Pacific railway.

Decorative stones other than marble have received little attention, but some of the dark basic rocks of Rossland and Ymir are mentioned as sources of monumental stone. Sodalite and sodalite-bearing syenite from Ice river, fine black carbonaceous slates from Queen Charlotte island, and basic phases of the Coast range rocks are of possible value as decorative stone.

A full description of the methods of testing will be found in the introductory chapters of the earlier volumes of this report. The reader is advised to acquaint himself with the general principles therein considered before attempting to make practical use of the figures recorded in this volume.

The physical constants determined for each stone are indicated in the list below and they are recorded in the same order throughout the report:—

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

(a) *The specific gravity* was determined by the use of one-inch cubes of the stone which had been thoroughly soaked by treatment under reduced pressure and afterwards under a pressure of 2,000 lbs. to the square inch. The saturated cube was weighed while suspended by a fine silken thread in water, dried for 24 hours at a temperature a little above 100°C. and again weighed in air. The specific gravity is the weight in air divided by the loss of weight in water. It was found advisable to make the dry weighing after soaking and not before, as certain stones suffer a loss owing to solution during the process.

The ten sandstones tested vary but little in gravity, ranging from 2·656 for the Newcastle Island stone to 2·713 for the dark Denman Island type: the average is 2·67. The average gravity of ten marbles is 2·75, but if the two dolomitic stones from Grant Brook be omitted the average is 2·72 with very little variation. The igneous rocks range from 2·901 for the monzonite of Coryell to 2·643 for the reddish Shuswap granite from Okanagan lake.

(b) *The weight per cubic foot* was calculated by multiplying the weight of a cubic foot of water (62·426 lbs.) by the specific gravity of the stone and deducting the pore space as determined in "c."

Ten sandstones vary from 141·07 lbs. to 157·21 lbs. per cubic foot, with an average of 149·2 lbs. Eight ordinary marbles vary but little and give an average of 169·71 lbs. The two dolomitic marbles from Grant Brook have an average weight of 177·5 lbs. per cubic foot.

The "granites" fall naturally into two classes: the light-coloured types more nearly related to true granites and the dark rocks of more basic composition. The former show an average of 165·2 lbs. for 11 examples, and the latter 174·5 lbs. for 5 examples.

The lightest rock tested is the volcanic tuff from Dease lake near Kamloops which weighs only 135·9 lbs. per cubic foot.

(c) *The pore space* was determined as follows: The cube saturated for the gravity determination was weighed wet and from this weight was subtracted the dry weight of the cube. The difference is evidently the weight of the water in the pores of the stone. This difference was multiplied by the specific gravity of the stone and added to the weight of the dry cube, thus giving the weight of the cube if it were solid stone. The pore space per cent is easily calculated from the figures thus obtained.

Ten sandstones vary from 8·15 per cent to 15·55 per cent with an average of 10·7 per cent. Ten marbles vary from 0·177 per cent to 0·699 per cent with an average of 0·407 per cent. Sixteen granites and other igneous rocks vary from 0·618 per cent for the Granite Island stone to 1·559 per cent for the rock north of Kamloops lake.

The most porous stone is the volcanic tuff from Dease lake (18·02 per cent). The andesite of Haddington island shows 13·96 per cent.

(d) *The ratio of absorption* is the weight of the water absorbed under different methods of soaking expressed as a percentage of the dry stone. The conditions of soaking should be made to conform as far as possible to the conditions which will prevail when the stone has been placed in the building. It is obvious that all conditions which may be desirable can not be duplicated in the laboratory for a general work such as this; nevertheless, it is thought that determinations for one hour, for two hours, by slow immersion, in vacuo, and under pressure will meet all ordinary requirements.

The determination for one hour was made by plunging the thoroughly dried cube under distilled water for one hour, and immediately weighing while wet. The difficulty attending the weighing of wet objects has been referred to in earlier volumes of this report: a certain latitude must always be allowed for possible error.

(e) *The ratio of absorption for two hours* was determined in the same way as for one hour.

(f) *The ratio of absorption for slow immersion* was determined by placing the test cubes in a shallow vessel to which water was admitted at such a rate that the cubes were entirely covered in four hours. Before being weighed they were allowed to remain under water for 48 hours.

(g) *The ratio of absorption in vacuo* was determined by placing the cubes in a vessel containing a little water and exhausting the air by a water pump. After 24 hours treatment the cubes were flooded by allowing water to be gradually drawn into the vessel.

(h) *The ratio of absorption under pressure* was determined by subjecting the cubes from the vacuum test (without drying) to a pressure of 2,000 lbs. to the square inch for 24 hours.

The ten sandstones gave the average results shown in the table below. It will be noted that the greatest increment occurs between the two-hour and the slow-immersion tests:—

Average Ratios of Absorption and Increments for Ten Sandstones.

	One hour	Two hours	Slow immersion	In vacuo	Under pressure
Ratio of absorption	2·411	2·665	3·552	4·090	4·518
Increment.........	....	·2543	·887	·538	·428

A similar table for 16 granites shows that the greatest increment occurs between the slow-immersion and vacuum tests:—

Average Ratios of Absorption and Increments for Sixteen Granites.

	One hour	Two hours	Slow immersion	In vacuo	Under pressure
Ratio of absorption	·232	·243	·298	·371	·404
Increment ...	....	·011	·055	·073	·033

Ten marbles indicate that the maximum increment occurs between the slow-immersion and vacuum experiments and also that the increase between the vacuum and pressure experiments is relatively higher than in the other classes of stone. The table follows:—

Average Ratios of Absorption and Increments for Ten Marbles.

	One hour	Two hours	Slow immersion	In vacuo	Under pressure
Ratio of absorption.	·095	·103	·117	·133	·147
Increment.........	....	·008	·014	·016	·014

The ratios of absorption under the different conditions are recorded for all the stones tested in Table II of the Appendix. The *true* ratio of absorption is that obtained under pressure, as in this case the stone contains all the water it is possible to force into it: this figure only is recorded as the "Ratio of Absorption" in Table I.

(i) *The coefficient of saturation* is an expression indicating the extent to which a stone is saturated under the conditions of the experiment: it is expressed in the form of a decimal fraction. For example, if a given sample under the two-hour test has a ratio of absorption of 4 per cent, and under the pressure test a ratio of absorption of 8 per cent, it has a coefficient of saturation of 0·5 for two hours soaking.

This factor is thought to be indicative of the power of the stone to withstand the action of frost. The injury effected by frost is due to the expansion of the included water in passing into the form of ice: this expansion is equal to one-tenth of the volume of the water. If the pores of the stone are less than nine-tenths full, there is room for the water to expand, and no injury results. In other words, if the coefficient of saturation is less than ·9, theoretically, there is no danger of injury, but for practical reasons that need not be considered here, it is found better to consider ·8 as the critical figure. (See page 62 *et seq.*, Vol. I.)

It is apparent that one may desire to know this factor for many different conditions of soaking, which should simulate as far as possible the conditions under which the stone would be wetted and frozen after being placed in the structure. The factor has been determined for short immersions of one and two hours, and for slow immersion and long soaking as described under "f"; it has also been determined for the soaking in vacuum but this is of scientific interest only as the condition would not be met in nature. The *true* coefficient of saturation is the figure obtained for the slow soaking method and this only is recorded in Table I of the Appendix.

It is to be distinctly understood that this factor expresses only the *liability* to injury by freezing; it is independent of the amount of water present and, therefore, can not indicate the extent of the injury; and further it makes no allowance for the resisting power of the stone.

Under the one-hour experiment none of the stones reach the danger point of ·8. Ten sandstones vary from ·28 to ·65. Sixteen granites range from ·41 to ·71 and 10 marbles show factors between ·51 and ·78 with a generally higher average than in the other two classes of stone. The highest figure obtained was for the volcanic tuff from Dease lake (·75).

(j) *The coefficient of saturation for two hours soaking*, with one doubtful exception, never reaches the danger point. The increment over the one-hour test is usually small, but there are some interesting differences in the behaviour of individual stones.

(k) *The coefficient of saturation for slow soaking* shows a heavy increment over the two-hour factor in the case of the sandstones and granites, but a less relative increase in the case of the marbles. Four out of the 10 sandstones exceed the danger point of ·8. Of these 4 stones only one is seriously injured by the actual freezing test, but the stone with the highest factor, although not greatly affected by the freezing test, has a very bad reputation in this respect. On the other hand, certain stones with a relatively low coefficient suffer greatly under the freezing test. These observations tend to strengthen the opinion already expressed that the coefficient indicates liability only, and the actual freezing test indicates the power of resistance of the stone and not its action under normal freezing.

Four out of 16 granites exceed the critical point. The darker coloured and more basic stones seem to be in the greatest danger.

(l) *The coefficient of saturation in vacuo* is always high and exceeds the critical point in all the granites and marbles. In the case of one sandstone alone does the factor fall below·8. Scientific interest only attaches to these figures as this method of soaking is never duplicated under natural conditions.

(m) *The dry crushing strength* was determined on cubes of stone approximately two inches in dimensions. The cubes were made as carefully as possible, and the bearing faces ground as plane and parallel as the mechanical facilities of the laboratory would permit. The cubes were allowed to dry for several weeks at the ordinary temperature of the laboratory, and were crushed in the 100-ton Wicksteed machine at McGill University, Montreal. The bearing faces of the cubes were protected by sheets of blotting paper, and the pressure was applied by polished, case-hardened, steel plates.

Ten sandstones gave an average strength of 13,573 lbs. per sq. in.; a minimum of 8,256 lbs. was obtained for the buff Hornby Island stone (No. 1486) and a maximum of 27,229 lbs. per sq. in. for the fine-grained stone from Saltspring island (No. 1441). The average crushing strength of the Paskapoo sandstone of Alberta is only 7,320 lbs. and an average of 10,571 lbs. per sq. in. is shown by 32 sandstones from the Maritime Provinces.

The high average of the British Columbia stones is unduly increased by the inclusion of the remarkably strong stone from Saltspring island.

Excluding this stone, the average of the nine others is 12,055 lbs. per sq. in. It is apparent, therefore, that the Cretaceous sandstones of the Coast rank higher in average crushing strength than the other important groups of Canadian building sandstones.

The Cambrian marble from Grant Brook is much the strongest of this class of stone—34,670 lbs. per sq. in.—and the weakest is the Kootenay marble from Marblehead—11,943 lbs.

Fourteen granites show a strength ranging from 23,291 lbs. per sq. in. to 36,608 lbs., with an average of 30,959 lbs. per sq. in., which is almost the same as that obtained for 12 granites from the Province of Quebec.

In the case of the granites, the crushing strength determinations were made on several cubes cut from the same block and with the bearing faces similarly disposed with respect to the grain and rift. The greatest care was taken to make the cubes as perfect as possible, in order that the probable error of the determinations might be calculated. I am of the opinion that no essential differences were present in the different cubes of the same stone, nevertheless, the figures obtained show a wide variation in results. In four cases triplicate experiments did not vary more than 1,000 lbs. per sq. in. In one case the variation was between 1,000 and 2,000 lbs. per sq. in., and in two others it was between 2,000 and 3,000 lbs. In all other cases the variation exceeded 3,000 lbs. per sq. in. between the minimum and maximum figures. The most unsatisfactory figures obtained was a maximum variation of about 6,000 lbs. Two "black granites" show a variation between 1,000 and 2,000 lbs. per sq. in. in triplicate experiments.

The variation can be due to three different causes as follows:—

(1) Variations in the cubes due to flaws or imperfections in making.

(2) Inherent causes of variation in the stone substance.

(3) Instrumental error.

I am of the opinion that in the case of these solid and homogeneous stones and in view of the great care taken in the preparation of the cubes that the first set of causes plays very little part in the variation. Several results in which this factor was possibly of importance have been entirely neglected in the compilation of results.

The fact that the lack of agreement is much greater in some cases than in others seems to indicate that the quality of the stone has some bearing on the amount of variation. Nevertheless, the four stones that show the least variation have little in common; they include both coarse and fine-grained types, varieties with granitoid and gneissoid structure, and examples of different composition—monzonite, quartz diorite, and granodiorite.

Instrumental error seems to be the most important factor in the variation; not being a mechanical engineer, I do not feel competent to attempt an explanation. I can merely say that in using the Wicksteed machine of McGill University the best available instrument in Canada was employed.

Mr. McNab who operated the machine is thoroughly familiar with its construction and has had a long experience in work of this kind. It must be admitted, however, that many of the cubes began to fail from one corner and did not show the sudden collapse which, if my conclusions as expressed in the first volume of this report are correct, is the only ideal manner of failure.

With regard to the interpretation of the results one may regard the maximum figure as the nearest approximation to the true crushing strength or he may so consider the arithmetical mean of the results obtained. Under the conditions of the experiment it is difficult to imagine that the maximum figure can be much in excess of the true strength. Errors are much more likely to occur by failures taking place before the maximum strength is reached, owing to differential bearing or other peculiarities of the instrument.

In Table III will be found a complete compilation of the results with the probable error of a single experiment calculated by the formula:—

$$\text{Probable error} = \cdot 6745\sqrt{\frac{\Sigma (v^2)}{n-1}}$$

$\Sigma (v^2)$ = The sum of the squares of the differences between each result and their arithmetical mean.

n = Number of experiments.

The probable error in the arithmetical mean is calculated from the formula:—

$$\text{Probable error} = \cdot 6745\sqrt{\frac{\Sigma (v^2)}{n(n-1)}}$$

These calculations are not introduced on account of the value they may have to the users of the stone in question but as a commentary on the determination of crushing strength. It is to be understood also that these "probable errors" are complex expressions involving the character of the stone and the individual peculiarities of the Wicksteed machine at McGill University.

The maximum probable error of a single experiment was found to be 2,440 lbs. per sq. in. The average of the probable errors for 15 stones was 934 lbs. per sq. in. The maximum probable error in the mean of 2 to 4 experiments for a single stone was 1,613 lbs. per sq. in. The average of the probable errors of the means of 2 to 4 experiments for 15 stones was 644 lbs. per sq. in. We may conclude, therefore, that for granites and related rocks, crushing at about 30,000 lbs. per sq. in., the probable error of a single determination of crushing strength is 934 lbs. per sq. in. and that the probable error of the average of 2 to 4 determinations is 644 lbs. per sq. in. It is apparent that this error is too great to justify the use of crushing strength as a means of comparison between dry, wet, and frozen specimens of this class of stones. In view of the experience thus gained, I would recommend the use of some other method for comparisons of this kind.

(n) *The determination of the crushing strength of wet samples* is regarded as a good means of measuring the relative durability of stones. Cubes for this purpose were prepared for all the softer stones. They were soaked by subjecting them to a water pressure of 2,000 lbs. per sq. in. for 24 hours. The difference between the crushing strengths, dry and wet, indicates the loss of strength on soaking and is indicative of the general durability of the stone.

In the case of 10 sandstones the results were very satisfactory. The average loss was 3,552 lbs. per sq. in. which is practically one-third of the average dry crushing strength. The stones most seriously affected are of very different character—the hard, fine-grained stone from Saltspring island (No. 1441) and the soft blue stone from Denman island (No. 1481). The sandstone least affected in this respect is the average product of the quarries on Gabriola island (No. 1488).

In the case of the marbles, with their low porosity, the differences are too slight to be significant. The andesite from Haddington island is seriously affected, but the volcanic tuff from near Kamloops shows no loss whatever.

(o) *The wet crushing strength after freezing* was determined on cubes soaked as above, and alternately frozen and thawed 40 times. The loss in strength compared with the wet samples indicates the susceptibility of the stone to mechanical disintegration. It is not to be regarded as expressing the frost-resisting properties of the stone under normal circumstances, for cubes of stone thus unnaturally soaked are in a very different condition to that which prevails in stone only partially soaked by exposure to the weather.

The greatest loss was observed in the case of the Hornby Island stones, and the least in the case of the buff stone from Saturna island and the hard stone from Saltspring island. The loss in the case of the marbles is too slight to be significant, and in some cases the frozen stone shows an increase. This apparently anomalous result has been observed in other cases; for instance, Prouty states in his report on Alabama marbles—"A peculiar feature of these tests is the fact that the frozen cubes gave higher compressive tests, in all cases except one, than the unfrozen. This peculiarity has been found occasionally in tests of other stone at this laboratory and at present we are not able to offer any definite explanation for it.[1]"

Haddington Island andesite is appreciably affected and the volcanic tuff from near Kamloops shows complete disintegration under the test.

(p) *The transverse strength* was determined on slabs approximately one inch thick and two inches wide. They were broken in an Olson wire-

[1] Geol. Sur. Alabama, Bull. 18, p. 103, 1916.

testing machine the supports being five inches apart. The modulus of rupture (transverse strength in lbs. per sq. in.) was calculated from the following formula:—

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

R = modulus of rupture.

l = length in inches (in each case l = 5).

b = width in inches.

d = thickness in inches.

W = load in lbs.

Sixteen granites or other igneous rocks gave a maximum of 3,521 lbs., a minimum of 1,453 lbs., and an average of 2,284 lbs. The strongest stones in this respect were the granodiorite from Granite island and the rock from north of Kamloops lake. The weakest were the granodiorites from Hardy island and from Smith island.

Ten sandstones gave a maximum of 2,296 lbs., a minimum of 704 lbs., and an average of 1,084 lbs. Much the strongest stone is that from Saltspring island; other stones strong in this respect are the Newcastle Island stone, the buff variety from Saturna island, and the blue stone from Denman island. The other varieties tested vary so little that it is inadvisable to discriminate among them. It is worthy of note that these sandstones greatly exceed the Paskapoo sandstone of Alberta in transverse strength, as the latter average only 496 lbs. per sq. in.

The marbles vary from 1,254 lbs. for the coarse white stone from Kootenay lake to 2,466 lbs. for the red marble from Texada island. Haddington Island andesite gave 1,160 lbs., and the soft white stone from Dease lake showed the unexpectedly high transverse strength of 2,622 lbs. per sq. in.

(q) *The shearing strength* was determined in the manner described in the third volume of this report. The figure recorded is obtained by dividing the total load in pounds by the cross-section of the test-piece in square inches.

The sixteen granites gave a maximum of 2,807 lbs., a minimum of 1,393 lbs., and an average of 2,010 lbs. per sq. in. In all but three cases the shearing strength is lower than the transverse strength, with an average ratio of 1 : 1·13. Omitting the three cases where the shearing strength is higher than the transverse strength, the ratio becomes 1 : 1·22. It is interesting to compare these figures with those obtained for eleven granites from the Province of Quebec which showed an average shearing strength of 1,800 lbs. and an average transverse strength of 2,442 lbs. with a ratio of 1 : 1·3. The average shearing and transverse strength and the ratio between the two do not differ greatly in the two provinces.

Ten sandstones gave a minimum shearing strength of 628 lbs., a maximum of 1,925 lbs., and an average of 1,190 lbs. per sq. in. While the difference is not great, the average shearing strength exceeds the transverse: in this respect the sandstones differ from the other classes of stones examined. Of the ten sandstones, however, three have a greater transverse than shearing strength. These sandstones are much higher in shearing strength than the Paskapoo sandstones of Alberta which average only 70 lbs. per sq. in.

Eight marbles have an average shearing strength of 1,352 lbs. with a maximum of 1,688 lbs. for the coarse-grained white marble from Kootenay lake, and a minimum of 1,097 lbs. for the dark stones from the same locality.

Haddington Island andesite has a shearing strength of 1,156 lbs. and the soft white stone from Dease lake is unexpectedly high in shearing as well as in transverse strength as the former factor is 2,142 lbs., the highest figure obtained for any stone except the granites.

(r) *The corrosion test* is an attempt to subject the stone in an intensified manner to the active corroding agents present in the atmosphere. The cubes were suspended in a bottle filled with water into which streams of oxygen and carbonic acid were allowed to pass for a period of four weeks. The apparatus has been described in detail and figured in Vol. IV.

The loss in weight per square inch of surface exposed is roughly indicative of the disintegration which would result from a long exposure to the atmosphere. It is not really a measure of the changes that have occurred in the stone, as partial solution and loss may be made up by oxidation, as was distinctly observed in the case of some of the sandstones.

The test is of greater value as indicative of the changes in colour that may be expected to occur on exposure to the weather. The results of the test are given in Table VIII of the Appendix.

In this connexion may be mentioned some of the difficulties experienced in obtaining the exact weight of some of the dry cubes, not only for this experiment but for all the tests dealing with porosity. Despite the greatest care in thoroughly drying the stone for 24 hours at a temperature above 100°C. it was found that the weight almost invariably differs after any of the soakings. Assuming that no mechanical error occurs, and with a good balance and experienced manipulation there should be no such error, we must conclude that in some cases oxidation results in an increased weight and in others that solution occasions a loss. Under ordinary soaking the blue sandstones invariably increase in weight but under the pressure test they lose. The marbles usually show a slight loss with each ordinary soaking but under the pressure test the loss is pronounced. The loss is doubtless due, in large part, to solution, but decarbonation during the operation of drying may play a part in the variation. As no refinement of manipulation seems able to overcome this variation, it is necessary to determine whether the dry weight before the experiment or that obtained after is best suited as a basis for the calculation. For certain reasons that need not be discussed here, as they refer only to the procedure adopted, the following method was followed in all the tests:—

The dry weight before the experiment.	The dry weight after the experiment.
Two-hour soaking.	One-hour soaking.
Vacuum soaking.	Slow immersion.
Corrosion.	Pressure soaking.
	Specific gravity.
	Pore space.

(s) The difficulties attending the determination of an expression to denote the relative ease with which stones may be worked have been considered in some detail in the earlier volumes. No single expression to represent this property has yet been devised, but the stones have been subjected to two tests, the results of which are recorded as the *drilling factor* and the *chiselling factor*.

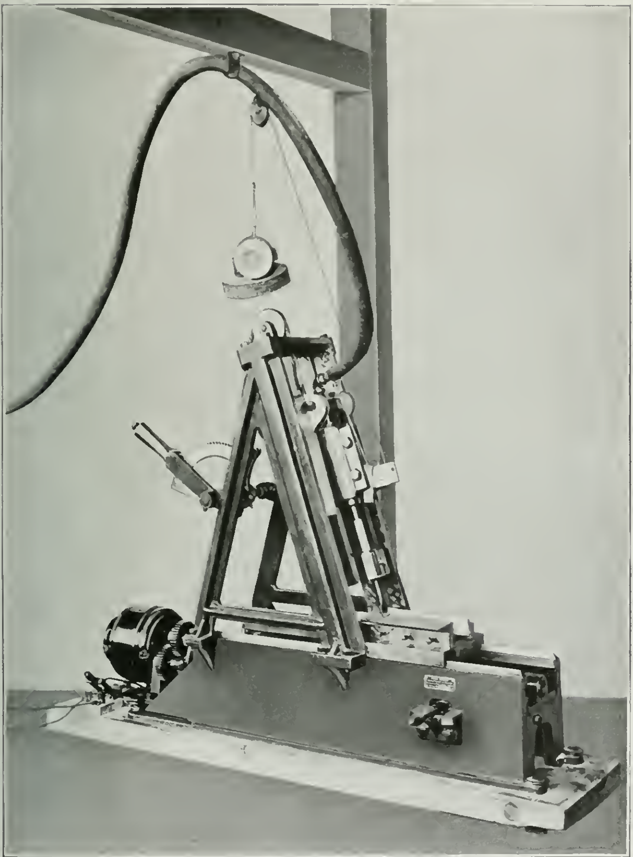
The former test was carried out by allowing a half-inch + bitted drill to sink into the stone for 30 seconds. The drill was pressed down by a weight of 8 pounds and actuated by a size A Barre pneumatic tool under an air pressure of 60 pounds. The depth of the hole in millimetres is recorded directly as the drilling factor. The drills were tempered and sharpened as nearly alike as an expert workman could make them, but some latitude must be allowed on account of the impossibility of exact uniformity. Duplicate experiments in certain stones agree very closely; in others a variation as high as 10 per cent is observed. The test is more satisfactory with soft stones, as the rapid dulling of the tool with hard stones tends to greater variation in duplicates. Within the different classes of stone the expression is of value, but comparisons between the figures given for granite and those recorded for sandstones should not be made—a tool sharpened to a blunter edge would increase the figures for granite and decrease those for sandstone. It is to be remembered that neither the drilling nor the chiselling factor are offered as expressions representing the ease of working; they are simply the results of fixed experiments and are offered as aids in forming conclusions as to this property in the stones examined.

The results of the drilling experiment as recorded in this volume may be compared with the figures of Vol. IV, but not with those of earlier volumes, as some changes were made in the manner of conducting the test.

Sixteen granites or other igneous rocks were tested with results ranging from 3·5 mm. in the case of the granite west of Nelson to 9·2 mm. for the monzonite from Coryell. The Okanagan granites are more easily drilled than those of the Coast range and of the Nelson batholith.

The sandstone from Saltspring island (12·4) and that from Newcastle island (15·1) are the hardest to drill. The softest sandstones are those from Hornby island (37·4 and 38). The other commercial sandstones from

PLATE II.



Instrument used for chiselling and drilling tests.

the Gulf islands vary from 19·6 to 27·8, whereas the commercial Paskapoo sandstones of Alberta vary from 9·6 to 32·3.

Of the marbles, the hardest to drill are the red Malaspina stone from Texada island (16·0) and the white coarse-grained stone from Kootenay lake (15·4). The dark stone from the latter locality is the softest (27·4).

The softest stone tested is the tuff from Dease lake (46·8). The andesite from Haddington island gave a test of 19·6.

(t) *The chiselling factor* was determined in the manner described in the fourth volume of this report by means of the apparatus shown in Plate II. The figure recorded as the *chiselling factor* is the weight in grams of the material removed by a three-quarter-inch chisel actuated by a pneumatic tool through a distance of three inches in approximately ten seconds. The experiments were conducted under two sets of conditions, and are referred to as the light and the heavy test, respectively. In the light test (I) the tool was inclined at 51° to the surface of stone acted upon, was pressed down by a weight of 3½ lbs., and was operated under an air pressure of 40 lbs. In the heavy test (II) these constants were 54° 30′, 8 lbs., and 60 lbs.

The most easily chiselled sandstone under both tests was the buff stone from Hornby island (3·6 and 11·3). The lowest results were obtained for the fine-grained stone from Saltspring island (0·15 and 1·1). The heavy test shows a greater relative increase over the light test in the case of the harder stones where it is about nine times as much, whereas in the softer stones it is increased about three times. The hardest stones to drill are also the hardest to chisel, while the easiest to drill are the easiest to chisel, but this ratio does not hold throughout the whole series. For instance, the rather coarse sandstone from Jack point near Nanaimo has a high drilling factor (25·4), but its chiselling factors are low (1·0 and 3·9).

The darker marble from Marblehead is the most easily chiselled under either test, but it is surpassed by several others in the drilling factor. The lowest chiselling factors were obtained for the white marble from Nootka sound, which is also low, but not the lowest in drilling factor. The dark stone is more easily chiselled than the white in all the cases tested—Nootka sound, Marblehead, and Kaslo.

The highest chiselling factor of all the stones tested was obtained for the volcanic tuff from Dease lake near Kamloops which gave 5·6 under the light test: no figure could be obtained for the heavy test as the chisel dug into the stone and the apparatus would have broken had not the machinery been stopped.

The chemical analyses of sandstones indicate that all the commercial stones have an argillaceous cement with a considerable amount of ferrous oxide and very little ferric oxide. The marbles are all calcium carbonate with more or less argillaceous matter with the exception of the stones from Grant Brook which are highly dolomitic. The granites were examined for sulphur only, with the object of determining the content of pyrite.

The Coast range types average about 0·005 per cent of sulphur; the Shuswap granites of Okanagan lake range somewhat lower, the rocks of the Nelson batholith average 0·015 per cent; the dark stones of Tyee and Smith island show an average of 0·033 per cent; and the monzonite of Rossland reaches the maximum of 0·078 per cent of sulphur.

CHAPTER II.

AN OUTLINE OF THE GEOLOGY OF BRITISH COLUMBIA FROM THE POINT OF VIEW OF THE BUILDING STONE INDUSTRY.

The whole of the Province of British Columbia lies within the great mountainous tract which forms the Pacific border of the North American continent, and is commonly called the Cordilleran region. The coast of British Columbia and the mountain ranges forming the cordillera have a general trend to the north of west. The width of the province, measured at right angles to this direction, is almost 400 miles, and its eastern boundary follows the height of land of the most easterly system of the cordillera—the Rocky mountains proper—from the international boundary to latitude 54°, north of which it is coincident with the 120th meridian to the southern boundary of Yukon territory.

The eastern part of the province, throughout its entire length, is characterized, therefore, by the great masses of the Rocky mountains, rising, in places, to altitudes of 11,000 and 12,000 feet. The western or Pacific border is likewise of truly mountainous character, with the peaks of the Coast range rising to 8,000 feet and more above the level of the sea. The broad belt of country between the Coast range and the Rocky mountains is of less average elevation, but it nevertheless presents imposing mountain ranges, particularly in the southern part of the province.

Immediately west of the Rocky mountain system is a pronounced depression, which extends from Montana to the Yukon boundary, and contains the upper valleys of the Columbia, Fraser, Peace, and Liard rivers. This great depression is known as the Rocky Mountain trench. In the southern part of the province, the Rocky Mountain trench is bounded on the west by the Purcell range of mountains, beyond which lies a second depression of less magnitude—the Purcell trench—in which are the valleys of the Beaver, Duncan, and Kootenay rivers. The Selkirk system of mountains lies west of the Purcell trench, and rises to altitudes of more than 11,000 feet. The valley of the Columbia river, in part occupied by the Arrow lakes, lies west of the Selkirk range, and is succeeded westward by the Columbian system of mountains. These mountains while rugged, are a less defined topographic unit, and fade into the broad region known as the interior plateaus, which continue to the eastern boundary of the Coast range.

This great interior region, while flat in comparison with the great mountain ranges, is nevertheless of a rugged character, with an average elevation of 3,500 feet, and with peaks rising as high as 5,000 feet. In the northern part of the province, where not constricted by the intermediate ranges mentioned above, it is of greater width, and extends from the Coast range to the Rocky mountain trench. Still farther north it is less pronounced, and is interrupted by the Telegraph and other northern ranges.

Vancouver island and Queen Charlotte island represent a bordering range belonging to the same system as the Coast range, and separated by the depression in which lie the Strait of Georgia, Queen Charlotte sound, and Hecate strait.

Early in the geological history of the North American continent, it is likely that a great land mass existed in the central and western parts of British Columbia, and that the sea covered the area at present occupied by the Rocky mountain and Purcell ranges. The rocks of this continental mass were doubtless derived from the decay of a still earlier, unknown land, for they are essentially of sedimentary origin although invaded by igneous rocks of many kinds and intensely altered by the long-continued action of the forces of nature. This series of rocks was greatly reduced by erosion throughout vast periods of time, in part depressed below the sea, and covered by later accumulations, both sedimentary and volcanic. At present, these rocks, known as the Shuswap terrane, are to be seen only in a limited area in the Selkirk and Columbian mountains. The characteristic appearance of the Selkirks, with their sinuous, rim-like crests, and intermediate snow fields, attests the great age of the rocks, and their long-continued glaciation.

This great series is divided into at least five formations: showing gneisses, quartzites, schists, and limestones, and is capped by a mass of greenstone (Adams Lake greenstones) which attains a thickness of 10,000 feet.

As we have already seen, a great depression (Rocky Mountain Geosyncline), occupied by an arm of the sea, lay to the east of the early landmass. The floor of this basin gradually sank throughout many succeeding geological ages, with the result that, the debris from the land surface accumulated in the form of new strata to an enormous thickness. Later, came an upwarping of the western part of this basin, whereby the region of the Purcell range and the western ranges of the Rockies became land. Sedimentation still continued in the eastern part of the basin, which remained under water to the close of Cretaceous time.

The following table of the formations which accumulated in this great basin is an abridged form of the table given by Daly in Guide-book No. 8 of the Thirteenth International Geological Congress.

Table Showing the Formations of the Rocky Mountain Geosyncline.

System	Formation	Thickness, feet
Lower Cretaceous	Upper Ribboned sandstone Kootenay Coal Measures Lower Ribboned sandstone	550 2,800 1,000
Jurassic	Fernie shale	1,500
Permo-Triassic	Upper Banff shale	1,400
Carboniferous	Rocky Mountain quartzite Upper Banff limestone Lower Banff shale	800 2,300 1,200
Devonian	Lower Banff limestone (partly Devonian) Intermediate limestone Sawback limestone	1,500 1,800 3,700
Silurian	Halysites beds	1,850
Ordovician	Graptolite shale Goodsir shale	1,700 6,040
Upper Cambrian	Limestone and shales	9,815
Middle Cambrian	Chiefly limestone	4,963
Lower Cambrian	Chiefly quartzite	7,750 (in Selkirks)
Beltian	Quartzites, limestones, metargillites	32,750

The western part of the province seems to have remained a land surface until Pennsylvanian (Upper Carboniferous) time, when it also was partly submerged, and strata of that age were deposited on the western flanks of the axis. These were succeeded by shales and limestones of Triassic age, the deposition of which was accompanied by extensive vulcanism, with the effusion of enormous masses of basalt (Nicola group). Extensive earth movements now began to affect the western region, and resulted in a folding and puckering of the Pennsylvanian and Triassic strata. These disturbances paved the way for the enormous outburst in Jurassic time of granite and related rocks which now form the core of Vancouver island, and extend for a distance of more than 800 miles along the coast of British Columbia—in the great bordering mountains known as the Coast range.

We have seen that rock-forming continued in the eastern basin during Jurassic time (Fernie shale), and we likewise find Jurassic sediments in Queen Charlotte islands and in the northern parts of the province. Cretaceous time is also represented west of the Coast range by the sandstones and shales of the islands, and east of the range by the Hazelton series of the north and the sandstones and conglomerates of the lower Frazer river.

At the close of Cretaceous time occurred those vast movements whereby the eastern cordilleran region was broken into huge blocks by fissures having a general northwest trend. Enormous pressure exerted from the direction of the Pacific ocean elevated these blocks into the great ranges of the Rocky mountains (see Vol. IV, pp. 23-26).

From that time to the present, the geological history of British Columbia is largely one of sub-aereal decay, and intense volcanic activity. Strata of Tertiary age are confined to local accumulations, in narrow valleys in the western area. The Oligocene division of the Tertiary is marked by great volcanic flows, and fissure eruptions, which built up the great masses of igneous rocks characterizing the mining regions of southern British Columbia. The Miocene was a period of profound erosion across the cordillera, while the Pliocene witnessed a general re-elevation of the region, whereby new life was given to the streams, and a second cycle of erosion inaugurated.

The Post-Mississippian (Lower Carboniferous) rock formations of the western part of British Columbia—as may be seen from the brief account given above—are, in part, sedimentary, and in part igneous. Further, they are very complex, and in many cases local, with the result that an extensive nomenclature has arisen. Any tabulation of these formations must of necessity, in a work of the present kind be very incomplete. The following table includes the major formations of western British Columbia, from the Selkirk and Columbian mountains to the coast. Readers will understand that the table is intended as the merest outline only, and that numerous formations are omitted, particularly in the case of the complex igneous rocks of the southern region.

Rock Formations of Western British Columbia.

System	Coast and islands		Main line, C.P.R.		Grand Trunk Pacific		Southern B.C.	
	Sedimentary	Igneous	Sedimentary	Igneous	Sedimentary	Igneous	Sedimentary	Igneous
Tertiary	Sooke (V.I.) Carmanah Puget		Tranquille Coldwater	Kamloops			Kettle River Huntingdon	Midway Skagit Kruger Coryell
Upper Cretaceous	Cowichan (Nanaimo)						Pasayten (upper)	
Lower Cretaceous	Queen Charlotte Island		Queen Charlotte Island	Spence Bridge Volcanics	Skeena	Eastern granitic stocks	Pasayten (lower)	Rossland ? Phoenix
Jurassic	Sutton Marble Bay	Saanich Beale Wark Metchosin Coast Range Porphyrites of Texada I.		Coast Range	Hazelton	Coast Range		Nelson Sumas Custer Remmel Osoyoos
Triassic	Nitinat Anderson Bay Parson Bay Open Bay ?	Sicker Vancouver Valdes	Nicola (part)	Nicola (part)	Kitsalas		Cultus	
Carboniferous	Leach River Open Bay ?		Cache Creek		Prince Rupert		Rossland Pend d' Oreille Attwood Knob Hill Anarchist Hozomeen Chilliwack	

It is evident that in a country of so pronounced mountainous character, accessible exposures of rock are everywhere to be found. It does not follow, however, that these exposures are suitable for our purposes; in fact, the same forces which have elevated the mountains have so crushed and broken the rocks, that only in comparatively rare instances are ledges found possessing the requisite solidity to permit the quarrying of dimension stone. Many of the formations are unsuitable for our purposes, on account of their original nature, and many others have been rendered useless by the intense metamorphism to which they have been subjected. Following the practice of earlier volumes of this report, a short account of the formations will be given; but only those will be referred to which have actually yielded stone, or are easily accessible, or have been referred to by authors as of possible value.

Shuswap terrane.—These ancient rocks consist of great accumulations of altered sedimentaries—schists, gneisses, quartzites, metargillites, and limestones, capped by greenstone schists—known as the Shuswap series, and injected granitic rocks which occur as sills and dikes in the older series, or as great masses of batholithic character. Most of these granitic rocks have been converted into orthogneisses; this change is expressed by the acquisition of a banded structure which unfits the stone for fine structural purposes.

The rocks of the terrane are well developed in the northern part of the Columbian and Selkirk mountains; they are crossed by the main line of the Canadian Pacific railway, from a point a little west of Albert canyon to beyond Shuswap station, and extend southward as far as the upper ends of Kootenay and Arrow lakes. The Priest River terrane—described by Daly as extending along the international boundary from lat. 116° 35′ to lat. 116° 55′—is ascribed to the same age as the Shuswap.

The extreme alteration and shattering of the rocks of the Shuswap series have made most of them impossible for our purposes, and I know of no attempt to open a quarry along the line of the Canadian Pacific railway. The numerous bands of crystalline limestone have attracted considerable attention as a source of marble, and many prospects have been located. An extensive plant has been erected at Marblehead north of Kootenay lake, and marble has been raised from this series at Kaslo, Grand Forks, and elsewhere.

The granitic intrusions of the terrane are generally too shattered to offer much encouragement to quarrying; but it is stated that "moderately good building stone, granite, and other crystalline rocks" occur along the Shuswap lakes. Stone is actually obtained in some quantity from two quarries on the east side of Okanagan lake.

Beltian series.—This great system, 32,750 feet in thickness, includes a lower division of predominating argillaceous composition (Nisconlith series), and an upper series charaterized by quartzitic composition (Selkirk series). The rocks overlie the Shuswap terrane on its eastern flank, and extend as a great belt from the international boundary across the main line of the Canadian Pacific railway, and to an undetermined distance northward. On the boundary they extend from lat. 115° 35′ in the McGillivray range, with some interruptions westward, to lat. 116° 35′ where the Priest River terrane is exposed in the Purcell trench as far west as lat. 166° 55′. Beyond this point the Beltian again occurs to lat. 117° 5′. On the main line of the Canadian Pacific railway, Beltian rocks occur from a point east of Beavermouth to the Shuswap contact west of Albert canyon.

The rocks of the Beltian system, being largely argillites and quartzites, are intrinsically ill-adapted to building purposes; and their unsuitability is further increased by the great amount of crushing and alteration to which they have been subjected. Crystalline limestones occur at more than one level in the series, and in the upper division reach a thickness of 350 feet (Nakimu limestone). The rock is described as "light grey, fine-grained, crystalline limestone; it is comparatively homogeneous, but carries disseminated sericitic mica in many beds." I have not learned of any attempt to quarry the rocks in this system.

Cambrian system.—The strata of this system reach a total thickness of 18,575 feet and are well exposed alongside all the lines of railway crossing the Rocky mountains. Three divisions are recognized, of which the lowest is chiefly quartzite, and the middle and upper largely limestone and shale. On the main line of the Canadian Pacific railway, Cambrian rocks extend from the eastern boundary of the province to Leanchoil; on the Crowsnest line they occur with some interruptions from Elko to the Moyie lakes; on the Grand Trunk Pacific railway they occupy the country between the eastern boundary of the province and Tête Jaune; and on the international boundary they occur at several points to the eastward of latitude 117° 10′.

The possibilities of the application of the Lower Cambrian quartzites to structural purposes, has been considered in Volume IV; see page 264. Marbles occur in Vermilion pass, in Yoho valley, and at Grant Brook on the Grand Trunk Pacific railway. Some developing was done at the latter locality, but I have learned of no other attempt to work any of the rocks of this great system.

Ordovician and Silurian systems.—The rocks of these systems are chiefly shale and slate, with some limestones and quartzites; they are crossed by the Canadian Pacific railway between Leanchoil and Golden. An abandoned slate quarry near Glenogle represents the only attempt to utilize the rocks for structural purposes.

Devonian system.—The Devonian rocks of the Rocky mountains are practically confined to the Alberta side of the interprovincial boundary, and have been fully described in Vol. IV, pages 110-120. Devonian rocks are not definitely known west of the Shuswap terrane, but some of the strata included in the Carboniferous may be of this age. In any case, there are no deposits of value from our point of view.

Carboniferous.—Strata of this age were developed to a great thickness in the Rocky Mountain geosyncline, and now constitute a large part of the Rocky mountains proper. In this region, three divisions are recognized: Lower Banff shale; Upper Banff limestone; and Rocky Mountain quartzite. These formations have been discussed with some detail in Vol. IV, pages 141-145; and to this description the reader is referred. In British Columbia the Carboniferous rocks do not play the large part that they do in Alberta; in fact, they do not occur on the British Columbia side of the boundary at all, along the Grand Trunk Pacific line, or the main line of the Canadian Pacific railway. On the Crowsnest line, the limestone is exposed at the summit and for a short distance west. The Wardner formation, which occurs along the railway both east and west of Wardner, is a whitish grey crystalline limestone, in beds up to 4 feet in thickness. Quarrying has not been attempted on the formation, but it is possible to obtain stone for ordinary building purposes.

We have seen (page 19) that in Carboniferous time the land mass—which had hitherto existed in the western part of the province—sank, and strata of this age were deposited in the resulting western geosyncline. Subsequent distortion and covering by later sediments, as well as by enormous masses of igneous rocks, have made it impossible to find continuous exposures of these rocks; in consequence, a large number of local formations have received distinctive names. The following list indicates only those formations of the western Carboniferous which have attracted attention as a source of building stone:—

1—*Rossland group.*—The rocks of this group are largely of igneous origin, but they include numerous lenses of crystalline limestone. They are developed in the Kootenay and Boundary districts, and have been worked for flux at Fife.

2—*Pend d'Oreille group.*—The rocks of this group are quartz and biotite schists, quartzites, and crystalline limestones. A prominent band of limestone has been worked for marble on Sheep creek east of Salmo.

3—*Cache Creek formation.*—Quartzites, argillites, and limestones, in a highly metamorphosed condition, constitute the bulk of this formation. Outcrops occur east of Kamloops, near Spatsum, Thompson, and other points along the main line of the Canadian Pacific railway. The limestone (Marble Canyon limestone), is a possible, but not promising source of marble.

4—*Leach River formation.*—This formation is questionably ascribed to the Carboniferous. It is developed in southern Vancouver island, and consists of slate, schist, and greywacke. It presents little material of use for structural purposes.

5—*Open Bay formation.*—This formation consists, chiefly, of argillites and quartzites, with some crystalline limestones. It occurs at many points along the shore in isolated exposures. The geological position is doubtful, and the only reason for including it here is, that some of the crystalline limestones of the coast *may* be of this age.

6—*Prince Rupert formation.*—The rocks of this formation are highly metamorphosed sediments, and consist of quartz and mica schists, with bands of crystalline limestone. Exposures occur near Prince Rupert, and on adjacent islands. The schists have been used for rough building in Prince Rupert, and the limestones have been quarried for lime and marble.

Triassic system.—Rocks of this system overlie the Carboniferous strata in restricted areas along the coast as well as in the western interior. Of the formations given in the table, the only one of present importance is the Anderson Bay formation of southern Texada island, in which are promising bands of red marble, which are being exploited by the Malaspina Marble Co.

The Nitinat formation of southern Vancouver island consists largely of crystalline limestone, but it has not yet been tested as a source of marble.

Jurassic system.—The only formations of sedimentary rocks of this age worthy of consideration here are the Sutton limestones of Vancouver island and the Marble Bay limestones of Texada island. The Sutton formation occurs as narrow lenses in the Vancouver volcanics and other rocks of southern Vancouver island. It has been quarried for lime and cement, and has been suggested as a source of marble. The Marble Bay formation occurs in northern Texada island, and consists of grey and white crystalline limestone, which has been quarried for lime-making and other purposes. It has been tested as an ornamental marble.

The igneous rocks of the Jurassic system include the Coast Range granitic batholith, several formations on Vancouver island of which the Saanich granodiorite is the most important, the porphyrites of Texada island, stocks and batholiths of granodiorite along the international boundary (Remmel, Osoyoos, Custer ?), the Nelson gabbro-granite batholith, the Rossland monzonite, and the Salmon Arm, and other batholiths on the main line of the Candian Pacific railway.

The Coast Range batholith consisting of granodiorites and other rocks—commercially regarded as granites—is the most important formation in British Columbia, from the present point of view. Granites are quarried in the vicinity of Vancouver, on the main line of the Canadian Pacific railway; at many points along the southern coast; and to the east of Prince Rupert. Numerous structures in Victoria and Vancouver attest the suitability of this stone for fine architectural purposes.

Several quarries are situated in the Nelson batholith near Nelson, but few of the other numerous exposures of rocks of this age have yet attracted the attention of quarrymen.

Lower Cretaceous system.—This system is represented in the Rocky mountains by the Lower Ribboned sandstone; the Kootenay coal measures;

and the Upper Ribboned sandstone. These formations do not occur on the British Columbia side of the interprovincial boundary on the Grand Trunk Pacific line, or on the main line of the Canadian Pacific railway. On the Crowsnest line, however, in the Fernie coal-mining region the Upper and Lower Ribboned sandstones present some possibilities as building stone. These stones are hard, and of variable colour, and have poor weathering properties. No quarrying has been attempted. For a description of typical examples of the stone see Volume IV, pages 155-159.

The sedimentary rocks of this age west of the Shuswap terrane are represented chiefly by the Queen Charlotte Island group, and the Skeena formation. Neither series has any proved value as a producer of building stone: the former consists of sandstones, slates, conglomerates, and volcanic flows; the latter is composed of feldspathic sandstones, conglomerates, and carbonaceous shales in an extremely fractured condition. Daly's description of the Pasayten series does not indicate that it contains material suitable for building purposes.

Lower Cretaceous volcanic rocks are, in many cases, indistinguishable from those of Jurassic age. Formations of doubtful age are numerous in the Boundary district, and some of the granodiorite masses east of the main Coast Range batholith are ascribed to this age. The granite exposure at the little canyon of the Skeena river is an example of this type of occurrence.

Upper Cretaceous system.—The only formation of this age worthy of mention is the Cowichan, which contains beds of desirable sandstone. This stone ranks next to the Coast Range granites in importance, and it has been extensively quarried near Nanaimo and on many of the Gulf islands. Numerous important buildings have been constructed of this stone in Victoria, Vancouver, Nanaimo, and elsewhere.

Tertiary system.—The sedimentary rocks of this system are of no importance as producers of building stone. The Puget is the chief formation, and is developed in the vicinity of Vancouver and the lower part of the Frazer river. The rocks are too friable and incoherent to be of any value. Some of the sandstones of the Kettle River formation are more promising, but nothing has been done to develop them.

Volcanic, and other igneous rocks of Tertiary age, are particularly abundant and varied, but, whatever their possibilities may be, they have not yet been seriously regarded as producers of building stone. Of the rocks to be described in this report the following are ascribed to this age:—

The monzonite of Coryell and Rossland.

The porphyrite on the north side of Kamloops lake.

The tuff on Dease lake east of Kamloops.

The andesite of Haddington island (?).

The geology of British Columbia is too complex to admit of an adequate description in a work of the present kind. The above short account is intended only to impress that complexity on the reader, and to form a basis whereby the building stones described in the body of the report may be roughly arranged as to geological age. The following works from which this account was largely compiled are of particular value to those desiring a general knowledge of the geology of British Columbia:—

Geology and Economic Minerals of Canada, Publication No. 1085, Geological Survey, Canada.

North American Cordillera, 49th Parallel: Publication No. 1203, Geological Survey, Canada.

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CHAPTER III.

THE SANDSTONES OF THE PROVINCE OF BRITISH COLUMBIA.

Sandstone suitable for structural purposes forms a large part of the Upper Cretaceous system as exposed on the islands of the Strait of Georgia, and to a less extent on the mainland of the southern part of Vancouver island. From this region has been derived all the structural sandstone quarried in British Columbia. The Lower Cretaceous formation of Queen Charlotte island (Queen Charlotte Island formation) consists largely of sandstones of unknown possibilities, and the Upper and Lower Ribboned sandstones of the Fernie coal-mining district are capable of use for local rough building; but the stones are too hard and of too poor weathering properties to be regarded as building stones in a commercial sense. The sandstones of the Skeena and Hazelton formations of the northern parts of the province are extremely hard, extensively fractured, and apparently of no promise whatever. No attempt has been made to quarry the Tertiary sandstones of the southern part of the province: they appear to be too soft and incoherent for our purpose.

Sandstones of the Cowichan Group.

The name "Cowichan" has been proposed by Clapp as a comprehensive term to embrace the unmetamorphosed sediments of Cretaceous and possibly of Lower Tertiary age in the southern part of Vancouver island and the adjacent islands of the Strait of Georgia. Two different and unconformable formations are included, as it is impossible to separate them on lithological or structural grounds. The larger part of the group doubtless belongs to the Nanaimo series, which has been described in greater detail for the region about Nanaimo. The Cowichan rocks are conglomerates, sandstones, and shales, of which the sandstones predominate near the coast, and are alone of value from the present point of view.

The rocks of the group are disposed in three basins: the Comox, the Nanaimo, and the Cowichan. In a general way the formations are upwarped on the southwest side and therefore present a varying dip to the northeastward; in consequence, the Gulf islands usually show steep scarped westerly and southwesterly faces with more gradual slopes on the northeast sides.

The Nanaimo series is divided into a number of formations, in descending series as follows:—

Gabriola.—Yellowish-grey sandstones and sandy shales.

Northumberland.—Shales, sandstones, and conglomerates.

De Courcy.—Chiefly thick-bedded, greenish-grey, pebbly sandstones.

Cedar District.—Chiefly greyish, sandy shales.

Protection.—Greyish-white, medium-grained sandstones with interbedded shaly sandstone.

Newcastle.—Greenish grit and green sandy shales.

Cranberry.—Dark green sandy shales and thin-bedded sandstones.

Extension.—Quartzose conglomerates and coarse-grained sandstones.

East Wellington.—Flaggy, olive-grey sandstones.

Haslam.—Chiefly shales.

Benson.—Conglomerate.

It will be observed that sandstones form an important part of the whole series; nevertheless, the only formations which have yielded commercial stone are the Gabriola, De Courcy, and Protection. As the systematic description of quarries will include the whole Cowichan group, the stratigraphy of the Nanaimo series will be disregarded. The actual quarries may be conveniently arranged in the following areas:—

Denman-Hornby Island area.

Nanaimo area.

Southern Gulf Islands area.

Koksilah area.

The sandstones vary much in grain and colour, but usually present a tint between bluish-grey and yellow. In many instances the original colour is bluish-grey, and the buff or yellow varieties are the results of oxidation. Accessible exposures are numerous, but sites suitable for quarrying are restricted by four main controlling factors, as follows:—

Hardness.—Much of the stone exposed in cliffs along the shores of the islands is very hard, and quite beyond the possibility of economic quarrying.

Fracturing.—Excessive fracturing destroys a large amount of stone; even in the more favourable localities the loss on this account is large.

Concretions.—Large and small concretions are abundant in certain beds of otherwise desirable stone, and occasion so much loss that quarrying is impossible.

The zone of oxidation.—In certain cases only the outer altered or oxidized zone is soft enough to yield commercial stone, consequently, the workings must be abandoned when this superficial portion is removed.

The commercial stones vary in colour from blue-grey to buff, and in extreme cases, to yellow. The blue variety has a strong tendency to become buff on exposure; in every case this change was effected by the corrosion test. While varying greatly in grain all the stones show a very similar composition: quartz, both varieties of feldspar in a fairly fresh condition, and dark grains of volcanic rock matter. The latter constituent has a tendency to occur in larger fragments, and usually makes up the bulk of the pebbly streaks common in many of the exposures.

The amount of cement, and its composition, was determined in the laboratory of the Mines Branch. Concerning the method of analysis, the chief chemist has furnished the following statement:—

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

In the soluble portion, the following constituents were determined in order to ascertain the general nature of the cementing material, and the probable effects of oxidation:—

Alumina, varying from 4·18 to 1·41 per cent.

Ferric oxide, varying from 1·20 to 0·04 per cent.

Ferrous oxide, varying from 3·50 to 1·18 per cent.

Magnesia, varying from 2·25 to 0·55 per cent.

Carbonic acid, varying from 0·12 to 0·04 per cent.

The total of these constituents in each case falls short of the total of the soluble portion: the difference is largely water and alkalies, with a very small amount of rarer substances.

The analyses show that the cementing matter in these stones is largely argillaceous and ferruginous. The amount of carbonate is insignificant and indicates a marked difference from the Paskapoo sandstones of Alberta, in which the commercial grades show a per cent of carbonic acid ranging from 5·08 to 14·43.

In all cases the amount of ferrous oxide is in excess of the ferric oxide, indicating an imperfectly oxidized cement which is liable to change in colour on exposure. The buff stones, being partially oxidized, do not show as great a difference between the oxides as do the unaltered blue varieties.

In order to ascertain with accuracy the changes that occur in the passage of the blue into the buff variety, it would be necessary to obtain samples of the latter derived from the actual blue stone used for the test. As this is practically impossible, typical examples of the two types from Hornby and from Saturna island were examined. Any conclusions are necessarily subject to modification, as there is no certainty that the two stones were originally of exactly the same structure and composition.

The analyses are given below:—

	Hornby Island stone		Saturna Island stone	
	Blue	Buff	Blue	Buff
Insoluble residue	90·82	91·82	90·86	91·57
Soluble portion	9·18	8·18	9·14	8·43
Partial analysis soluble portion:				
Alumina	2·48	1·89	2·17	1·85
Ferric oxide	·34	·61	·41	·76
Ferrous oxide	2·46	2·15	2·28	1·92
Lime	·37	·13	·11	·31
Magnesia	2·35	1·02	1·62	1·32
Carbonic acid	·10	·07	·10	·10
Total of soluble constituents determined	8·10	5·87	6·69	6·26
Water, alkalies, etc	1·08	2·31	2·45	2·17

The two examples agree in the following changes:—

(a) No appreciable loss of carbonates by solution.

(b) A reduction in the total amount of soluble material.

(c) A slight oxidation of the ferrous oxide with a consequent increase in the ferric oxide.

(d) A pronounced decrease in alumina and magnesia.

The two examples differ in the following changes:—

(a) The Hornby stone decreases, and the Saturna stone increases, in lime. The changes involve such small amounts that they may easily be due to original differences, hence may be neglected.

(b) The Hornby stone increases, and the Saturna stone decreases, in water, alkalies, etc.

It should also be noted that the Hornby stone increases in porosity, and that the Saturna stone decreases slightly in this respect.

In the case of the Saturna stone, the reduction in total soluble material; the reduction in alumina and magnesia; and the failure of an increased porosity, indicate that nothing has been removed by solution.

In the case of the Saturna stone the reduction in total soluble material in alumina, and in magnesia, can not be explained by solution and removal, as the porosity of the stone is not increased. The only other explanation of the change is that the alumina and magnesia have been rendered insoluble by the process of alteration, and consequently, have been added to the insoluble residue.

In the Hornby stone with its increased porosity, magnesia and lime may have been removed by solution, but it is unlikely that alumina would be reduced in this way. On the whole it seems reasonable to conclude that the alteration in these stones consists of an oxidation of the iron, and in a setting of alumina, magnesia, and silica into new compounds of less solubility. If these conclusions are correct the buffstone should prove stronger and more durable than the unaltered variety.

The stone from Newcastle island is of a different colour and general appearance from the average product of the quarries, and must be omitted in any attempt to average the physical characteristics of these sandstones. Omitting this example, the less important product of the Hornby island and Mayne island quarries, and the hard fine-grained Saltspring stone, a fair idea of the general physical properties of the more important commercial sandstones of the Gulf islands may be obtained from the following table, which includes the stone from Jack point near Nanaimo, and the product of the quarries on Denman, Gabriola, and Saturna islands:—

Specific gravity	2·674
Weight per cubic foot, lbs	149·61
Pore space, per cent	10·86
Ratio of absorption, per cent	4·55
Coefficient of saturation	·79
Crushing strength, lbs. per sq. in., dry	11,733·
" " " " wet	8,920·
" " " " wet after freezing	7,071·
Transverse strength, lbs. per sq. in	999·
Shearing strength, lbs. per sq. in	1,130·
Loss on corrosion, grams per sq. in	·0121
Drilling factor, mm	25·7
Chiselling factor, grams (I)	1·6
Chiselling factor (II)	5·8

Denman-Hornby Islands Area.

Denman island is traversed in a general north and south direction by a prominent escarpment, which presents many places at which quarries might be opened. The outer stone is oxidized and broken, but at slight depth strong beds of bluish stone are encountered. Similar stone occurs on Hornby island, but here the outer buff zone is the more valuable, as much of the blue stone is too hard to work.

Denman Island Stone Company, Limited, Vancouver (in hands of liquidator).

The quarry of this company was opened on the west side of Denman island near Denman Island post-office at a considerable elevation above sea-level, and a quarter mile inland.

A prominent escarpment, approximately parallel to the shore, is capped by 60 feet of solid sandstone, which is succeeded downwards by 17 feet of less perfect stone, passing into thin stone and shales. The formation dips at 12–15°, N. 30° E. i.e., away from the face of the escarpment. Prominent and well defined joints run approximately northwest and southeast with a dip of 75° to the southwest: these define the escarpment and form the successive faces of the quarry. It will be observed that these joints are not exactly at right angles to the dip of the formation, but nevertheless fairly rectangular blocks are obtained.

The quarry (Plate III) in its present condition shows three benches as follows:—

Upper bench.—This section is 90 feet long on the strike, and 25 feet wide on the dip of the formation: it lies between two of the prominent northwest-southeast joints. Neither intermediate nor cross joints were observed on the floor. The face is about 40 feet high. The upper 20 feet consists of somewhat broken, concretionary sandstone, with bands of conglomerate: this is not marketable stone and constitutes an overburden which would increase on account of the dip of the beds. The lower 20 feet is of uniform, dark greyish-blue sandstone (1481), in a solid bed, presenting a few local flaws and mud holes: it has been removed in five tiers by channelling to an artificial floor.

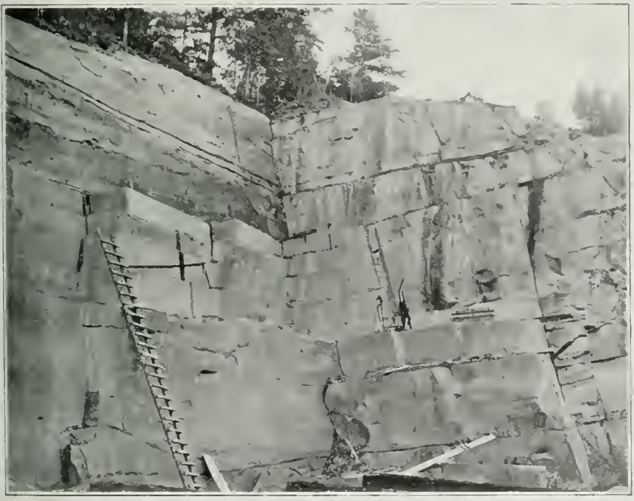
Middle bench.—This section extends 66 feet farther northwest than the upper bench, but it is 25 feet shorter at the southeast end. Like the upper bench it lies between two joints 25 feet apart. At the northwest end an intermediate joint occurs, but this does not continue the full length of the bench. The face is 20 feet, of which the upper 14 feet is in the same bed as the upper bench. The lower 6 feet is a separate bed to a natural floor. A block 25 feet by 12 feet in rear of the intermediate joint has not been quarried in the northwest corner of this section. The stone is essentially the same as that of the upper bench.

Lower bench.—The southeast end of this section is about in a line with the southeast end of the upper bench; its length is 60 feet on the strike, and its width 48 feet on the dip. The stone is broken and imperfect in several ill-defined beds, hence is of little use for purposes of construction.

The good stone from the middle bench and from the lower part of the upper bench is fairly uniform throughout; occasional coarse streaks and mud holes are the only causes of variation. The bluish colour of the fresh stone is gradually replaced by a buff tint, which is apparent on the blocks now lying in the quarry. The same colour has been developed on the planes of parting. Doubtless the outer zone of stone in all three benches was of this colour, but the oxidized material was not of sufficient depth or solidity to be marketed as buff stone. Along the escarpment, beyond the confines of the quarry, much stone of a buff colour is presented; it is in a fractured condition and would have to be removed before the underlying blue stone could be quarried. The heavy overburden of undesirable stone, and the outer zone of oxidized and broken material, are factors to be considered in opening other quarries along the escarpment.

The stone: No. 1481.—This stone is of the "blue" type, and most closely resembles the Gabriola Island stone described as No. 1488 on page 49: it is shown in No. 6, Plate XLVI. A comparison with No. 2, Plate XLVII, shows that the present example is slightly less blue, and of finer grain, than

PLATE III.



Sandstone quarry on Denman island, B.C.

the Gabriola Island stone. It also resembles No. 1434 from Jack point, but it is finer in grain, and of more even texture. Smoothed surfaces show very fine white and black specks in a greyish groundmass, but fractured surfaces have a "muddy" appearance. The constituent grains are quartz, orthoclase, plagioclase, and indeterminable volcanic rock: the whole cemented in a rather abundant argillaceous cement.

A microscopic examination shows that the plagioclase fragments are usually quite fresh, but that the orthoclase grains are considerably decomposed, and fade into the cementing matter: this results in a lack of definition in the section, and makes it the least "clean" of those examined. The general grain is finer than one would expect from an examination of the surface; in fact, it is but slightly coarser than in the Saltspring stone (No. 1441). The occasional occurrence of quartz fragments, up to ·75 mm. in diameter, gives an impression of coarser grain when the stone is examined by the naked eye.

The crushing strength determined for the dry sample is not much inferior to that of the average sandstone of the district, but both wetting and freezing have a serious effect on this property. Under the latter test the cube almost parted into two sections at about the 31st freezing, and finally became so friable that it could have been rubbed to pieces by the fingers. Under the corrosion test the blue colour is rapidly lost, and a buff tone is produced, with the component grains more sharply defined.

A cube placed in a vessel with a little water in the bottom, rapidly becomes wet through by capillarity; such a stone is said to be "bibulous." In this respect the present sample is about equal to Nos. 1449 and 1485, and is exceeded only by No. 1486 from Hornby island.

The physical properties are as follows:—

Specific gravity	2·713
Weight per cubic foot, lbs.	145·45
Pore space, per cent	14·20
Ratio of absorption, per cent, one hour	1·73
" " " two hours	2·06
" " " slow immersion	5·28
" " " in vacuo	5·96
" " " under pressure	6·09
Coefficient of saturation, one hour	·28
" " " two hours	·34
" " " slow immersion	·87
" " " in vacuo	·98
Crushing strength, lbs. per sq. in., dry	8,551·
" " " " wet	3,963·
" " " " wet after freezing	2,052·
Transverse strength, lbs. per sq. in.	1,128·
Shearing strength, lbs. per sq. in.	846·

Loss on corrosion, grams per sq. in.	·01775
Drilling factor, mm.	27·8
Chiselling factor, grams (I)	2·8
" " " (II)	10·0

An analysis by N. L. Turner follows:—

Insoluble portion	83·70
Soluble portion	16·30

Partial analysis of soluble portion:—

Alumina	4·18
Ferric oxide	·90
Ferrous oxide	3·50
Lime	·66
Magnesia	1·18
Carbonic acid	·10

The total cement (soluble portion) in this stone is much the highest of the ten sandstones tested. It is to be noted, however, that the excess is not due to magnesia or lime, but to the ferrous oxide and alumina. The stone undoubtedly contains a large amount of clay; this is further indicated by the considerable difference (5·78%) between the total of the constituents determined and the "soluble portion" of the stone.

The company installed an extensive plant, and constructed an inclined tramway to the wharf, a distance of nearly a half mile. The mill is situated on the level of the floor of the middle bench; it is 40 feet by 36 feet, and contains two single-pitman gang saws. Other equipment on the property is as follows:—

1 portable boiler.
1 swivel-head channeller.
1 derrick with steam hoist and boiler.
4 gang cars.
1 compressor with separate engine.
1 engine for gang saws.
1 steam winch with cable and cars for tramway.
1 derrick with steam hoist and boiler at wharf.
Drills, piping, cables, pumps, and minor appliances.
Several small buildings including a boarding house.

Denman Island stone has been used in small quantities for trimmings in many buildings. The most important structures in which it may be seen are:—

Normal school, Victoria.
Drill hall, Victoria.
Metropolitan building, Vancouver.
Dawson school, Burrard street, Vancouver.

These buildings all show a rather dead, dark, bluish-grey colour which is not attractive. Although the stone when freshly laid is uniform in colour, the individual blocks tend to assume varying tints, often with a marked contrast. It is probable that longer weathering would tend to unify the colour of these blocks. Light-coloured spots were observed as well as occasional mud holes, and a little pyritic staining. Notwithstanding the softness of the stone when freshly quarried, it was found that dressed surfaces are sufficiently hard to resist abrasion by the thumb-nail.

The normal school in Victoria is a new structure, and may be regarded as indicative of the appearance of the stone shortly after being laid in the wall. The general appearance is dark, and not attractive. The grain of the stone is fine, but occasional streaks of coarser grain are to be seen. Much variation in the colour of individual blocks detracts from the appearance of the building; when a light yellowish block is close to a very dark one the difference is striking. Some of the darker blocks show light blotches, and mud holes occur sparingly, but they are inconspicuous on rock-face work. Pyritic staining is not common, but much efflorescence was observed; it is impossible to state whether this is due to the stone itself or to the mortar.

Much of the stone is in heavy coursing two feet thick, and some rather intricate carvings indicate that the stone is capable of fine chiselling.

Murray, Martin & Murray, Hornby Island, B.C.

Cliffs of sandstone are exposed near the water on the south shore of Hornby island. A property of 10 acres was purchased about 12 years ago from the Ford estate. The present ownership is in doubt, but it was held by the above firm or syndicate while the work was being done.

The quarry (Plate IV), is situated about a mile to the southeast of Hornby Island wharf. The face of the cliff is about 30 feet high, with a general trend N. 15° E. Southward from the quarry the face gradually rises to a height of at least 100 feet; inland there is no perceptible rise for some distance. The formation dips at a low angle in a general northward direction.

The section shows an underlying conglomerate, with a single heavy bed of sandstone above. This bed is not solid, but is divided by numerous curving horizontal partings, and is marked by streaks of a pebbly nature. The most conspicuous joints strike with the face (N. 15°E.), and dip 70° eastward. The stone, where naturally eroded, is conspicuously honeycombed, and weathered surfaces are of a buff colour (1486. 1483). The unaltered stone, on the face, is blue (1485, 1480), and much of it is very hard (1482). The face is exposed to southeast gales; consequently, the blocks in the quarry are very soft on the surface. Much stone of the blue type is available, but I fear that the pebbly streaks and the hard nature of certain parts would make systematic quarrying difficult.

The stone: No. 1485.—This is a selected example of the blue type of stone, and is undoubtedly better than the average run of the quarry. It is intermediate in colour between the typical blue and buff stones, and in this respect resembles No. 1450 from Saturna island (No. 5, Plate XLVI).

The mineral grains consist of orthoclase, plagioclase, quartz, volcanic rock, and mica. The volcanic fragments often exceed 2 mm. in diameter, and the quartz and feldspars sometimes exceed one mm. The feldspars are not greatly altered, but the mineral grains are not closely appressed, and there seems to be a large amount of cement.

Under the freezing test the stone showed serious disintegration on all edges and angles, and became very friable. Very little change was produced under the corrosion test. The stone is rather bibulous, and in this respect resembles No. 1481 from Denman island; it differs from that stone, however, in absorbing relatively more water by quick immersion, and in having a coefficient of saturation on the safe side of the danger line.

The physical properties are as follows:—

Specific gravity	2·673
Weight per cubic foot, lbs.	145·09
Pore space, per cent	13·05
Ratio of absorption, per cent, one hour	3·57
" " " two hours	3·82
" " " slow immersion	4·37
" " " in vacuo	4·82
" " " under pressure	5·62
Coefficient of saturation, one hour	·63
" " " two hours	·68
" " " slow immersion	·78
" " " in vacuo	·86
Crushing strength, lbs. per sq. in., dry	10,226·
" " " " wet	8,080·
" " " " wet after freezing	2,741·
Transverse strength, lbs. per sq. in	778·
Shearing strength, lbs. per sq. in	1,058·
Loss on corrosion, grams per sq. in	·0836
Drilling factor, mm	37·4
Chiselling factor, grams (I)	2·6
" " " (II)	7·2

An analysis by Turner follows:—

Insoluble portion	90·82
Soluble portion	9·18

Partial analysis of soluble portion:—

Alumina	2·48

Sandstone quarry on Hornby island, B.C.

Ferric oxide	·34
Ferrous oxide	2·46
Lime	·37
Magnesia	2·35
Carbonic acid	·10

The high content of magnesia is the most striking feature brought out by the analysis. For a comparison of this stone with the more altered variety, No. 1486, see page 32.

No. 1486.—This stone is of the buff type, but it is not so distinctly yellow as No. 1445 from Mayne island and No. 1449 from Saturna island. The structure of the stone is identical with that of No. 1485 and scarcely any difference can be seen under the microscope.

The stone is seriously injured by freezing, as the edges disintegrate, and the whole mass becomes friable: it is not quite so seriously affected as No. 1485. It is to be observed that these two stones have a coefficient of saturation below the danger line; it is obvious that the freezing test indicates their general weakness and not their liability to injury by frost under normal conditions of soaking.

This stone, and No. 1485, are by far the softest of the sandstones tested; they are also the most bibulous, particularly the present example, which absorbs water more quickly than any other stone tested. The absorption tests give results very similar to those of No. 1485, and like that example the stone is not visibly affected by the corrosion test.

The physical properties are as follows:—

Specific gravity	2·676
Weight per cubic foot, lbs	141·07
Pore space, per cent	15·55
Ratio of absorption, per cent, one hour	4·47
" " " two hours	4·48
" " " slow immersion	4·89
" " " in vacuo	6·82
" " " under pressure	6·87
Coefficient of saturation, one hour	·65
" " " two hours	·65
" " " slow immersion	·71
" " " in vacuo	·99
Crushing strength, lbs. per sq. in., dry	8,256·
" " " " wet	6,990·
" " " " " after freezing	3,577·
Transverse strength, lbs. per sq. in	704·
Shearing strength, lbs. per sq. in	628·
Loss on corrosion, grams per sq. in	·01036
Drilling factor, mm	38·

Chiselling factor, grams (I)	3·6
" " " (II)	11·3

An analysis by Turner is given below:—

Insoluble portion	91·82
Soluble portion	8·18

Partial analysis of soluble portion:—

Alumina	1·89
Ferric oxide	·61
Ferrous oxide	2·15
Lime	·13
Magnesia	1·02
Carbonic acid	·07
Total	5·87

Compared with the unaltered stone No. 1485, it will be noted that the present example has a lower total cement, and that this difference is largely due to a loss of alumina and magnesia. The oxidation of the iron has not proceeded far, and there is only an inappreciable loss in carbonates. (See page 32).

No. 1482.—This stone forms a considerable part of the exposed face: it differs from No. 1485 only in the possession of a much greater hardness. The stone effervesces strongly with acids, indicating a content of carbonate of lime which is not present in No. 1485. The formational features do not indicate whether the lime has been leached out from No. 1485 or whether its presence in No. 1482 is due to secondary infiltration.

No. 1480.—This is a selected example of the best product of the quarry known at the time of working as "light blue." The mineral composition of the stone is identical with No. 1485, except for a much finer grain. The colour is good, being nearer to a grey than to the "concrete" colour of the so-called blue stones. The stone is soft and uniform, and dresses to as fine a surface as any of the stones tested. Unfortunately, the resisting properties are probably not superior to those of the other stones from this locality. I saw no evidence on the ground that this type of stone could be procured in quantity.

No. 1483.—This example represents a more extreme state of oxidation than No. 1486. The grain is very similar, but the colour is much more yellow—almost as yellow as in No. 1445 from Mayne island. All variations in colour from the typical blue of No. 1485 to the decided yellow of this stone are to be seen in the face of the exposure.

Quarrying on Hornby island has consisted merely in the breaking off of blocks from the face by means of explosives and, in consequence, it is very difficult to determine the jointing and other formational features. The stone removed consisted chiefly of the outer oxidized buff variety, but some of the blue stone was taken as well. A dismantled derrick is still on the property. The water is deep, and no difficulty would be found in loading in calm weather; the exposed position, however, would make loading or even operating the quarry, difficult or impossible in stormy weather.

The heavy sandstone layer appears at greater elevation along the west side of the island south of the wharf, and might afford favourable quarry sites.

Hornby Island stone has been used to a very limited extent, and I am informed that it has not proved very durable. The best example is the blue variety used in the Dodson block, Hastings street east, Vancouver.

Port McNeill, Vancouver Island.

The "Ledge" at Port McNeill has been referred to as a possible source of sandstone for building purposes. The easterly part of the point is low, and sandstones are exposed only in the zone between high and low water, though, doubtless, there is an axis of sandstone along the point. About half a mile within the harbour the exposures are accessible, but they are much cut by joints and do not present a very promising appearance. The average stone seems rough and unsuitable (1557).

The stone: No. 1557.—This sandstone is of coarser grain than most of those tested; it is of greyish rather than of the typical blue colour, and shows distinct component grains of white and black colour. The stone resembles No. 1485 from Hornby island, but it is rather more grey and more distinctly of the "pepper and salt" aspect. Despite the rather dark colour, this stone would prove a possible building material if it could be procured in quantity.

Nanaimo Area.

Although most of the stone outcropping within the corporation of Nanaimo is rough and unsuitable for building purposes, a quarry was formerly worked within the limits of the town at the "Machine shop." A small amount of dark-coloured sandstone was quarried above the town at the Millstream, and was used in the construction of the Presbyterian church. More important quarries have been worked on Newcastle, Protection, and Gabriola islands, and on Jack point across Nanaimo harbour. The court house and post-office in Nanaimo are good examples of the use of the local stone.

On Newcastle and Protection islands the stone does not rise to considerable altitudes, but on Gabriola island there are cliffs of 100 feet of sandstone overlying conglomerate along the southwest shore. This rock is concretionary in places, and shows a pronounced system of joints parallel to the shore. Quarrying sites could doubtless be located at favourable points along this coast, and also on the shores of Valdes island to the south.

Henry Lys, Nanaimo: Jack Point quarry (Portage quarry).

This quarry is situated in the DeCourcey formation on the east side of Nanaimo harbour, at a point a little south of the narrows of Jack point, where a portage is sometimes made into Northumberland channel.

The beds of sandstone exposed along the west side of Jack point strike about northwest, and dip at a low angle to the northeast: they are fairly heavy-bedded, and show a peculiar cave-like weathering due to a hardening of the exterior and the subsequent wearing away of the inner part. The quarry is about 150 feet long, and its floor is 20 feet above high water. The face presents the following section:—

2–3 ft.—Thin sandstone.
12 ft.—Solid bed.
3 ft.—Thin and shaly.
2–3 ft.—Solid bed.
6 ft.—Solid bed, divided in places.
6 ft.—Solid bed.

The stratification is somewhat obscured by a tendency to horizontal lenticular breaking. The joints are not very distinct, but there seems to be an ill-defined set striking with the face and dipping 70° towards the harbour.

The stone varies considerably in grain, and is quite coarse in places. Mud holes are not infrequent, and vegetable-bearing streaks occur to some extent. Loss would occur from these causes and also from the presence of an oxidized zone on the joint planes, A large amount of heavy stone is available in the lower beds, but the removal of a considerable amount of the upper inferior material would have to be reckoned with in conducting quarrying operations (Plate V).

The stone: No. 1434.—On account of considerable variation in the stone, the description of this sample must not be applied too closely to the whole product of the quarry. Types of finer grain and more yellow colour were observed. I believe, from information received, that much of the stone removed was of better grain and colour than this sample, which, nevertheless, represents the bulk of the stone now available (No. 1, Plate XLVII).

This rock is classified under the blue type, but it shows less blue and more yellow than either the Denman Island or Gabriola Island stone, Nos. 1481 and 1488. It is the coarsest in grain of the stones tested, and frequently shows rounded grains of a dark colour, reaching a diameter of over 5 mm. These grains consist of very fine-grained crystalline volcanic rock, the same as occurs in the Gabriola and Denman Island stones. The

42'

PLATE V.

Sandstone quarry on Jack point, Nanaimo, B.C.

5

PLATE VI.

Jack Point sandstone. Post-office, Nanaimo, B.C.

remaining component fragments range up to one mm. in diameter. They consist of quartz, orthoclase, remarkably fresh plagioclase, and a little mica. The grains are not closely appressed, but are connected by a mass of very small grains and considerable indeterminable cement. The porosity is fairly high, but the stone is not very bibulous, i.e., it soaks up water very slowly compared with other of these sandstones. It seems to be seriously weakened by soaking, and is impaired appreciably by freezing. No cracking was observed under this test, but the edges and angles showed some disintegration. The coefficients of saturation are normal for quick immersions, but that for slow immersion is much above the danger line. The corrosion test results in the total loss of the blue tone and the assumption of a buff colour with sharply defined dark and light component grains.

The physical properties are as follows:—

Specific gravity	2·689
Weight per cubic foot, lbs	153·36
Pore space, per cent	8·64
Ratio of absorption, per cent, one hour	1·92
" " " two hours	2·27
" " " slow immersion	3·09
" " " in vacuo	3·43
" " " under pressure	3·51
Coefficient of saturation, one hour	·54
" " " two hours	·64
" " " slow immersion	·88
" " " in vacuo	·97
Crushing strength, lbs. per sq. in., dry	11,276·
" " " " wet	7,116·
" " " " wet after freezing	5,265·
Transverse strength, lbs. per sq. in	841·
Shearing strength, lbs. per sq. in	1,053·
Loss on corrosion, grams per sq. in	·0122
Drilling factor, mm	25·4
Chiselling factor, grams (I)	1·0
" " " (II)	3·9

An analysis by Turner follows:—

Insoluble portion	91·50
Soluble portion	8·50

Partial analysis of soluble portion:—

Alumina	1·29
Ferric oxide	·76
Ferrous oxide	2·41

Lime	·79
Magnesia	·77
Carbonic acid	·12

This stone is the highest in carbonates and the lowest in alumina of the ten examples tested; it is also the lowest in magnesia, with the exception of the rather different type of stone from Newcastle island.

The floor of the quarry is provided with a track leading to a small mill to the south of the workings. The mill is equipped with a small boiler and engine, a single pitman gang saw by M. Beatty and Sons, Welland, Ont., and a compressor in good repair. The quarry equipment consists of a derrick, a loading derrick, rock drill, and quarry bar. A small wharf has been constructed, but it is accessible at high water only.

Stone from this quarry was used in the construction of the new part of the Nanaimo post-office (1911) and the tower (1912). The general appearance is good, and the yellowish colour is more pronounced than in others of these sandstones. The stone is of fine to medium grain but has pebbly streaks in places as well as occasional vegetable remains: it darkens by imbibition of dirt (Plate VI).

Western Fuel Co., Nanaimo: Machine shop quarry.

This quarry was opened on the southwest side of a little knoll near the wharf of the Western Fuel Co. in Nanaimo. It received its local name of "Machine shop quarry" from the fact that blasting was said to interfere with a machine shop to the northeast.

The face strikes E. 30° S. for a distance of 240 feet. The height is about 25 feet at the maximum, and the beds dip 10° to 12° northeasterly. At the northwest end the stripping is slight, and an upper 3-foot and a lower 5-foot bed are exposed. Proceeding to the southeast these two beds coalesce, but, owing to the dip, the top of the upper bed reaches the floor at the end of the quarry in that direction. The overlying stone (15 to 20 feet) is hard and thin-bedded. The formation is considerably broken, with rather pronounced vertical joints striking E. 35° N. Other joints, almost parallel in strike, dip 60° to the northwest. The lower stone is of the general nature of No. 1435 described below, but it is pebbly in places and presents many concretions (1436). The heavy overburden and the unfortunate site will probably prevent the further quarrying of stone at this point.

The stone: No. 1435.—A medium-grained sandstone closely resembling No. 1449, the buff Saturna Island stone described on page 59. It is a little more yellow, somewhat finer in grain, and with a more pronounced laminated structure than the Saturna Island stone.

No. 1436.—A hard dark grey sandstone of the same grain and mineral composition as No. 1435. Unlike No. 1435, it effervesces strongly with acid, indicating an addition of carbonate of lime to the cement. These concretions have doubtless arisen by the gathering of carbonate of lime about certain centres.

The chief structure in which this stone may be seen is the old part of the Nanaimo post-office built in 1883.

Mr. A. Henderson states that stone from the local quarries can be sold for 50 cents per cubic foot, and in rough blocks for 40 cents.

Western Fuel Company, Nanaimo: Newcastle Island quarry.

This well known quarry was the first opened in the district, and has furnished stone for many important buildings, but it has not been worked during recent years.

The quarry is in the Protection formation on the north side of the island opposite Pimbury point. The general face bears about E. 30° S. and the beds, while more or less undulatory, dip E. 10° S. at 10°. The excavation is 400 feet long, with a maximum width of 100 feet. The floor is 50 feet above tide water, and the face is about 20 feet in height. After a short interval (100 yards), the rock rises inland to a height of 75 feet above the top of the present face.

The beds exposed vary somewhat in different parts of the quarry; in consequence, a generalized section might be misleading. Near the middle the following section was observed:—

5–10 ft.—Stripping.
1–2 ft.—Thin stone.
3 ft.—Solid bed.
12 ft.—Solid bed.

At the southeast end the upper beds fail, and a 14-foot bed of practically solid stone occurs under 5 or 6 feet of drift.

Very decided joints cross the formation N. 5° W., but they are widely spaced—20 feet and even more in places—and they are discontinuous. Other irregular cracks are present, but there is nothing in the fracturing to prevent the extraction of stone of any reasonable size without undue waste from this cause.

The stone below the heavy bed is thin, and this condition probably maintains to the water level. The upper stone, above the present quarry, is not clearly revealed: the surface material is weathered soft and yellow, but the unweathered cores are harder and finer in grain than the average stone from the quarry. At the north end of the island are bluffs of sandstone in fairly heavy beds.

The stone in the quarry proper is fairly uniform throughout, but cross-bedding and the occurrence of streaks with vegetable matter would occasion some loss. Large concretions are of occasional occurrence in the lower bed, and are of greater frequency in the upper layer. The stone exposed by the operations has not greatly altered, but natural surfaces and joint planes show a yellow oxidized zone of an inch or two in depth.

Two dismantled derricks are the only equipment now on the property.

The stone: No. 1429.—This stone differs strikingly in general appearance from any other of the sandstones tested. It is of fine and even grain, with true light-grey colour, and clean "pepper and salt" appearance. Smoothed surfaces present a fine-dotted aspect, with light-coloured grains in excess of the scattered greenish-grey specks (No. 2, Plate XLVI).

The light-coloured grains are quartz, orthoclase, and plagioclase. The quartz grains are most abundant, sharply angular, and seldom of more than ·5 mm. in diameter.

The orthoclase and plagioclase grains resemble the quartz fragments in size and angularity. The latter of these minerals is comparatively fresh, but the former is of muddy appearance, indicating incipient decay.

The dark grains are biotite or black mica, partially decomposed and bent between the other grains, which are closely pressed together and united by only a small amount of cementing material.

This stone is one of the hardest of those tested and is exceeded in this respect only by the Saltspring Island stone. It is the least bibulous of the sandstones as it takes in scarcely any water by capillarity. Under the freezing test only a few small chips became detached at the angles of the cube. The corrosion test seems to roughen the surface, but it produces no visible change in colour. A striking feature of the absorption tests is the low results for the quick immersions.

The physical properties are:—

Specific gravity	2·656
Weight per cubic foot, lbs.	152·38
Pore space, per cent	8·15
Ratio of absorption, per cent, one hour	1·09
" " " two hours	1·34
" " " slow immersion	2·53
" " " in vacuo	3·15
" " " under pressure	3·38
Coefficient of saturation, one hour	·32
" " " two hours	·39
" " " slow immersion	·75
" " " in vacuo	·93
Crushing strength, lbs. per sq. in., dry	14,849·
" " " " wet	11,874·
" " " " wet after freezing	9,670·
Transverse strength, lbs. per sq. in	1,170·
Shearing strength, lbs. per sq. in	1,406·
Loss on corrosion, grams per sq. in	·00997
Drilling factor, mm	15·1

Chiselling factor, grams (I)	·3
" " " (II)	3·1

The analysis, as well as the physical properties of this stone, indicate a sandstone with characteristics differing somewhat from those of the average stones of the Cowichan group. The total amount of cement is relatively low, carbonates are practically absent, oxidation of the iron has scarcely begun, and the lime exceeds the magnesia.

The analysis by Turner follows:—

Insoluble residue	94·09
Soluble portion	5·91

Partial analysis of soluble portion:—

Alumina	2·02
Ferric oxide	·04
Ferrous oxide	1·43
Lime	·63
Magnesia	·55
Carbonic acid	·05
Total	4·72

Hardness is undoubtedly the most troublesome property of this stone, and its lighter colour compared with the other sandstones of the Gulf islands, is its chief advantage. The necessity of avoiding false bedding, coaly streaks, and concretions, occasions a great amount of selection, and increases the cost of quarrying. Observations on the older buildings constructed of this stone in Vancouver and Victoria indicate that its weathering properties are scarcely as good as might be expected of a sandstone so thoroughly cemented. This feature is seen in the building occupied by the Dominion Assay Office in Vancouver, which shows exfoliation, and also illustrates the property of the stone to turn very dark by the imbibition of dirt. The building of the Vancouver Trust Co., 614 Pender street, Vancouver, is apparently of this stone and shows disintegration in an aggravated form.

The stone may be seen in the following structures:—

The mint, San Francisco, Cal.

Government assay office, Granville street, Vancouver.

Building at corner of Main and Hastings streets, Vancouver.

Building at corner of Douglas and Yates streets, Victoria.

Quebec bank, Vancouver.

Bank of Montreal, Vancouver.

Bank of British North America, Vancouver.

Building of Vancouver Trust Co., Vancouver (?).

Western Fuel Co., Nanaimo: Protection Island quarry.

A small quarry was worked many years ago on Protection island, at a point immediately opposite Nanaimo. The operations were not extensive, and the location was abandoned on account of the profusion of concretions (1432, 1433).

The stone: No. 1432.—This stone is probably not very representative, as the present condition of the quarry prohibits the obtaining of good specimens. The rock is a very fine-grained, greyish type, with pronounced lamination.

No. 1433.—A buff, medium-grained sandstone, very closely resembling the stone from Mayne island, described as No. 1445 on page 55. It has a tendency to turn reddish on exposure, but in a pleasing rather than in an unsightly manner. Most of the exposed stone has a rosy hue to considerable depth.

The only important building of this stone is the court house in Nanaimo: it presents a general yellowish-grey colour, with some variation in different blocks. The stone is of finer grain than the average sandstone of the district, and appears to be harder. Cross bedding, a little vegetable matter, and dark stains as if from the presence of petroleum were observed, as well as some disintegration in places. The building shows some heavy stone in coursing, sills, etc.: pieces 8 feet by 2 feet were observed. There is a strong tendency, as with the Newcastle Island stone, to turn dark by the imbibition of dirt: this is particularly evident on horizontal and exposed surfaces (Plate VII).

Vancouver Granite Co. Limited, 815 Bower building, Vancouver; Robert Armstrong, president; H. F. Keefer, secretary-treasurer: Gabriola Island quarry.

The quarry is located in the Gabriola formation at the southeast corner of Descanso bay on the west side of Gabriola island. The general direction of the shore line is S. 30° W. The cliff facing the water is about 150 feet high, and a highway has been constructed along the declivity, at an elevation of 50 feet. Below the road the stone is not well exposed, and has not been quarried. Above the road the beds of sandstone have a somewhat variable dip at N. 33° E., of from 12° to 15°, or a little more in places. It is apparent, therefore, that the beds dip inland, away from the face, and that lower beds are encountered on proceeding southwest along the face of the quarry.

The quarry is about 175 yards long, but its width is indefinite, as intermittent workings have been opened at different points.

At the easterly end the main face is 30 feet high, presenting a slight

PLATE VII.

Protection Island sandstone. Court house, Nanaimo, B.C.

stripping, 2 to 3 feet of broken yellow stone, and a solid bed of about 25 feet in thickness (1430). Discontinuous, horizontal cracks divide this bed somewhat, and irregular but not close joints traverse it nearly vertically. The face shows a number of large round concretions. A considerable knoll of stone is available here, but it is interrupted by a ravine beyond which the same beds outcrop at a higher level. Here is situated the main quarry, with a working face S. 25° W. for about 100 yards. Under a slight stripping and a few feet of shattered rock, the workable sandstone lies in one solid layer. Joints are widely spaced, curved, and somewhat irregular. The most pronounced system strikes S. 25° E., and dips at varying, but high angles to the southwest. Another set crosses this major series nearly at right angles. The bedding is so heavy that plugging is necessary to "raise" the blocks. Concretions are far less frequent here than in the section first described. The stone varies somewhat in grain, and presents pebbly streaks in places. A good average is described in detail as No. 1488.

A third section, farther southwest, shows the same bed increasing in thickness at a higher level. Other fairly heavy beds underlie the thick bed here, and are succeeded downwards by thin sandstones of greater hardness and finally by shales.

An enormous quantity of stone is easily available under a slight stripping. Old surfaces are weathered to a buff colour, but this zone of oxidation is not sufficiently deep to warrant attempts to save it for buff stone, as has been done at Mayne and Saturna islands. Iron-stained spots are rare, and concretions are not numerous except at the east end. Pebbly streaks and the oxidized zones along the joint planes occasion considerable waste. (Plate VIII).

The stone: No. 1488.—This is a medium to fine-grained sandstone of the "concrete" colour usually termed blue, although there is little of real blue in the tint (No. 2, Plate XLVII). In respect to this colour, the present example is the most pronounced of the stones tested, but it is closely approached by No. 1481, from Denman island, which it resembles in other respects. The grain is coarser than in the Denman Island stone, and the general aspect is cleaner, with better defined grains and less cement.

The stone dresses to a good smooth surface and sharp edges. The smoothed face shows white and dark specks scattered through a greyish base, in which small glistening flakes of white mica are also apparent.

Examined in thin section under the microscope, the rock shows component particles of quartz, orthoclase, plagioclase, and a finely crystalline volcanic rock. The mineral grains are of variable size up to about 1 mm. in diameter; while the plagioclase is usually quite fresh, the orthoclase is in a state of incipient decay. The rock fragments are of rounded shape, and reach a diameter of 3 mm., but they are comparatively rare. The microscopic section indicates a much cleaner stone than No. 1481, and suggests a comparison with the stone from Jack point, No. 1434, but presents a finer grain. The stone is among the least bibulous of those tested, but it is within the danger zone of injury by frost. The actual freezing test resulted only in the disintegration of the sharp corners of the cube. As with all these blue stones, the corrosion test results in oxidation, with a consequent loss of the blue colour, and an assumption of yellow or buff.

The physical properties are as follows:—

Specific gravity	2·695
Weight per cubic foot, lbs	152·34
Pore space, per cent	9·45
Ratio of absorption, per cent, one hour	2·38
" " " two hours	2·69
" " " slow immersion	3·21
" " " in vacuo	3·56
" " " under pressure	3·87
Coefficient of saturation, one hour	·61
" " " two hours	·69
" " " slow immersion	·88
" " " in vacuo	·92
Crushing strength, lbs. per sq. in., dry	10,589·
" " " " wet	10,068·
" " " " wet after freezing	7,564·
Transverse strength, lbs. per sq. in	849·
Shearing strength, lbs. per sq. in	1,054·
Loss on corrosion, grams per sq. in	·00861
Drilling factor, mm	23·2
Chiselling factor, grams (I)	1·1
" " " (II)	5·2

The analysis of this stone indicates a cement comparable with that of the stone from Jack point in the low content of alumina. The much higher ferric oxide indicates more complete oxidation, and the high content of magnesia suggests a comparison with the buff Saturna Island stone, No. 1449.

Insoluble residue	90·95
Soluble portion	9·05

Partial analysis of soluble portion:—

Alumina	1·41
Ferric oxide	1·20
Ferrous oxide	2·23
Lime	·42
Magnesia	1·37
Carbonic acid	·10
Total	6·73

PLATE VIII.

Sandstone quarry of Vancouver Granite Co., Gabriola island, B.C.

PLATE IX.

Gabriola Island sandstone. Post-office, Victoria, B.C.

No. 1430.—This is a rougher stone than the selected specimen No. 1488: it is of the same general type, however, and differs only in possessing a coarser grain and a slightly more yellow colour. The texture is like that of No. 1434 from Jack point, but it is scarcely as coarse, and there are fewer of the characteristic grains of volcanic rock; the colour also is less "blue."

The stone is quarried by sinking deep holes nearly through the heavy bed, a distance of 20 to 25 feet. These holes are rimmed, and fired with black powder, with the production of remarkably straight breaks. The large masses thus dislodged are cut to suitable sizes by plug and feathers.

Quarrying operations have been suspended, but the company has available supplies at the Vancouver yard, and is prepared to resume work on the receipt of orders. Serviceable derricks are in place on the property.

Gabriola Island sandstone is quoted at 50 cents per cubic foot at the Vancouver plant, plus 10 cents per square foot for sawing.

The stone may be seen in the following structures:—

Post-office, Victoria (Plate IX).

Federal Life building (Williams building), Vancouver.

Roman Catholic church, Dunsmuir street, Vancouver.

Of these buildings the best example is the post-office in Victoria. The older part, built about 30 years ago, presents a general greyish colour with a slightly greenish cast. Both rock-face and bushed work have weathered well, but certain blocks show evidence of disintegration. It is said that this defect is due to the use of material which had been soaked with salt water. The newer part, built in 1914, is considerably lighter and less uniform in colour, with a yellowish-green cast. On some of the smoothed work there is a strong tendency to brownish staining. The grain of the stone varies considerably: streaks showing pebbles up to a quarter inch in diameter were observed in places. Individual blocks are already showing disintegration; but it would appear that a more careful selection of the stone would have obviated this defect. There is no doubt that a more uniform, if darker, appearance is produced by the passage of time.

Valdes Island.

At the north end of Valdes island stone is exposed on the west face in cliffs of 50 feet. At the extreme north it is thin-bedded, but about a mile south three distinct and heavy beds, dipping northeast at a low angle, present possibilities for a quarry site. The average stone (1437) is of a muddy colour, and hard concretions occur to a limited extent. The lower stone is harder (1438), but it occurs in a particularly heavy bed. The bluffs continue for some distance south of this point; the stone is thin-bedded for a distance, but gradually gives place to layers of remarkably even bedding, and of sufficient thickness to yield good coursing stone. The stone exposed in the higher cliffs near the westerly point of the island is thin-bedded, and unpromising, but evenly bedded strata of moderate thickness occur at the southern extremity of the island.

The stone: No. 1437.—This is a yellowish-buff sandstone of medium grain, and closely resembles the Hornby Island buff variety described as No. 1486, on page 39. It is slightly more yellow, and with larger and more numerous flakes of both white and black mica. Examined with the hand lens, and compared with the Hornby Island stone, it is seen to be less clean and with a greater amount of cement. This is a possible building stone, but its durability should be ascertained by experiment before attempts at quarrying would be justified.

No. 1438.—This stone is essentially the same as No. 1437, but it is harder and of somewhat coarser grain.

Southern Gulf Islands Area.

This area includes Galiano, Saltspring, Mayne, Pender, Saturna, and adjacent small islands. Quarrying has been attempted at a number of places, but the greatest production has been from Taylor's quarry on Saturna island.

Galiano Island.

The cliffs along the west side of the northern part of Galiano island are not high, and show sandstones in beds of moderate thickness. Opposite the Secretary islands the cliffs are high; the stone is rather thin-bedded, but it is well jointed by two sets at right angles. Stone of moderate thickness could be obtained in places. Opposite the lower end of Wallace island are cliffs of 150 feet in height, showing a hard type of stone (1439). A similar variety in upturned ledges of slight elevation occurs on the west side of Wallace island. The south end of Galiano island is bold and high, with enormous quantities of sandstone of undetermined character in sight.

The stone: No. 1439.—This stone is of the buff variety, and is nearer in colour to the Mayne Island stone, No. 1445, than to any of the other stones tested. It differs from the Mayne Island stone in its slightly less yellow colour and considerably coarser grain. The component particles are the same as in the average sandstones herein described. The prominence of whitish grains gives the stone a white-speckled appearance. It seems to be rather hard under the hammer.

E. G. Bittancourt, Vesuvius Bay, B.C.: Saltspring Island quarry.

Accessible ledges of sandstone, dipping at high angles to the southwest, occur along the west side of the northern part of Saltspring island. Operations have been carried on at points along the shore of Vesuvius bay.

The most important quarry is located on the north side of Booth bay near its head: it was opened at a height of 100 feet above the water in the side of a hill sloping at about 25°. The formation stands vertical, and strikes exactly east and west. The quarry proper is 150 feet long, and has been opened in a series of steps to a total height of 50 feet. The north wall is a bedding plane with shale parting. Ten feet south is another such parting which is succeeded by a solid bed of 75 feet to a third parting, beyond which the stone is broken and weathered on the face of the hill. Curved fractures parallel to the face of the hill (25° dip southward) divide the stone into great lens-shaped masses, with a maximum thickness of 10 or 12 feet. The east and the west boundaries of the quarry are well defined joint planes striking vertically north and south. The stone varies in grain and hardness, but it shows little reediness and no concretions. An enormous quantity is easily available, but the lenticular character of the parting planes must cause considerable loss. Quarried faces are considerably darkened by the soaking in of dirt, and naturally weathered surfaces are deeply oxidized (1440). Additional smaller openings have been made both to the east and to the west of the main location.

The stone: No. 1441.—This is an average sample, but as considerable variation in grain occurs throughout the exposure the description is not applicable to all the product of the quarry. The stone is the finest in grain of those tested, as rarely do any of the grains exceed ·5 mm. in diameter. These grains are of the usual mineral character, and are connected by a mass of very small particles and a minimum of actual cement. Glistening flakes of mica are visible, and the microscope reveals incipient decay in the orthoclase fragments. The sample belongs to the "blue" series of sandstones, but this colour is less pronounced than in Nos. 1488, 1481, and 1434, the three other typical examples that have been described in full.

In hardness, and in dry crushing strength, the present specimen exceeds the other sandstones which have been tested, but the strength is seriously impaired by soaking in water although the loss on freezing is negligible.

The coefficient of saturation is very high, and indicates grave danger of injury by frost, although the actual freezing test produced very little effect. It is worthy of note, however, that the stone does not enjoy a good reputation in respect to its resistance to weathering. These facts serve to emphasize the statement often made, that the coefficient of saturation indicates only a liability to injury, and that the actual freezing test on unnaturally soaked stone is indicative only of the power to resist mechanical strains. The corrosion test produces a slightly yellow appearance, but the blue tone is not so completely lost as in the case of other of these blue sandstones. The rock is not markedly bibulous.

The physical properties are:—

Specific gravity	2·67
Weight per cubic foot, lbs	157·21
Pore space, per cent	5·678

Ratio of absorption, per cent, one hour	1·40
" " " two hours	1·67
" " " slow immersion	2·11
" " " in vacuo	2·11
" " " under pressure	2·26
Coefficient of saturation, one hour	·62
" " " two hours	·73
" " " slow immersion	·93
" " " in vacuo	·93
Crushing strength, lbs. per sq. in., dry	27,229·
" " " " wet	17,800·
" " " " wet after freezing	17,797·
Transverse strength, lbs. per sq. in	2,296·
Shearing strength, lbs. per sq. in	1,926·
Loss on corrosion, grams per sq. in	·00533
Drilling factor, mm	12·4
Chiselling factor, grams (I)	·15
" " " (II)	1·1

The cement of this stone shows the least amount of carbonates of any of the stones tested. As usual the ferrous oxide greatly exceeds the ferric oxide and the magnesia exceeds the lime. The analysis follows:—

Insoluble residue	90·95
Soluble portion	9·05

Partial analysis of soluble portion: —

Alumina	2·31
Ferric oxide	·68
Ferrous oxide	2·22
Lime	·61
Magnesia	1·54
Carbonic acid	·04
Total	7·40

No. 1440.—This sample shows that the hard bluish stone alters on exposure to a buff variety. The grain of this sample is coarser than in No. 1441, and illustrates the variation in this respect observed throughout the exposures.

The amount of stone actually quarried is small: it was used chiefly for the old post-office in Victoria. The weathering properties of the stone as indicated by this building are not of a high order, as so much disintegration had occurred in a few years that re-facing was resorted to in order to make the structure presentable.

Truesdale & McGregor, Victoria, operators; Mrs. David, Mayne Island, owner. Mayne Island quarry.

This quarry is situated on the north shore of Campbell bay, on the east side of Mayne island. The formation strikes about east and west, parallel to the shore, and dips north at an angle of 10°. The quarry is opened for 150 feet along a single bed 12 feet thick, at a height of about 10 feet above high water. The bed shows little horizontal parting, but strong joints cross 5° north of west and dip 80° to the south: these are wide spaced—2 to 10 feet apart. Other joints cross at E. 45° N. with a dip of 80° to the southeast. The present face of the quarry is a joint plane striking E.15°S. and dipping southward at 75°. The dip of the formation carries the heavy bed under an increasing overburden, and within 50 feet of the present face it would pass under higher strata. East and west, however, large quantities of stone are available. The material exposed by the operations is hard and dark: it is so hard as to be of questionable value (1444).

The outer stone, now largely removed in the quarry proper, is yellow and softer (1445). This type of stone is evidently secondary, and may be seen to varying depth on all weathered surfaces and on joint planes. No concretions and but few mud holes were observed.

The stone: No. 1444.—This is an even-textured sandstone of medium grain, and of a light bluish-grey colour. In the latter respect it is comparable with No. 1450 from Saturna island and with No. 1485 from Hornby island. It also closely resembles No. 1450 in grain, but is, perhaps, slightly coarser. The stone is said to be hard, but no experiments were made to determine this point.

No. 1445.—This rock is the result of oxidation of No. 1444, and is of the same grain. The colour, however, is strikingly different, as it is the most yellow of all the stones examined. The constituent grains occasionally reach one mm. in diameter, but the average size is less—about ·5 mm. with many grains still smaller. More than in any other stone tested, is to be observed a distinct cementing material of brownish-yellow colour. The stone is appreciably affected in strength by soaking and by freezing, but the freezing experiment produced no effect beyond the breaking off of the sharp angles. The corrosion test effected little change in colour.

The physical properties are:—

Specific gravity	2·661
Weight per cubic foot, lbs.	149·02
Pore space, per cent	10·29
Ratio of absorption, per cent, one hour	2·73
" " " two hours	2·98
" " " slow immersion	3·33
" " " in vacuo	3·71

Ratio of absorption, per cent, under pressure	4·31
Coefficient of saturation, one hour	·63
" " " two hours	·69
" " " slow immersion	·77
" " " in vacuo	·86
Crushing strength, lbs. per sq. in., dry	16,505·
" " " " wet	10,869·
" " " " wet after freezing	8,893·
Transverse strength, lbs. per sq. in	892·
Shearing strength, lbs. per sq. in	1,227·
Loss on corrosion, grams per sq. in	·0109
Drilling factor, mm	19·6
Chiselling factor, grams (I)	·6
" " " (II)	4·7

The significant feature of the analysis is the high content of alumina and the degree to which the oxidation of the iron has proceeded. The ferric oxide is almost as great in amount as the ferrous oxide, a condition not seen in any others of the stones tested. The analysis follows:—

Insoluble residue	90·00
Soluble portion	10·00

Partial analysis of soluble portion:—

Alumina	3·51
Ferric oxide	1·10
Ferrous oxide	1·18
Lime	·48
Magnesia	1·67
Carbonic acid	·07
Total	8·01

Two good derricks and a boarding house have been erected on the property. Excellent shipping facilities are presented by deep water along the cliff which permits the direct loading of stone at any height of tide.

Yellow Mayne Island stone was used in postal station "C" at the corner of Main and 15th streets, Vancouver (Plate X). This building presents a very fair appearance, but there is considerable variation in the colour of different blocks. The upper part of the building is distinctly buff, but the lower part inclines to the blue colour of the less thoroughly oxidized stone.

Pender Islands.

Sandstones are exposed all along the southwest side of Pender island, in cliffs running up to 300 and 400 feet a short distance inland. The beds

PLATE X.

Mayne Island sandstone. Post-office at corner of Main and 15th streets, Vancouver, B.C.

dip at about 35° to the northeast, i.e., inland. All the visible stone is coarse and pebbly, and does not look promising as seen from the water. At the narrows between North and South Pender islands, on the south island, are several heavy beds in nearly vertical position; quarrying has been done here as well as on the east side of the north island, at Hope bay. The formation at the latter locality strikes E. 30° S. and dips 20° to the southwest. Stone is accessible in quantity at several points. A small quarry, the site of which is now occupied by a saw mill, was worked here in the year 1896 by Wm. Hoosen (1443).

The stone: No. 1443.—This is a rather hard sandstone of coarse grain: it is very similar in both colour and grain to the stone from Jack point described as No. 1434 on page 42. The present example shows fewer and smaller rounded fragments of volcanic rock than the Jack Point stone.

John Mortimer, Victoria: Pender Island quarry.

On South Pender island, at the east end of the narrows between North and South Pender islands, a small quarry was opened on a property of 40 acres by Mr. Mortimer.

The sandstone beds are nearly vertical, and strike E. 27° N. Curving horizontal joints divide the formation into lens-shaped masses as on Saltspring island. The actual quarry is only 50 feet across, and of inconsequent depth; it seems to include two beds. In spite of the horizontal jointing and other irregular partings it is possible to quarry some large stone. The immediate hill is only 30 feet high, but the formation rises into large hills along the strike on South Pender island. The average stone is hard (1442), and the external oxidized zone is softer and yellow as usual.

The stone: No. 1442.—This rock is of the blue variety, and is very similar in colour to the stone from North Pender island (No. 1443, described above). The grain is much finer, however, and the even dissemination of distinct flakes of black mica gives it a minutely speckled appearance. The stone is hard under the hammer, and exposed surfaces are weathered buff to a varying depth.

The product of this quarry was used chiefly for the tower of the Episcopal church in New Westminster, and for a building at the corner of Carroll and Cordova streets, Vancouver. The stone, as indicated by these buildings, has the property of retaining its original colour remarkably well.

Bradley Dyne, Saturna Island, B.C.

The west shore of Saturna island is high and rocky all along. Sandstones of varying grain and hardness are accessible at many places, but I am informed that most of the stone is too hard for commercial exploitation.

A quarry was opened on the west side of Saturna island on the above property by Taylor and Hoosen, and was subsequently worked to a small extent by Hagarty of Victoria.

The beds of sandstone strike W. 15° S., dip 40° to the northwest, and are immediately accessible in a ridge of about 50 feet in height. Inland the stone rises to a great height; but here as in Taylor's quarry, these upper beds appear to be hard and much broken.

The following section was measured in descending order:—

——Conglomerate.
4 ft.—Shale.
10 ft.—Sandstone bed.
2 ft.— " "
15 ft.— " "
6 ft.— " "
2 ft.— " "
6 ft.— " "
10 ft.— " "

The jointing is very irregular, with the most pronounced series at right angles to the dip, and facing the sea. Cross joints are very irregular.

The unaltered stone is blue, but the exposed stone is of a buff colour due to oxidation; this outer zone is of very limited depth, and has been largely removed by the slight amount of quarrying done.

The blue stone (1446), now exposed in the face of the quarry, seems to retain its colour well, and even sea-washed blocks have not assumed the yellow tone although this oxidation is to be observed on all joint planes.

The stone is of fine grain, but in many places it is filled with small round pellets of pyrites: this feature, together with the very irregular jointing, probably led to the abandonment of the quarry.

The stone: No. 1446.—In both colour and grain this stone is almost identical with No. 1450 from Taylor's quarry at the south end of the island. It is, perhaps, a little softer and has slightly fewer grains of black mica.

The only important building of this stone is the Weiler block at the corner of Government and Broughton streets, Victoria.

George B. Taylor, Saturna Island, B.C.

The quarry is situated at Taylor's point near the southwest angle of Saturna island. The formation strikes W. 25° S. and dips 25° to the northwest. The elevation of the exposure actually worked does not exceed 50 feet, but sandstones occur to a much greater altitude in the big hills to the north and east. The dip of the beds permits a considerable section to be measured in descending order as follows:—

——Higher beds, accessible but not uncovered.
8 ft.—Sandstone bed.
5 ft.—Sandstone bed of inferior quality.

4 ft.—	Sandstone beds of varying quality but chiefly of commercial stone. They are worked on the cove side of Taylor's point. No. 1448 is from the top bed of this series.
4 ft.—	
10 ft. —	
2 ft.—	
6 ft.—	
14 ft.—	
2 ft.—	
9 in.—	Sandstone beds of varying quality exposed in the more southerly workings on the seaward side of Taylor's point.
4 ft. 6 in.—	
1 ft.—	
4 ft.—	
6 in.—	
4 ft.	
14 ft.—	
3 ft.—	Sandstone beds of varying quality exposed in the more northerly workings on the seaward side of Taylor's point. No. 1447 is from the 10-foot bed.
10 ft.—	
3 ft.—	
1 ft. —	
1 ft. 6 in.—	
6 ft.—	
2 ft. 6 in.—	

30 ft.—Broken sandstones, not quarried, exposed to the northward of the present workings on the seaward side of Taylor's point.

The dip and strike vary slightly in different parts of the workings which are about 250 yards long. The main joints are vertical at S. 15° E., and are cut by less frequent, but strong joints at S. 10° W. Cross joints, used as backs in quarrying, are practically vertical to the bedding, but they are very irregularly developed. The stone of all the beds varies in grain and colour, but two general types are recognized—buff (1449) and blue (1450). The buff stone which is the most desirable material is evidently the result of oxidation of the original blue variety: it occurs only in a superficial zone, the depth of which depends on the degree to which jointing has permitted the passage of surface waters into the formation. In consequence of this manner of occurrence of the buff stone, quarrying operations have consisted largely in the removal of this material throughout the extent of the workings. It is said that in 5 or 6 years the blue stone assumes a colour indistinguishable from that of the buff variety, but the stone from different beds, both buff and blue, retains its individual characteristics. In other words, all the stone tends to assume a general buff colour, but the material from different beds does not weather to a uniform appearance. Soft spots occur in places and excessive shattering or pronounced diagonal fracturing cause considerable loss in quarrying. The stone is practically devoid of reediness, and pyrite was not observed on any of the natural surfaces.

The stone: No. 1449.—A medium-grained sandstone of buff colour but with less of the yellow component than the yellow stone from Mayne island. Smoothed surfaces show a "clean" and minutely speckled appearance, marred only by the occasional occurrence of rounded slate-coloured fragments up to 4 or 5 mm. in diameter.

Under the microscope the grains do not exceed ·5 mm. and average about ·25 mm. in diameter. The usual quartz, both varieties of feldspar, mica, and the small rounded fragments of volcanic rock constitute the mineral grains which are closely appressed and united by very little cementing material. The section is distinctly "clean".

Freezing produces little or no visible effect, and the loss of strength on wetting and freezing is not excessive. The alteration of the blue stone, No. 1450, into this variety has not produced any pronounced differences in the physical properties. The corrosion tests result in a slight deepening of the yellow colour. The coefficient of saturation is lower than in any other of the sandstones, and indicates good frost-resisting properties.

The physical properties are:—

Specific gravity	2·667
Weight per cubic foot, lbs.	148·31
Pore space, per cent	10·92
Ratio of absorption, per cent, one hour	2·42
" " " " " two hours	2·68
" " " " " slow immersion	3·09
" " " " " in vacuo	3·63
" " " " " under pressure	4·60
Coefficient of saturation, one hour	·52
" " " two hours	·58
" " " slow immersion	·67
" " " in vacuo	·78
Crushing strength, lbs. per sq. in., dry	14,800·
" " " " wet	11,837·
" " " " wet after freezing	11,601·
Transverse strength, lbs. per sq. in	1,212·
Shearing strength, lbs. per sq. in	1,404·
Loss on corrosion, grams per sq. in	·0113
Drilling factor, mm	25·4
Chiselling factor, grams (I)	2·3
" " " (II)	5·9

The analysis of this oxidized variety of Saturna Island stone should be compared with that of the unaltered type given on page 32. Remarks on the nature of the alterations may be found on the same page.

The analysis by Turner follows:—

Insoluble residue	91·57
Soluble portion	8·43

Partial analysis of soluble portion:—

Alumina	1·85
Ferric oxide	·76
Ferrous oxide	1·92
Lime	·31
Magnesia	1·32
Carbonic acid	·10
Total	6·26

No. 1450.—This stone is of the same grain and mineral composition as No. 1449. The colour, however, is intermediate between the typical buff and typical blue examples. In this respect it resembles No. 1485 from Hornby island. The microscopic section shows no differences from No. 1449, but the smoothed surface is without the larger rounded fragments seen in that stone.

The freezing test produced no visible effect, but the corrosion test results in the assumption of a lighter and distinctly yellow colour.

A comparison of the physical properties of this stone with those of No. 1459 shows very little difference. The alteration of the blue stone to the buff variety has scarcely affected the gravity or the properties dependent on porosity. The altered stone, however, seems to be somewhat stronger and yet more amenable to chiselling.

The physical properties are:—

Specific gravity	2·674
Weight per cubic foot, lbs	148·41
Pore space, per cent	11·10
Ratio of absorption, per cent, one hour	2·40
„ „ „ two hours	2·65
„ „ „ slow immersion	3·42
„ „ „ in vacuo	3·72
„ „ „ under pressure	4·67
Coefficient of saturation, one hour	·51
„ „ „ two hours	·56
„ „ „ slow immersion	·73
„ „ „ in vacuo	·79
Crushing strength, lbs. per sq. in., dry	13,450·
„ „ „ „ wet	11,617·
„ „ „ „ „ after freezing	8,976·
Transverse strength, lbs. per sq. in	967·
Shearing strength, lbs. per sq. in	1,297·
Loss on corrosion, grams per sq.in	·01066
Drilling factor, mm	27·0

Chiselling factor, grams(I)	1·2
" " " (II)	4·2

The analysis of this less altered type of Saturna Island stone should be compared with that of the buff variety given on page 32. A comparison of the two analyses with remarks on the probable nature of the alterations is given on the same page.

Insoluble residue	90·86
Soluble portion	9·14
Partial analysis of soluble portion:—	
Alumina	2·17
Ferric oxide	·41
Ferrous oxide	2·28
Lime	·11
Magnesia	1·62
Carbonic acid	·10
Total	6·69

No. 1447.—A fine, even-grained, buff sandstone very similar to No. 1449 but of slightly more yellow tone.

No. 1448.—Similar to Nos. 1449 and 1447, but slightly more yellow than either, and softer under the hammer. These variations are due to the degree to which oxidation has progressed.

The equipment is as follows:—

3 steam derricks.
1 steam rock drill.
1 engine and boiler.
1 small gang saw.

Mr. Taylor quotes the following prices:—

Saw blocks, roughly squared—25 cents per cubic foot. Dimension stone—40 cents per cubic foot.

Saturna Island stone, all of the buff variety, may be seen to best advantage in the following buildings:—

Carnegie library, Victoria (Plate XI).
Hatley Park house, Victoria.
Bank of British North America, Victoria.
Post-office, New Westminster.
First Presbyterian church, Victoria.
P. Burns building, Hastings street, Vancouver.
Normal school, Vancouver.

The Carnegie library, Victoria, has a general grey-green-yellow colour, but the stone varies considerably in different blocks. The surface is quite hard and shows no disintegration, but copings and exposed parts are darkened by imbibition of dirt. The building has a good general appear-

Saturna Island sandstone. Carnegie library, Victoria, B.C.

ance, and proves the adaptability of the stone to fine carving. Pillars of 8 feet in length have been cut from single blocks.

Koksilah Area.

Koksilah Quarry.

This quarry, known locally by the above name, is situated immediately east of the track of the Esquimalt and Nanaimo railway at a point about a mile north of Cowichan station. Here the road bed has been cut through a spur of rock for 250 yards. The formation strikes E. 10° N. and dips 25° to the northward. The general section as exposed here and at points to the south is as follows, in descending order:—

0-10 ft.—Drift.
——.—Shaly sandstone (1452).
20 ft.—Sandstone bed divided in places.
20 ft.—Soft sandstones, shales, and conglomerates.
——.—Shale.

The quarry is opened at the south end of the cut where the conglomerate is encountered at an elevation of 20 feet above the track. The dip of the strata carries these layers down to the level of the track at the north end of the exposure. The overlying sandstone bed is accessible throughout this distance.

Joints cut the formation in a general north and south direction. They are highly inclined, but dip both ways from the vertical, and consequently cause the loss of much stone. In places, these joints are 10 to 12 feet apart, but usually they are much closer. Cross joints, at right angles to the above, are very irregularly developed with a prevailing dip of 70° to the southward. On the whole the formation is rather seriously shattered.

The heavy sandstone bed shows a fairly uniform blue-grey colour and even grain which is interrupted by occasional coarser streaks and fossil-bearing bands. On joint planes and long-exposed surfaces a yellow oxidized zone is developed, but the alteration must go on very slowly as none of the artificially exposed stone, either in the rock-cut or in the quarry, shows any appreciable change in colour except a darkening due to the imbibition of dirt.

Intrinsically, the stone from this quarry has much to recommend it. The colour is good and uniform; the grain is fine and even; the wearing properties are excellent, and the amenability of the stone under the chisel is above the average. On the other hand, the serious shattering of the formation would entail a very large waste in quarrying.

The stone: No. 1451.—This stone is a very fine-grained and uniform sandstone of the "blue" type; it is very similar in colour to No. 1488 which has been described as the most blue of the stones tested in detail. The mineral composition is the same as in the average stone of the type, but the grain is very fine—finer even than in No. 1441 which has the closest grain of the stones tested in full. This seems to be a very desirable stone, and it would have been tested in full if the formational features were more promising.

No. 1452.—A hard, dark-grey, indurated sandstone, containing impressions of fossils: it is of no promise as a building stone.

The Koksilah stone may be seen in "Craigdoric" and in the Methodist church at the corner of Pandora and Quadra streets in Victoria.

Summary—Sandstones of the Cowichan Group.

The only sandstones of commercial importance in British Columbia are quarried from the islands adjoining the Vancouver coast in the southern part of the Strait of Georgia. The normal stone is of blue colour, but by oxidation the superficial part of the outcrops become altered to buff. Both varieties are employed for building. The most important quarries are on Gabriola and Saturna islands, whence stone has been taken for many important buildings in Victoria and Vancouver. A harder stone of more nearly true grey colour was formerly obtained from Newcastle island near Nanaimo, but the quarry has not been operated recently.

The typical buff stone is described in full as No. 1449, on page 59 and blue varieties are similarly treated as No. 1488, on page 49, and No. 1481 on page 34.

A summary of the general characteristics of the average stone is given on page 33.

Literature:—Geol. Sur. Can., Sum. Rep. for 1909, pp. 98-102.
Am. Jour. Sci., 3rd series, vol. 39, pp. 180-183, 1890 (Dawson).
Geol. Sur. Can., Sum. Rep. for 1906, pp. 55-59 (Poole).
Report of the Minister of Mines of British Columbia for 1904, pp. 248-251.
Geol. Sur. Can., Memoir 13, Pub. No. 1121, 1912 (Clapp).
Geol. Sur. Can., Memoir 51, Pub. No. 1344, 1914 (Clapp).
For extended bibliography see the last mentioned reports.

CHAPTER IV.

THE GRANITES AND RELATED ROCKS OF THE PROVINCE OF BRITISH COLUMBIA.

True granite is a rock of igneous origin, which has cooled from a state of fusion at great depths in the earth. In consequence of this manner of origin it consists entirely of crystals which are approximately of the same size. The minerals represented by these crystals are quartz, orthoclase or potash feldspar, and mica. The last mineral may be replaced in whole or in part by others of like nature giving rise to varieties distinguished by prefixing the name of the mineral which replaces the mica, e.g., hornblende granite.

The term "granite" in the usage of builders and monument makers is of much wider application, and may be employed for almost any igneous rock, but in the case of the very dark stones it is customary to prefix the adjective "black." This use of the term, while quite indefensible on scientific grounds, has been adopted throughout this series of reports and will be retained for the present volume. Most of the British Columbia stones herein called granite are really *granodiorites*, which differ from true granite in the presence of soda-lime feldspar or plagioclase, in addition to the orthoclase. The total failure of orthoclase and its replacement by plagioclase makes the rock *quartz diorite*, and a rock with the composition of granite, but without quartz, is *syenite*.

On geological grounds the commercial granites of British Columbia may be considered under three heads as follows:—

1—Ancient granites of Pre-Cambrian time, included in the Shuswap terrane, and quarried on Okanagan lake.

2—Granites of the great multiple batholith of the Coast range, quarried at a number of points on the coast, and to a less extent inland.

3—Granites belonging to intrusions of later age than Jurassic. The chief of these is the granitic mass in which are situated the quarries near Nelson.

Practically, the better known commercial granites fall naturally into four groups as follows:—

1—The reddish, coarse to medium-grained granites of the Shuswap terrane which are quarried on Okanagan lake.

2—A series of rocks of general granitic appearance showing clearly three constituents to the naked eye, and usually presenting a grey or slightly pinkish colour. These stones are all granodiorites. Arranged in order of grain from fine to coarse the more important representatives are as follows:—

i—Granites on the Canadian Pacific railway west of Nelson (Nos. 1523 and 1524, pages 109 and 110).

ii—Granites of Jervis inlet (Nos. 1462, 1453, and 1487, pages 89 and 85).

iii—The coarser type of Jervis Inlet stone (No. 1467, page 86) and the granite of Three-mile point Kootenay lake (No. 1514, page 112).

3—The rocks of this class are darker in colour and differ from the second series in presenting to the naked eye a general effect of two constituents only—a sharply defined, black component, and a similarly defined white ingredient. The rocks included here vary from granodiorites to quartz diorites, and pass insensibly into the types commonly called black granites.

The more important representatives of this class arranged in order of grain from fine to coarse are as follows:—

i—The quartz diorite of Agassiz on the main line of the Canadian Pacific railway (No. 1454, page 73).

ii—The granodiorite of Smith island (No. 1577, page 96).

iii—The granodiorite or quartz diorite of Tyee on the Grand Trunk Pacific railway (No. 1578, page 98).

4—The quartz diorite porphyrites of Cathmar on the Canadian Pacific railway and of Little Canyon on the Grand Trunk Pacific railway (No. 1493 page 76, and No. 1589, page 115).

While for commercial reasons it might be better to describe the granites in the order and according to the grouping indicated above, the desirability of retaining the geological basis of classification throughout the report is apparent. On this account the rocks will be grouped geologically in the detailed description which follows.

Granites of the Shuswap Terrane.

The intensely altered sediments of the Shuswap series are cut by numerous eruptive masses of granite which generally show a gneissoid structure, and, as a rule, are much too shattered to serve as a source of building stone. Granites of this kind are seen along the Shuswap lakes, and a wide band is crossed by the Canadian Pacific railway between Craigellachie and Sicamous. The Okanagan mountains to the south of this locality have furnished the only building stone from this horizon. Speaking generally, it appears that the great mass of these mountains is severely shattered, and it is only in very restricted areas that the stone is of sufficient solidity to justify quarrying operations. It is unlikely that very large quarries will ever be worked, as the large stone is soon taken out, and fractured headings necessitate the transferring of operations to a more favourable place.

Okanagan Lake Area.

The stone has been worked at points on both sides of the railway between Sicamous and Okanagan Landing, and more particularly on the east side of Okanagan lake.

Benjamin Lefroy, Okanagan Landing, B.C.

The eastern side of the upper part of Okanagan lake is bordered by hills of granite reaching to several hundred feet in height. The exposures along the shore are much broken, for the most part, and present few places at which quarrying could be done. The present location is about 4 miles south of Okanagan Landing, and has been worked by the Vernon Marble Works and others.

The quarry is about 50 feet long, with a maximum face of 20 feet. Distinct sheeting is not shown, but the upper part of the face is cut by close-set arching partings conforming to the contour of the hill, more particularly on the northern slope. A strong set of vertical joints run north and south; one of these forms the present face and near it parallel joints are numerous forming a fractured heading. The southern end of the quarry shows that the outermost stone is also severely fractured; consequently, it may be assumed that the good stone, now removed, lay between the outer broken material on the shore and the fractured heading forming the present face. Other vertical joints cross the formation in a direction approximately southeast. I would venture the opinion that this site has furnished fair-sized stone for building purposes, but that it gives no promise of being able to yield really large blocks.

The stone has a good rift and grain; it works easily under the hammer; and is practically devoid of knots or flaws. The freshly broken stone has a more "lively" appearance than the blocks in the quarry, which have become dulled on the surface.

The stone: No. 1497.—This is a dull, light reddish granite, lacking in "liveliness." It is rather coarse in grain, with feldspar crystals up to 8 mm. in diameter. Quartz is much less abundant than the feldspar, and the dark mineral is biotite in relatively small amount.

The microscope shows large orthoclase crystals in a semi-decomposed condition, less plagioclase, biotite, and a few grains of olivine. The rock is nearer to a true granite than any other stone tested for this report.

The stone is not affected by the freezing test, and the only observable effect of corrosion is a slight increase in the definition of the individual components. The content of sulphur is only 0·005 per cent.

The physical properties of this stone follow:—

Specific gravity	2·643
Weight per cubic foot, lbs	162·57
Pore space, per cent	1·47
Ratio of absorption, per cent, one hour	·31
" " " two hours	·325
" " " slow immersion	·42
" " " in vacuo	·498
" " " under pressure	·563

Coefficient of saturation, one hour	·55
„ „ „ two hours	·58
„ „ „ slow immersion	·74
„ „ „ in vacuo	·88
Crushing strength, lbs. per sq. in., dry (a)	29,481·
„ „ „ „ „ (b)	30,598·
„ „ „ „ „ (c)	31,288·
„ „ „ „ „ (average)	30,455·
Transverse strength, lbs. per sq. in	2,032·
Shearing strength, lbs. per sq. in	2,205·
Loss on corrosion, grams per sq. in	·001963
Drilling factor, mm	7·9

Between 6,000 and 7,000 cubic feet of stone have been quarried; it was used for building purposes and for monument bases. Good examples are to be seen in the following structures:—

Post-office, Vernon.

Railway station, Vernon.

Hudsons Bay Company's building, Vernon.

Church of England, Kelowna.

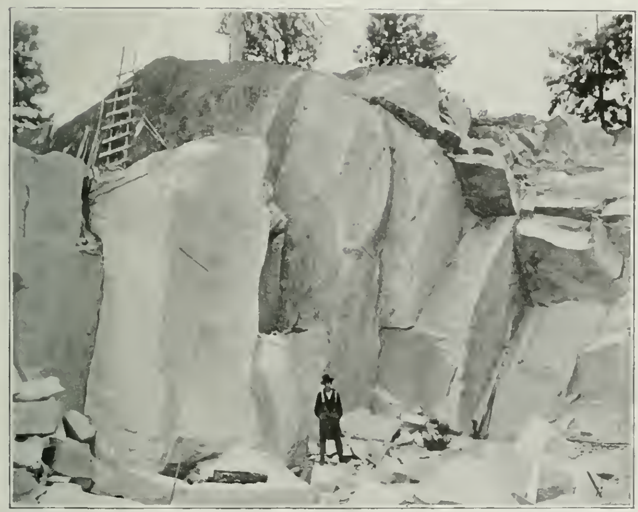
Royal Bank, Kelowna.

The Vernon post-office, built in 1911, shows a uniform and pleasing pinkish tint, without any sign of knots, flaws, or iron staining. Examined closely, however, the stone is seen to be dull and to lack brilliancy.

Vernon Granite and Marble Works, operators, Price Street, Vernon; Wm. Inkster, manager; Price Ellison, owner, Okanagan Landing, B.C.

The quarry is situated on the east side of Okanagan lake about six miles south of Okanagan Landing; it is 75 feet long, parallel to the shore, and extends back to a distance of 50 feet. The face is about 30 feet high (Plate XII).

The sheeting of the formation is irregular, and is poorly developed at the north end; near the middle, at the top of the face, the sheets seem to dip eastward at about 30°; at the south end 3 or 4 very irregular sheets are observed. The main joints strike N. 20° W. and dip 85° westwardly; they are widely spaced and permit the quarrying of large stone. It is stated that blocks 15½ × 3 × 2 feet, have been raised. Other more irregular joints with varying strike cross the formation in an opposite direction. Intimate diagonal fracturing is also observed in certain parts of the quarry. Summing up the formational features here, one might make the statement (applicable to the whole of this district) that large stone is obtainable only in places of very restricted extent. Large quarries are not likely to prove successful, as a great amount of unmarketable material must be removed to obtain a limited amount of dimension stone. Operations are more likely to prove successful if conducted on a small scale with light



Granite quarry of the Vernon Granite and Marble Works, Okanagan lake, B.C.

PLATE XII.

Okanagan granite, quarry of the Vernon Granite and Marble Works, Okanagan lake, B C.

Okanagan granite, Vernon Marble and Granite Works. Court house, Vernon, B.C.

machinery capable of being easily moved from place to place, as favourable ledges are located. In the rear of the present workings some good outcrops were observed, and, doubtless, many others could be found in the region.

The rift of the stone is vertical at N. 15° E, and therefore, is not parallel to the main jointing. The grain is horizontal. I am informed that very little difference in splitting is observed in the three directions—rift, grain, and hardway. Knots are practically absent.

The stone: No. 1498.—This granite is a brighter, fresher, and somewhat coarser stone than No. 1497 from Lefroy's property; it is shown in Plate XIII. The mineral constituents are quartz, orthoclase in crystals up to 10 mm. long, plagioclase in less amount, and black mica or biotite with a little green chloritic matter. The orthoclase crystals show considerable decomposition, but the plagioclase individuals are quite fresh. The relatively small amount of plagioclase makes the rock almost a true granite.

The freezing and corrosion tests produce no appreciable results. The absorption tests are satisfactory and show a particularly low coefficient of saturation. An analysis shows only 0·003 per cent of sulphur.

The physical properties of this stone follow:—

Specific gravity	2·67
Weight per cubic foot, lbs.	164·30
Pore space, per cent	1·427
Ratio of absorption, per cent, one hour	·254
„ „ „ two hours	·260
„ „ „ slow immersion	·354
„ „ „ in vacuo	·465
„ „ „ under pressure	.543
Coefficient of saturation, one hour	·47
„ „ two hours	·48
„ „ slow immersion	·65
„ „ in vacuo	·85
Crushing strength, lbs. per sq. in. dry (a)	25,254·
„ „ „ „ (b)	24,319·
„ „ „ „ (c)	24,800·
„ „ „ „ (average)	24,791·
Transverse strength, lbs. per sq. in.	1,968·
Shearing strength, lbs. per sq. in.	1,821·
Loss on corrosion, grams per sq.in.	·00153
Drilling factor, mm.	8·5

The total production from this quarry was about 30,000 cubic feet, most of which was used for the court house in Vernon, and a small amount for monuments chiefly for bases. The court house is a very fine building with a uniform, pleasing, slightly pinkish colour; it shows less disfiguration due to knots, veinlets, etc., than most of the granite structures in British

Columbia. The building bears the date 1914; it is consequently too new to furnish evidence as to the durability of the stone (Plate XIV).

The following prices are quoted, all f.o.b. quarry. Rock-face, reveals cut:—

Sills up to $7\frac{1}{2}$ in. high, 10 in. on bed, plain or lug, per lineal ft.......	$1.75
" " " 12 " " " "	2.00
Window heads up to 12 in. high, 8 in. on bed " "	1.75
Window archstones, 12 in. by 14 in. by 6 in., each..................	2.25
Cut ashlar, 12 in. high, 8 in. on bed, 4-cut, per lineal ft.............	2.00
" " " 6-cut " "	2.25
Door sills, up to $7\frac{1}{2}$ in. rise, 12 in. tread, 4-cut, per lineal ft..........	2.50
(Over 12 in. tread, add 50 cents per foot for every 3 in.)	
Rough blocks, random squared, per cu.ft.........................	·50
Rough blocks, dimension, per cu. ft.............................	·60

Lengths over 7 ft. up to 9 ft., add 10 per cent. Over 9 ft. special prices.

——*Lumsden, Armstrong, B.C.*

A quarry was opened by Mr. Lumsden on the granite ridge at a point about $1\frac{1}{2}$ miles south of Armstrong and a mile east of the track of the Canadian Pacific railway. The stone has a good rift and grain, and works with facility. Unfortunately it contains an undue amount of pyrite with the result that all cut stone becomes badly spotted after a short period of weathering (1499).

The stone: No. 1499.—This rock is a fine-grained, light grey granite or granodiorite resembling in a general way No. 1489 from Sinclair's bluff; it has the same white ground and about the same grain as that stone, but it differs in containing amber-coloured mica instead of the mixed biotite and hornblende of Sinclair's stone. The rock is not at all comparable with the granites from Okanagan lake described as Nos. 1497 and 1498.

This stone would be a very desirable building material were it not for the profusion of easily oxidized grains of pyrite. A small amount was used for monument bases and in the base of the Bank of Montreal in Vernon.

Granites of the Coast Range.

The great Coast range, extending for more than 850 miles along the coast of British Columbia from the Fraser river to beyond the northern boundary of the province is composed of intrusive rocks of general granitic aspect. A large and deep-seated intrusion of this kind is called a "batholith" and when, as in this case, the rocks do not belong to a single period of intrusion it is termed a "multiple batholith." It has been proven that the initial igneous masses of the range appeared in late Jurassic time and that subsequent intrusions, extending into Cretaceous time, greatly increased the extent of the original batholith.

A great mass of molten matter in cooling does not necessarily crystallize into the same rock throughout its whole extent, adding to this the fact that the molten masses (magmas) were not all of the same age and consequently not all of the same chemical composition, it is clear that the Coast range will present rocks of many varieties differing in chemical and mineral composition. The rocks actually occurring vary from true granites to those dark-coloured rocks known to quarrymen as "black granites," and of which gabbro will serve as an example. The great bulk of the mountains is made up of an intermediate type known as "granodiorite" which differs from true granite in containing feldspar crystals belonging to both the potash and the soda-lime varieties (orthoclase and plagioclase). The darker rocks are characterized chiefly by the failure of quartz as one of the constituents and the preponderance of soda-lime feldspar and ferro-magnesian minerals such as biotite and pyroxene. In the present chapter only those rocks will be considered which have the general appearance of granites; the dark-coloured rocks will be referred to under other heads.

The rocks of the Coast range have been so affected by metamorphic agencies during the period of cooling and crystallizing that over great areas they no longer have the uniform distribution of the constituent minerals characteristic of granite but have acquired the more or less laminar arrangements of the rock known as "gneiss."

It is a natural inference that these vast ranges would present numerous sites at which quarrying operations would be justified by the nature of the stone and the condition of the formation. Such inference, however, is not borne out by the facts, for the number of desirable locations is not great and not at all in proportion to the extent of the granitic masses. This statement applies, of course, only to the accessible exposures along the coast and railways; the possibilities of the great interior are entirely unknown.

The failure of the great bulk of the batholith to furnish sites suitable for quarrying is to be attributed to a number of causes among which the following are the more important:—

1.—Inaccessibility.

2.—The precipitous character of many of the accessible exposures.

3.—Coarseness of grain and the development of gneissoid and porphyritic structure.

4.—The prevalence of the black aggregations known as "knots."

5.—Veinlets of aplitic matter formed during the closing stages in the cooling of the magma.

6.—Thin and irregular sheeting.

7.—Shattering. The great bulk of the mountains is so excessively jointed that for miles along the railways and coast it is evident that any attempt to obtain dimension stone could result in nothing but failure.

8.—Injection by later igneous rocks. This is unimportant as such injections are not general and areas so affected may easily be avoided.

The granites of the Coast range undoubtedly constitute the most desirable building and monumental stone of the province; they have been used for most of the important structures in Victoria and Vancouver, and have been exported to points outside the Province of British Columbia.

The areas of actual production may conveniently be arranged as follows:—

Canadian Pacific Railway area.

Pitt River area.

Burrard Inlet area.

Jervis Inlet area.

Prince Rupert area.

In addition to these areas in which actual quarrying has been done, the literature contains reference to numerous possible sites; a description of these localities, and some fragmentary notes resulting from my itinerary, will be given under the caption "Other Occurrences."

Canadian Pacific Railway Area.

The rocks of the Coast Range batholith are not very distant from the line of railway from Vancouver to Thompson. In the lower part of the valley of the Fraser they are covered by Tertiary and Cretaceous sediments in the immediate vicinity of the railway. Near Agassiz station, however, outcrops occur on the line, and a little quarrying has been done. Between Waleach and Ruby Creek is another exposure which, like the one at Agassiz, will be described in detail as a definite locality. East from Ruby Creek the granite is accessible in numerous rock-cuts almost to North Bend. The stone is nearly all gneissoid in structure, severely fractured, and in many places reticulated with aplitic veinlets. At a point a short distance east of Spuzzum quarrying was attempted, and more extensive operations were conducted at Cathmar. From North Bend to Lytton the granite is covered by Cretaceous sediments and volcanic rocks near the railway. In the vicinity of Gladwin exposures are more accessible but the stone is shattered and unpromising.

The granite quarried along the line has been used almost exclusively for rough building in connexion with the railway. No regular quarrying of building stone has ever been attempted, but I understand that a Vancouver company proposes to take stone for monumental purposes from a point near Agassiz.

Findlay Sinclair, Agassiz, B.C.

About a mile east of Agassiz station a spur of granite from the neighbouring mountain to the north is cut by the main line of the Canadian Pacific railway at Sinclair's bluff. A small amount of quarrying was done here with the intention of using the stone for the post-office in Vancouver, but the few blocks quarried were not shipped.

The bluff rises to a height of 200 feet and is very massive with little evidence of distinct sheeting. The jointing is by no means excessive and there is no doubt that very large stone could be obtained. The precipitous character of the bluff and the lack of distinct sheeting would occasion extra expense in opening a quarry.

The rock varies a little in colour along the railway cut, and, in places, black knots are too frequent to make it a commercial stone. In other parts, however, particularly at the west end where the quarrying has been done, this objectionable feature is less pronounced. The stone breaks easily and the blocks in the quarry show no iron-staining or other signs of weathering except a slight whitening of the feldspar.

The stone: No. 1489.—This is a medium to fine-grained grey granodiorite comparable with the best stones from Jervis inlet. The light-coloured minerals are clean and of pure white colour. The dark minerals show rather more hornblende than the Jervis Inlet stones, but most of the grains are biotite evenly distributed in small crystals throughout the mass of more abundant light-coloured minerals. The purity of the colour of the light minerals, a feature common to this stone and to No. 1490 from Seabird bluff, and in which they exceed the Jervis Inlet stones, is a feature highly in their favour.

Patterson, Chandler & Stephen, 3149 Main St., Vancouver, B.C.

This company holds quarry lands near Agassiz station on the main line of the Canadian Pacific railway. The property consists of subdivision 5, section 14, township 4, range 29 west of the 6th meridian. An opening was made at a point about three miles from the railway, and some blocks were taken out for monumental purposes. Since my visit the company has located a more favourable site close to the Fraser river where they propose to begin operations in the spring of 1917. It is stated that a good quarrying site has been found within 20 feet of deep water and that stone can be loaded directly on barges for transportation down the river. The waterway between the quarry and Harrison is obstructed by a bar on which a government dredge has been working but has not yet succeeded in entirely removing the obstruction. On the completion of this work the firm will have an excellent means of transportation to Vancouver. The exposure is described as being 45 feet in height and 125 to 150 feet long with practically no flaws.

The stone: No. 1454.—This example was taken from the older workings but I am informed that the stone on the river is of the same quality. The four stones Nos. 1454, 1577, 1578, and 1512 are of very similar character and increase in coarseness in the order given. The present example is much the finest in grain and shows a very even structure with the dark and light components in about equal amount. The grains do not average over 2 mm. in diameter and are evenly disposed giving a clear, even, speckled appearance on polished surfaces (Plate XV). The microscope shows the light minerals to be chiefly plagioclase in lath-like forms of remarkably good preservation. Smaller amounts of orthoclase and microperthite and still less quartz make up the remainder of the light minerals. The dark minerals are brown biotite and greenish hornblende in about equal amounts. The great excess of plagioclase and the small amount of orthoclase and quartz makes the rock a quartz-biotite-hornblende diorite rather than a granodiorite.

The corrosion test produced no visible effect and the coefficient of saturation is well below the danger line. The sulphur content is 0·006 per cent.

The physical properties are as follows:—

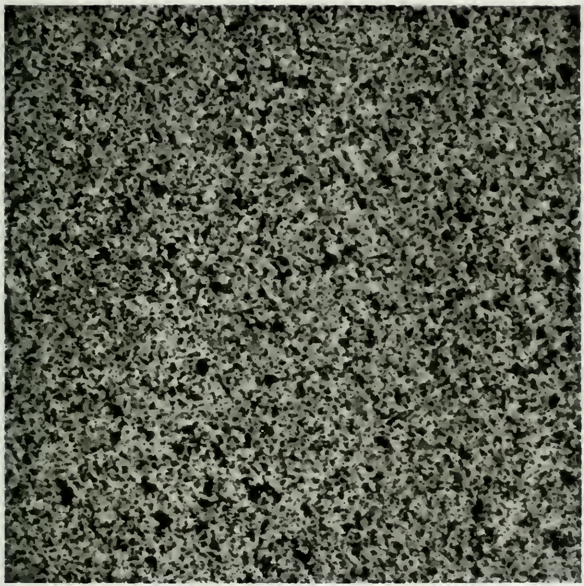
Specific gravity	2·782
Weight per cubic foot, lbs	171·18
Pore space, per cent	1·432
Ratio of absorption, per cent, one hour	·307
„ „ „ two hours	·318
„ „ „ slow immersion	·362
„ „ „ in vacuo	·511
„ „ „ under pressure	·523
Coefficient of saturation, one hour	·60
„ „ „ two hours	·61
„ „ „ slow immersion	·69
„ „ „ in vacuo	·97
Crushing strength, lbs. per sq. in., dry (a)	32,166·
„ „ „ „ (b)	31,673·
„ „ „ „ (average)	31,919·
Transverse strength, lbs. per sq. in	2,457·
Shearing strength, lbs. per sq. in	1,842·
Loss on corrosion, grams per sq. in	·000536
Drilling factor, mm	6·8

Seabird Bluff, Canadian Pacific Railway.

On the main line of the Canadian Pacific railway, between Waleach and Ruby Creek, a long rock-cut is occasioned by the proximity of the mountain on the north. A small amount of stone was quarried at the west end of the cut and was shipped to Vancouver under the name "Seabird granite."

The stone here is locally jointed in a manner to make the quarrying of small blocks very easy. The most pronounced set strikes N. 10° E. and

PLATE XV.



Agassiz granite, quarry of Patterson, Chandler and Stephen, Agassiz, B.C.

dips 70° westwardly. The joints of this system seem to be later than the other fractures; they are fairly closely spaced and are seldom more than 1 or 2 feet apart. A second set of joints strikes N. 20° W. with a dip of 45° to the northeast; these are widely spaced. The third set strikes about east and west with a dip of 70° to the south; the parting planes are from 4 to 6 feet apart. These well defined jointing systems permit the easy extraction of stone of fair sizes. The blocks, however, are not of rectangular shape. The stone is coarse in grain with respect to the black minerals and shows scattered large black knots (1490). Flow structure is observed parallel to the two latter sets of joints, but never parallel to the first set which cuts distinctly across the formation.

Eastward the stone is more shattered and less regularly jointed with evidence that the northeast system of joints is really sheeting. At about a quarter mile from the first exposure another zone of evenly jointed stone is observed. Still farther east the granite is cut by dikes, and at about a mile from the first exposure it terminates against a highly inclined, altered, schistose rock.

The stone: No. 1490.—This is a grey granodiorite of the same type as No. 1489 from Sinclair's bluff. The light-coloured minerals are clean and white and of about the same size as in Sinclair's stone. The dark minerals are considerably larger, with crystals up to 5 mm. in diameter; this gives the stone a coarser aspect. Hornblende is more abundant than biotite; in this respect, the stone differs from the product of the Jervis Inlet quarries. In the pure white colour of the light minerals both this example and No. 1489 exceed the average Jervis Inlet stone and are much superior to Nos. 1461, 1463 and 1465. While working in the quarry I was much impressed by the facility with which the stone can be broken.

Canadian Pacific Railway Co., Camp 16 (Cathmar).

A considerable amount of stone was quarried at this point for use in culverts, bridge piers, etc., along the line of the railway. Operations were carried on from time to time up to 1912.

An irregular excavation in the mountain side has been made for a distance of about 200 yards but regular quarrying has been confined to about half that distance. The present face is about 75 feet high but it would rapidly increase if quarrying were continued; its general direction is N. 20° W. The sheeting is very irregular; in places it is thin, in others it is quite thick. This feature alone would occasion a great loss in systematic quarrying. The sheeting planes conform roughly to the shape of the mountain; at the north end of the quarry they dip about 10° to the eastward; higher up, at the south end, the inclination is fully 45° in the same direction. The main joints strike about north and south, and dip 80° to the east; while irregular, they are quite pronounced and determine the face of the quarry.

A less defined set strikes east and west with a dip of 70-80° to the south; it shows evidence of slipping in a horizontal direction and the planes are frequently marked by stringers of quartz. The spacing of both sets is very irregular and variable; in places, it would permit the extraction of large stone, in others, the amount of thin and broken material would be excessive. On the whole, it may be said that the railway company, which can make a certain use of the large amount of waste, is able to obtain fairly heavy stone at this site. On the other hand, I fear that the formation is much too shattered to attract the attention of an operator for building stone *per se* (Plate XVI).

The rather coarse grain of this stone and the occasional occurrence of porphyritic crystals of large size make it difficult to dress the blocks to a fine edge. Black knots are less frequent than in many of these granites, but much of the stone is marred by the presence of veinlets of aplite. It is distinctly a stone for rough and heavy construction rather than for fine building or ornamental purposes.

The stone: No. 1493.—This stone is distinctly different from the other so-called granites tested for this report. The smoothed surface shows large white dots up to 8 or 9 mm. in diameter in a fine-grained mass of white and black grains. Lack of purity in the white elements detracts from the clean appearance of the stone (No. 4, Plate XLVII).

A microscopic examination shows that the white dots are crystals of plagioclase or aggregates of such crystals frequently showing a pronounced zonal structure. The groundmass is made up of an abundance of intimately interlocked small crystals of quartz, a small amount of orthoclase, greenish hornblende, and a little biotite. The rock may be called a quartz-diorite porphyrite. The test cubes were not appreciably affected by either the freezing or corrosion test, but the coefficients of saturation are all high, and that for slow immersion is above the danger line.

The physical properties are as follows:—

Specific gravity	2·697
Weight per cubic foot, lbs	166·79
Pore space, per cent	·932
Ratio of absorption, per cent, one hour	·248
" " " two hours	·248
" " " slow immersion	·299
" " " in vacuo	·341
" " " under pressure	·350
Coefficient of saturation, one hour	·71
" " " two hours	·71
" " " slow immersion	·85
" " " in vacuo	·97
Crushing strength, lbs. per sq. in., dry (a)	31,368·
" " " " " (b)	32,533·

PLATE XVI.

Granite quarry of the Canadian Pacific Railway Co. at Cathmar, B.C.

Crushing strength, lbs. per sq. in., dry (average)	31,950·
Transverse strength, lbs. per sq. in....................	2,340·
Shearing strength, lbs. per sq. in.......................	2,120·
Loss on corrosion, grams per sq. in......................	·0008
Drilling factor, mm..................................	5·5

Although the excavation is of some size and a large amount of stone has been removed there is no evidence of systematic quarrying. The method seems to have consisted in breaking down masses between the joint planes by means of explosives; in consequence of this the face is very irregular and rough. Six hand derricks are still in place on the property.

The stone was used for railway bridge piers, and for culverts, tunnels, and fills along the line. The stone may be examined in the roundhouse at North Bend.

Pitt River Area.

This area lies a short distance east of Vancouver. Access to the exposures may be had from Pitt Meadows on the railway or by boat from New Westminster. One large quarry has been worked for crushed stone and a small amount of building stone has been taken from the shore of Pitt lake.

Gilley Bros., Limited, 902 Columbia St. West, New Westminster.

The quarry of this company, which is operated for crushed stone only, is situated at Pitt Meadows on the west side of Pitt river, 3 miles below the lake.

The formation is rather badly shattered and the stone is hard with many black knots (1478).

The stone: No. 1478.—This is a dark-coloured rock on the whole, with the lighter minerals lacking a true white colour. The dark minerals are hornblende with some biotite, and constitute about one-third of a polished surface: they occur in crystals up to about 5 mm. in diameter. The stone is probably a quartz diorite and resembles Nos. 1578 and 1512. It is nearer to No. 1512 but shows less gneissoid structure and the light minerals are of less clarity giving the whole surface a "dead" and less attractive appearance. The stone is much darker than the typical granodiorites from Jervis inlet and presents a very different general appearance.

The equipment consists of:—

2 large rock drills.

10 small rock drills.

2 Marion steam shovels (Nos. 35 and 51).

4 crushers with capacity of 500 cubic yards per day.

Tracks, cars, wharf, scows, etc.

The plant is operated by water power with a head of 660 feet developing 400 h.p.

Crushed stone is quoted at $1.25 a cubic yard f.o.b. scows or in bunkers at New Westminster.

Pitt Lake.

On the west side of Pitt lake above Bridal falls, A. W. Gray, H. G. Magor, C. A. Bourne and others, have leased lands as quarry sites. The formation is not excessively jointed, is comparatively free from black knots, and is not cut by eruptive dikes. The granite ridge rises to a height of 50 feet from deep water and presents several places at which quarries could easily be located. The stone varies somewhat in colour and grain, and shows, in places, a silvery appearance due to the development of secondary mica in the dark-coloured component; this is well seen in the blocks used for the registry office in New Westminster. Bridal falls would furnish excellent water power should these properties be developed.

The stone: No. 1479.—This rock is a granodiorite essentially the same as the typical examples from Jervis inlet; it might be compared most closely with the Fox Island stone described as No. 1463 on page 91. A characteristic of the stone is the feathery nature of the black mica and its tendency to aggregate into spots. In contrast with the true white of the lighter minerals this arrangement imparts an attractive appearance to the polished surface. It is undoubtedly a desirable building stone.

Burrard Inlet Area.

The proximity of the north arm of Burrard inlet to Vancouver, its protected waters, and the accessible stone along the shores, have resulted in the development of a quarrying industry of importance. Both granite and hard volcanic rocks have been quarried and the output has been used chiefly as crushed stone. Definite quarrying for building stone was conducted only on Croker island by the Vancouver Granite Company. The quarries in volcanic rock are not included here, but a brief description is given on page 183.

Coast Quarries, Limited, 909 Metropolitan building, 837 Hastings St. West, Vancouver; W. W. White, president; J. E. Bird, secretary; W. J. Bickell, managing director.

The quarry of this company is situated at Granite falls, near the head of the north arm of Burrard inlet on the east side; it is operated almost entirely for the production of crushed stone, but as the product is available for building a short account is included. The original quarry was opened near the water level and has been worked back about 200 feet. Forty feet above this level a later quarry has been extended 150 feet into the hill;

its length is 500 feet in a direction N. 20° W. and the height of the face is about 100 feet and will rapidly increase.

The exposed face shows a very rough dome-like sheeting. At the southeast angle close-set vertical joints strike E. 10° N. Another prominent set of joints, nearly vertical, strikes E. 25° S., and still another series strikes N. 10° E. and dips 70° westwardly. Near the middle of the quarry a dike of later rock (1457) strikes N. 10° E. and dips 80° eastwardly. Northwest of this dike the rock is even more shattered, and at the extremity in this direction are several smaller dikes and a darker phase of the prevailing granite.

The great mass of the available stone is granite (1455) which is cut by stringers of a darker colour (1456). Knots are common throughout the exposure and variations in grain and colour are marked. These features together with the shattered nature of the formation would make impossible the exploitation of the property for building stone, but occasional large blocks could doubtless be obtained in the course of operations for other purposes.

The stone: No. 1455.—This rock is a granodiorite of much coarser grain than the average product of the building stone quarries at Jervis inlet. The white minerals—quartz and the two feldspars—lack the clean white colour shown by these stones, and the much larger flakes of black mica give it a rougher appearance. While this is not so desirable a stone as that from Jervis inlet it is, nevertheless, a good building stone, but it would be harder to cut and it is more adapted to rock-face work in heavy structures.

No. 1456.—This is a much darker and finer-grained stone with a slightly gneissoid structure; it resembles No. 1454, from Agassiz, which has been determined as a quartz diorite. Under the microscope, this rock shows abundant fresh green hornblende and orthoclase, a less amount of plagioclase, and but little quartz; it is nearer a syenite than most of these stones. The present example is even darker than the Agassiz stone, but it is less even in grain, and would not make a very desirable monumental stone on that account. In any event the formational features prohibit the winning of the stone in quantity.

No. 1457.—A very hard and tough, fine-grained rock. Under the microscope it shows a structure similar to No. 1456, but with a much finer grain; it also contains relatively large porphyritic crystals of both orthoclase and plagioclase, and considerable pyrite.

The equipment is briefly as follows:—

1 Canadian Rand compressor.
2 Little Giant rock drills.
4 plug drills (Butterfly).
1 large jaw crusher.
1 small crusher.
1 tug.

7 scows.

4 Pelton water-wheels.

Blacksmith and machine shops, boarding house, offices, etc.

This company formerly supplied the city of Vancouver with crushed stone at the following rates, on scow, Vancouver:—

1912—$1.45 per cubic yard.
1915—$0.77 „ „
1916—$1.23 „ „

The consumption was from 50,000 to 55,000 cubic yards a year, but during the war little money has been available for municipal work in Vancouver.

Vancouver Granite Company, Limited, 815 Bower building, Vancouver: Robert Armstrong, president; H. F. Keefer, secretary-treasurer.

This company formerly operated on Burrard inlet for crushed stone and for building blocks; recently, however, its activities have been directed to the more promising locations on Nelson island (see page 82). An extensive stone yard and sawing plant is maintained on Beech avenue, Vancouver.

A quarry has been opened at about the middle point of the west side of Croker island near the head of the north arm of the inlet. Here the granite rises to a height of 100 feet and presents fairly uniform and horizontal sheets from 1 to 15 feet thick. The jointing is well developed at S. 30° E. and also in an east and west direction. Both sets are approximately vertical, but irregular: the former series formed the backs as the quarry was advanced into the base of the hill. The opening is very small and embraces only the lower sheets at the foot of the cliff.

Observed from the south the sheeting on Croker island appears very distinct, with a dip of 25° to the eastward. Possible quarry locations were observed at different places, but there is much variation in the degree to which jointing, sheeting, and superficial cracking are developed.

The grain of the stone, in the quarry and along the shore, is very uniform, and black knots, while present in small amount, do not seriously interfere with the production of clean stone. The rift and grain are well developed, but the stone is said to be somewhat hard and it is to this cause that cessation of operations is attributed (1458).

Directly opposite the Croker Island quarry, on the west side of the arm, a small quarry was opened in a bluff of about the same height. The stone is essentially the same but the sheeting is thinner and the jointing closer and more irregular. It would be difficult to obtain satisfactory quarry blocks at this point.

The stone: No. 1458.—This rock is a granodiorite differing very little from the Jervis Inlet stones; it is slightly coarser in grain than the best examples from that locality, but it is much finer than the stone (No. 1455) from the quarry across Burrard inlet. A feature of this stone is the sharp definition of the mica crystals: broken parallel to the rift the rock shows a very defined black-speckled appearance with the flakes of black mica ranging from small specks up to 3 or 4 mm. in diameter. The light-coloured minerals are clean and white.

Granite Quarries Limited, 543 Granville St., Vancouver; Dr. Stirling, president; E. A. Carew-Gibson, managing director; C. M. Barclay, superintendent.

The quarry of this company is situated at Deep cove on the west side of the north arm of Burrard inlet; it has been operated exclusively for crushed stone, but as is usual in such quarries, rough building stone might be obtained as an incidental product.

The present quarry is about 500 feet long and 150 feet wide with a face of 165 feet. The rock is granodiorite, disposed in very irregular and discontinuous sheets conforming to the contour of the hill. Rather pronounced vertical joints strike nearly north and south, and a less defined set crosses these at right angles. On the whole, the formation is much shattered and is crossed by dikes of later eruptive.

The stone (1460) is hard and does not seem to have a well developed rift or grain. Black knots are numerous in all parts of the quarry.

The stone: No. 1460.—This rock is a grey granodiorite of medium grain closely resembling No. 1458 from Croker island; it is a less desirable stone, however, as it is not so clean in the colour of the light components and black knots are much more frequent. In this case the black biotite is replaced, in part, by hornblende the enlongated crystals of which give a less evenly granular appearance to the fresh fracture.

The equipment is as follows:—

1 Bucyrus electric shovel.
4 rock drills.
6 plug drills.
1 compressor, electric.
1 large Blake crusher with accessories.
2 small jaw crushers with accessories.
Track, cars, crusher building, offices, boarding house, etc.

The capacity of the plant is 15,000 cubic yards of crushed stone per month.

Jervis Inlet Area.

The best known and most promising stone of the Coast range has been quarried on the islands at the entrance to Jervis inlet. It is likely that the most desirable sites have already been pre-empted, as observations seem to prove that shattering and the presence of knots render quarrying impossible, even in this favourable locality, along most of the shore line. Quarries have been worked on Sechelt, Granite, Hardy, Fox, and Nelson islands by several companies.

The Jervis Inlet stone is essentially a grey granodiorite, varying in grain and in the relative proportions of the light and the dark-coloured components. Tinges of pink in the feldspar crystals and a lack of pure colour in the quartz also occasion some variations in the general appearance of the stone. The better grades of building granite are essentially alike in appearance and differ very little in their physical properties. In consequence of this similarity, the following average of the four stones tested may be considered as fairly indicative of the physical properties of Jervis Inlet stone.

Specific gravity	2·675
Weight per cubic foot, lbs	165·84
Pore space, per cent	·67
Ratio of absorption, per cent, one hour	·138
" " " two hours	·147
" " " slow immersion	·179
" " " in vacuo	·218
" " " under pressure	·252
Coefficient of saturation, one hour	·53
" " " two hours	·58
" " " slow immersion	·71
" " " in vacuo	·86
Crushing strength, lbs. per sq. in	34,555·
Transverse strength, lbs. per sq. in	2,741·
Shearing strength, lbs. per sq. in	2,198·
Loss on corrosion, grams	·000753
Drilling factor, mm	6·5

Vancouver Granite Company, Limited, 815 Bower building, Vancouver; Robert Armstrong, president, Hugh E. Keefer, secretary-treasurer.

The southwesterly angle of Nelson island is indented by two bays—the easterly is Whalebone bay and the westerly Quarry bay. The point between the two bays is divided by a lesser indentation—Deadmans cove. On the westerly tongue of land and on the west side of Deadmans cove the company holds 450 acres of quarry lands (Lot 2009). The surface rises gradually to a moderate height, and both on the shore and for some distance inland quarrying sites could easily be located. The sheeting is practically horizontal but undulatory. Only one prominent sheet of 15 feet in thickness has received much attention. The jointing is not constant in direction and is referred to in more detail below. The occurrence of fractured headings or zones of close-set joints has made it more expedient to move to another point than to attempt the removal of the broken stone.

The first opening was made about 30 years ago on the small point separating Quarry bay from Deadmans cove. The heavy 15-foot sheet is the only one worked and the excavation extends only for 9 feet between two prominent vertical joints at S. 5° E.

Cross joints cut at varying angles, and occasion the loss of much stone. Inland from the opening the formation is not excessively shattered, and unlimited good stone is available. The rift is vertical, north and south, and the grain is horizontal and independent of the sheeting which inclines at a low angle to the westward.

The stone is fairly uniform and shows only a few black knots. I am informed by Mr. Keefer that operations here were suspended owing to the necessity of making horizontal floors on account of the thickness of the sheet. Stone from this opening was used for the graving dock in Victoria and for the New Westminster bridge.

At a later date a second quarry was opened on the shore of Deadmans cove, and was extended along the 15-foot sheet and some lower layers for 300 feet. Above the old workings some thinner sheets occur, but they are succeeded by heavy layers up to a height of about 150 feet above the water. The major jointing is vertical at E. 10° S. Irregular cross jointing occurs in a general northwesterly direction. The stone is the same as in the quarry already described (1461). This opening was abandoned on account of running into a fractured heading.

At a point on the east side of Quarry bay, near its head, the company has granted to Morrice and Abel the privilege of quarrying stone for the making of paving blocks; the consideration being 8 cents per square yard of stone measured on the completed pavement.

In descending order the sheets worked at this point are: 4-5 ft., 8 ft., 8 ft., 6 ft., 6 ft. These sheets are lenticular, and consequently vary from the above figures. The general dip of the sheeting is S. 35° W. at 10°. The rift is well developed and vertical at S. 30° E. and the grain is horizontal. The stone splits with remarkable facility on both rift and grain, rendering paving cutting comparatively easy. The joints are very irregular, but blocks of sufficient size for the present purpose are easily obtained (1467).

The standard size for paving blocks is 9 inches long, 4·5 inches wide, and 5·5 to 6 inches deep. They are valued at $2 per sq. yd., in Vancouver. Cutters are paid 2·75 cents per block, working on material already quarried. In July 1916, 40,000 to 50,000 blocks were on hand.

At the head of Quarry bay a prominent ridge of granite causes a minor point to jut into the inlet. Here (Lot 468), near the point, and on the easterly side of the ridge, are situated the larger quarries of the company.

The sheets at the point dip 10° E. 35° S. and present the following section in descending order:—

25 ft.—Solid in places, in others divided.
8 ft.—Solid sheet.
35 ft.—Solid in places only.
12 ft.—Solid sheet.
8 ft.—Solid sheet.
—Floor of upper opening, 100 feet wide.
22 ft.—Solid in part but generally divided into sheets of 4, 5, and 6 ft.
8 ft.—Solid sheet.

The most pronounced joints are at W. 30° N., with a high dip to the northeast. Cross joints run vertically due northeast. Other less defined joints cut the formation diagonally to the above more defined sets. The rift is vertical, directly down the dip of the sheets, *i.e.* E. 35° S. The grain is horizontal. The quarry extends for a length of 150 feet in the three lower sheets only, with the northwest joints for backs. The stone is uniform in grain, and colour, and although knots occur they are small and scattered. The worst feature at this point is the diagonal character of the jointing, which occasions considerable loss.

On the easterly side of the ridge an extended section is presented in sheets having a general dip of 25° S. 35° E. The sheets given in the following section are at a higher level than those described from the point:—

20 ft.—Solid sheet of good stone, not quarried.
25 ft.—Solid sheet, quarried as an upper working.
12–15 ft.—Solid sheet, quarried as a lower working.

The rift is vertical, and very distinct at W. 42° N.: the grain is horizontal, and therefore disposed at an angle of 25° to the sheeting. Two systems of joints are well developed—one parallel to the hardway (N. 42° E.), and another striking W. 30–60° N. The former set is characterized by the presence of pyrite on the joint plane (1466), which are widely spaced, correspond to the general face of the ridge, and constitute backs as the quarry is advanced. The second set is represented by only two joints in the lower opening—one at the southwest side of the quarry striking W. 60° N. and another 50 feet to the southeast striking W. 30° N.

The lower quarry, in the 15-foot bed, shows a horizontal surface of 100 feet on the rift and 300 feet on the hardway, divided only by the widely spaced joints described above. Very large stone of uniform grain and almost free from knots is obtainable in quantity here.

The upper quarry, in the 25-foot bed, is being worked between two hardway joints 24 feet apart: it is being extended along the ridge northeastwardly between these joints, and in consequence the rift forms the immediate working faces. Plate XVII shows this face with plug holes on the grain.

Granite quarry of the Vancouver Granite Co., Nelson island, B.C.

Northwest of the hardway wall there is a narrow, wedge-shaped fractured heading, beyond which is another excellent strip of stone 15 feet wide to the next hardway joint. Stone of any practical dimensions may be obtained in this upper quarry. Some blocks 24 feet long, 2 feet 4 inches wide, and 2 feet 6 inches thick, were observed in the company's yard in Vancouver. These pieces, by their rectangular shape and smooth surfaces, illustrate the remarkable facility with which the stone may be split by plug and feathers (1487).

Over the top of this ridge and on the ridge west of the head of the bay, similar stone in heavy sheets is accessible at many points.

The stone.—The product of all the quarries is of fairly uniform grain, and is free from pyrite. Knots and veinlets are very few and small. Differences in the colour of the feldspar constitute the chief variation.

No. 1487.—This stone is to be regarded as a typical example of the best quality of building stone from the quarries of the company: it is an even-grained grey granodiorite of medium texture, and is essentially the same as the stone from Hardy island (No. 1462) and that from Granite island (No. 1453). Black mica is rather less abundant than in No. 1453, and the stone has a somewhat lighter appearance in consequence (Plate XVIII). A microscopic examination shows that this stone is a little nearer to a true granite than the other two examples, as it contains more orthoclase and less plagioclase; quartz, also, is less abundant. The black minerals are chiefly biotite, but a little hornblende and a few grains of magnetite are present. Some of the orthoclase crystals show incipient decay, but the plagioclase is usually quite fresh. The coefficient of saturation is well below the critical point, and the corrosion test produces no visible result. The sulphur content is 0·005 per cent.

The physical properties are as follows:—

Specific gravity	2·657
Weight per cubic foot, lbs.	164·82
Pore space, per cent	·691
Ratio of absorption, per cent, one hour	·143
" " " two hours	·152
" " " slow immersion	·175
" " " in vacuo	·226
" " " under pressure	·262
Coefficient of saturation, one hour	·54
" " " two hours	·58
" " " slow immersion	·67
" " " in vacuo	·86
Crushing strength, lbs. per sq. in., dry (a)	32,019·
" " " " " (b)	37,060·
" " " " " (c)	35,391·
" " " " " (average)	34,823·

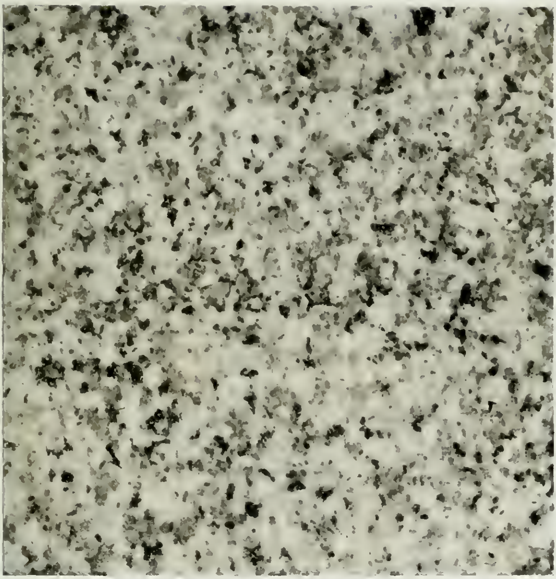
Transverse strength, lbs. per sq. in.	2,871·
Shearing strength, lbs. per sq. in.	2,300·
Loss on corrosion, grams per sq. in.	·000851
Drilling factor, mm.	7·0

No. 1467.—This stone is of the same general type as No. 1487, but it is coarser in grain and of less clean colour, as the feldspar crystals frequently show a pinkish shade and the black mica is less abundant. In grain this stone resembles the product of the quarries at Three-mile point, Kootenay lake (No. 1514), but it is pinker in colour and generally darker on account of the presence of more black mica. On polished surfaces the light minerals show sections up to 5 mm. in diameter. A microscopic examination shows fairly fresh orthoclase in large crystals with undulatory extinction, fresh or slightly altered plagioclase in large crystals and also in short columnar form. The quartz is relatively less abundant, and in places is intergrown with the orthoclase. The dark mineral is chiefly biotite, which is associated, in places, with a little greenish hornblende. On the whole, the stone is very fresh, and in this respect is much superior to No. 1514. In respect to the absorption and strength tests, this stone differs very little from No. 1487, and from the other examples from the Jervis Inlet area. Sulphur shows only 0·005 per cent.

The physical properties are as follows:—

Specific gravity	2·66
Weight per cubic foot, lbs.	164·93
Pore space, per cent	·679
Ratio of absorption, per cent, one hour	·143
" " " two hours	·143
" " " slow immersion	·187
" " " in vacuo	·216
" " " under pressure	·257
Coefficient of saturation, one hour	·55
" " two hours	·55
" " slow immersion	·73
" " in vacuo	·84
Crushing strength, lbs. per sq. in., dry (a)	39,082·
" " " " " (b)	36,083·
" " " " " (c)	32,737·
" " " " " (average)	35,967·
Transverse strength, lbs. per sq. in.	3,139·
Shearing strength, lbs. per sq. in.	2,343·
Loss on corrosion, grams per sq. in.	·001264
Drilling factor, mm.	5·6

PLATE XVIII.



Nelson Island granite, quarry of the Vancouver Granite Co., Nelson island, B.C.

No. 1461.—This rock is essentially the same as No. 1487, but tinges of colour in the white components and a lack of uniformity in structure make it a less desirable material.

In working the upper quarry Mr. Keefer has established a face by attacking the strip between hardway joints from the southwest end. The quarry is advanced to the northeast by sinking one hole to a depth of 16 feet, 10 feet back from the face: this is fired 2 or 3 times with a quart of black powder. The result is a straight break along the rift through the 25-foot bed. The resulting block, 24 × 10 × 10 ft., is easily cut up by plug and feathers.

The equipment of the quarry is as follows:—

3 25-ton derricks with steam hoists.

1 derrick operated from one of the above hoists.

1 inclined tramway with cars and cable operated by steam hoist.

1 8″ × 8″ compressor.

2 Ingersol Rand tripod drills.

6 plug drills.

Blacksmith shop, wharf, boarding house, and several small buildings.

The company's yard on Beech avenue, Vancouver, contains the following equipment:—

1 derrick, electric hoist of 40 h.p.

1 derrick, electric hoist of 20 h.p.

2 hand derricks.

1 mill 60 ft. × 50 ft., used for sandstone only, contains 1 gang saw, 12 ft. × 8 ft. frame. Patch Manufacturing Co.

1 gang saw, 16 ft. × 7 ft. frame.

1 40 h.p. motor for saws.

4 gang cars.

1 transfer car.

The company has granted to independent firms the privilege of erecting mills on the property as follows:—

Keast and Allan.

Mill 100 ft. × 50 ft. equipped with:—

1 double bladed diamond saw. Geo. Anderson, Montreal.

1 large lathe.

1 single planer. Patch Manufacturing Co.

1 double planer. Patch Manufacturing Co.

2 surfacers. Livingstone Mfg. Co., Rockland, Me.

1 hand derrick.

1 crane.

1 compressor, electric, duplex 10″ × 12″.

J. McDiarmid & Co.

Mill.

2 surfacers.

Quarry blocks of Nelson Island granite are quoted at 50–55 cents per cubic foot loaded at the Vancouver plant. If over 8 feet long, or over 150 cu. ft. in volume, they are valued at 60 cents, or even more in special cases. The production in 1915 was 25,000 cu. ft.

Nelson Island stone is probably the best known of all the Coast Range granites: it has been largely used in Victoria and Vancouver, it has been exported to the coast states, and it has been sent in small quantity to Australia and Honolulu.

Important examples of Nelson Island stone are as follows:—

Parliament buildings, Victoria (base).

Credit Foncier building, Vancouver (base).

Merchants Bank, Granville and Pender streets, Vancouver (base).

Bank of Commerce, Main and Pender streets, Vancouver (base).

Court house, Vancouver (base).

Hudson Bay Company's building, Granville and Georgia streets, Vancouver (base).

The base of the Government buildings in Victoria shows a medium to coarse-grained granite, with but few knots. A somewhat coarser and lighter stone, with more knots, is mixed with the other variety, and occasions a certain lack of uniformity.

Alexander McLennan and James Craig, Vancouver, B.C.

The above firm has applied for a lease of granite property situated about half a mile southwest of Billings bay, Nelson island. The stone is darker than the average product of the neighbouring quarries in the Jervis Inlet area, and is more suitable to monumental work.

The stone: No. 1542.—This rock is comparable with the other granodiorites of the area, and most closely resembles the Granite Island stone, No. 1453. It contains much more black mica, however, and is decidedly the darkest of the stones of this series. The white components are glassy and not opaque white; this gives the stone a resemblance to the quartz-diorite series exemplified by the Smith Island stone, No. 1577. This rock is coarser in grain than No. 1577, and may be regarded as intermediate in grain and colour between that stone and No. 1453. It is probably nearer to a quartz diorite than the other stones from Jervis inlet. This should make a very desirable monumental material.

West Coast Granite Co. (Successor to Kelly and Murray); J. A. Soderberg, Alaska building, Seattle, Wash.

This company has worked quarries on Granite and Fox islands, Jervis inlet. The product has been used for building, and is in some demand for monumental purposes. Both quarries were idle at the time of my visit.

Jervis Inlet granite. Bank of Montreal, Victoria, B.C.

Granite Island quarry.

On the northwest side of this island a small quarry was opened for the making of paving blocks. This working embraced only one sheet which is about 12 feet thick and dips S. 30° W. at 10°. This sheet forms the top of the exposure and is underlaid by thinner material. The main joints strike S. 40° E. and dip 80° northeasterly. Almost parallel to this direction (S. 60° E.) the stone breaks with great facility, and also in a direction S. 40° W. The third direction of cleavage, i.e., the horizontal, is likewise well defined. I am unable to state with certainty which of these directions is the rift, grain, or hardway, but it is significant and of great value in making paving blocks that excellent cleavage is presented in the three planes. The stone is dark in colour and uniform in grain with but few black knots (1464).

A second and much larger quarry has been opened on the southerly side of the island and has been worked in a somewhat scattered manner for some distance towards the northwest (Plate XX). Beginning at the southeast corner of the island a face of 40 feet is presented by a single sheet of stone, which, however, is divided in places. Pronounced joints cross the sheet irregularly at about N. 55° E. with a dip of 7° northwesterly. These joints are in places closely set and have a strong tendency to curve, with a consequent loss of a considerable percentage of the stone. A short distance northwest of this exposure the rock runs up to a greater altitude, but it is so severely jointed that it is impossible to reduce the fracturing to definable systems. The lower stone at this point seems to be darker than the material at higher levels. Northwest of this working the ridge is interrupted by a ravine beyond which other rather extensive workings have been opened at a higher level. Quarrying has been done for a distance of 500 feet, exposing an irregular face 40 to 50 feet in height. The sheeting is heavy in places but the sheeting planes are strangely discontinuous with a prevailing southerly dip at a low angle. The jointing is severe and so irregular as to defy description in general terms: the trend of the strike is 15° to 40° east of north, and the dip is high in both directions from the vertical. The face of the quarry is approximately W. 15° N. and parallel to this direction is a pronounced cleavage which represents either the rift or the grain. Much good stone is accessible here but systematic quarrying would be difficult owing to the large waste resulting from the uncertain jointing and sheeting (1453, 1465).

The stone: No. 1453.—This rock is a granodiorite essentially the same as Nos. 1523, 1524, 1462, 1487, 1467, and 1514. It belongs to the series, 1462, 1453, 1487, and resembles these more closely than it does the others. It is coarser in grain than Nos. 1523 and 1524, but finer than Nos. 1467 and 1514.

The three Jervis Inlet stones, Nos. 1462, 1453, and 1487 are clean grey granodiorites differing but little. The present stone may be distinguished by the presence of a little more black mica giving it a darker tone and making it more desirable as a monumental material.

Under the microscope this rock shows a little more quartz than the other members of the series; the plagioclase is mostly fresh, and only incipient decay is observed in the orthoclase crystals. The dark component is nearly all biotite with only a few specks of green hornblende.

The even grain and dark colour of this granite has caused it to be regarded with favour by monument makers in Vancouver and Victoria.

The physical properties are as follows:—

Specific gravity	2·681
Weight per cubic foot, lbs.	166·33
Pore space, per cent	·618
Ratio of absorption, per cent, one hour	·121
" " " two hours	·134
" " " slow immersion	·178
" " " in vacuo	·200
" " " under pressure	·232
Coefficient of saturation, one hour	·52
" " " two hours	·57
" " " slow immersion	·77
" " " in vacuo	·86
Crushing strength, lbs. per sq. in., dry (a)	34,093·
" " " " " (b)	37,500·
" " " " " (c)	33,841·
" " " " " (average)	35,144·
Transverse strength, lbs. per sq. in.	3,521·
Shearing strength, lbs. per sq. in.	2,756·
Loss on corrosion, grams per sq. in.	·0001973
Drilling factor, mm.	6·3

No. 1465.—This rock is essentially the same as No. 1453, but shows a little more black mica and a more pronounced gneissoid structure; it serves to illustrate the slight differences observed throughout the quarry.

No. 1464.—A slightly rougher stone but essentially the same as the two examples described above.

The following equipment is on the property:—

3 derricks with separate boilers and steam hoists.

2 compressors.

Tramway with cable, friction brake, and cars.

Several buildings and minor appliances.

Granite Island stone may be examined in the following structures:—

Federal buildings, Seattle, Washington.

Sea-wall, Victoria harbour (Plate I).

Granite quarry of the West Coast Granite Co., Granite island, B.C.

Post-office, Vancouver (Plate XXII).
Bank of Commerce (main building), Vancouver.

Fox Island quarry.

The company opened a small quarry on the east side of this island at about 25 feet above water level (Plate XXI). The sheeting is dome-like with increasing dip towards the shores. Erosion has affected the centre more than the margins with the result that the slope of the surface is lower than the dip of the sheets. A break has occurred in the centre of the island and the quarry is located immediately to the south of this break. The dip of the sheets is therefore quite low at the quarry. The sheeting in descending order is as follows:—

15-20 ft.—Fairly solid sheet at south end.
10 ft.—Solid sheet at south end, divided at north end.
10 ft.—Solid sheet at south end but divided at north end.
15 ft.—Solid sheet at south end but divided into two at north end.

The quarry is bounded on the north by a strong joint striking W. 35° S. and dipping 65° to the southeast. Cross joints occur irregularly at about S. 30° E.; one of these forms the main face of the quarry. Other joints not parallel to either of these sets divide the stone rather seriously, but nevertheless some fairly large material is obtainable. The rift seems to be horizontal and the grain vertical at S. 40° E. The stone is said to be easy to work, but black knots are frequent and the diagonal character of the jointing is to be reckoned with (1463). Towards the south fairly heavy sheets overlie those exposed at the quarry and present possibilities for further exploitation.

The stone: No. 1463.—This is a grey granodiorite almost identical with No. 1487 from the Vancouver company's quarry; it is a little lighter and slightly coarser in grain than the Granite Island stone.

The only equipment at the quarry is one dismantled derrick. The Winch building in Vancouver is the best example of the use of this stone for building purposes. This building has a good uniform appearance with only a few blocks marred by knots. Some very large stone has been used particularly in the pillars (Plate XXII).

Sechelt Granite Quarries, Limited, 327 Seymour St., Vancouver; C. T. R. Nickson, president; L. B. Heese, secretary.

This company formerly operated but has long since abandoned a small quarry which was worked for paving stone near Sechelt village on the island of the same name. The quarries now being operated are situated on the south side of Hardy island in Jervis inlet (Plate XXIII).

The total present output of these quarries is delivered to the Sir John Jackson Company at the breakwater in Vancouver for $6 per square yard. This figure is not to be taken as representing the actual value of the stone as certain agreements, not intended for publicaton, have been entered into by the two companies.

The more easterly quarry has been worked 150 feet into the hillside at a level of about 100 feet above the water; the face is about 300 feet long in a direction S. 10° W., and shows a vertical exposure of 60 feet. The sheeting is very irregular and discontinuous, but on the whole, it dips eastward at about 15°. The parting planes vary greatly in spacing, but very heavy stone is presented in places. The outer part of the stone on the quarry site (now removed) consisted of a fractured heading of decomposed material striking S. 35° W. The present face is another heading of similar type, but striking a little more to the westward. The excavation lies between these two headings and the stone in this interval is cut by 6 joints (dries) which are practically parallel to the headings and dip at a very high angle outwards or southeasterly. In places these joints are very tight, but the stone usually parts and shows either unaltered pyrite or a deeply stained oxidized zone on the planes. Jointing at right angles to this direction is scarcely developed; only one such joint occurs at about the middle of the quarry. The fractured heading forming the present face is about 12 feet thick; although it yields some good stone, it must be removed before the solid material behind can be quarried.

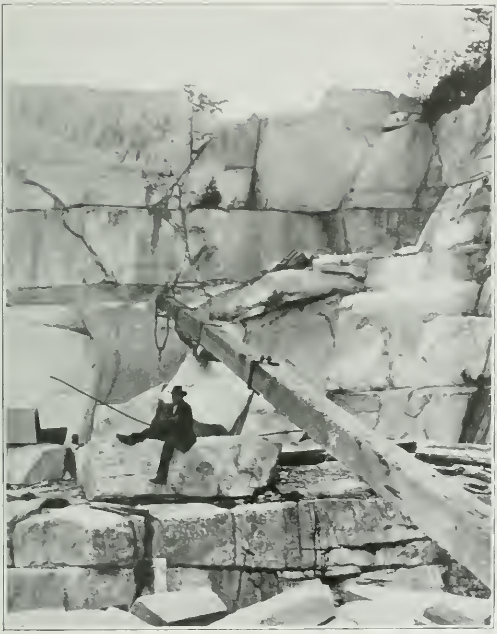
The rift and grain are both very pronounced; the former is horizontal and the latter vertical at S. 30° E. All the stone is more or less marred by the presence of black knots.

A short distance around the point to the south of the above opening a large quarry is being worked in two benches. The upper bench is at about the same level as the floor of the quarry already described, and would break into it on being advanced about 300 feet. The working face, which is parallel to the grain at S. 20° E., shows three heavy sheets of 15, 25, and 15 feet in descending order. These sheets dip S. 55° E. at 17°. Infrequent but pronounced vertical joints cut the formation at S. 60° W. These joints belong to the same series as the pyrite-bearing dries of the first quarry, but the strike is tending more to the west.

The lower bench of this quarry is an extensive opening 300 feet long which has been worked back about 100 feet. The sheets are more nearly horizontal but still have a slight dip to the southeast. The descending section presented by this face is as follows:—

28 ft.—Solid sheet.
19 ft.—Solid sheet.
12 ft.—Solid sheet.
24 ft.—Solid sheet.
24 ft.—Solid sheet with artificial floor.
60 ft.—Unworked to water level.

PLATE XXI.



Granite quarry of the West Coast Granite Co., Fox island, B.C.

Plate XXII.

Fox and Granite Island granites. Winch building and post-office, Vancouver, B.C.

As in the other quarries the rift is horizontal but the grain seems to be a little more to the east (S. 35° E.). The dries vary slightly in strike and dip, but they are nearly vertical at N. 35-40° E.

The stone is practically the same in all the openings. The well developed rift and grain make it easy to work but render somewhat difficult the production of fine edges on finished blocks. The presence of black knots may be regarded as the most serious objection to the stone which is doubtless procurable in large sizes and in practically unlimited quantity (1462).

The stone: No. 1462.—This example may be regarded as a fair average of all the quarries: it was obtained from one of the heavy beds at the opening first described. In small specimens the stone is scarcely to be distinguished from No. 1487, from Nelson island; under the microscope it shows less quartz and considerably more hornblende than No. 1453 from Granite island. The specific gravity and the weight per cubic foot is higher than in the other examples from Jervis inlet, but the porosity and absorption properties are practically the same. It is a matter of report that this stone is harder to work than the Nelson Island stone, but according to our drilling test this is not the case. The much lower transverse and shearing strength is not explained by any characteristics of the stone revealed by our experiments.

An analysis gave 0·006 per cent of sulphur.

The physical properties of Hardy Island stone are given below:—

Specific gravity	2·703
Weight per cubic foot, lbs.	167·56
Pore space, per cent	·695
Ratio of absorption, per cent, one hour	·147
" " " two hours	·161
" " " slow immersion	·177
" " " in vacuo	·232
" " " under pressure	·259
Coefficient of saturation, one hour	·56
" " " two hours	·62
" " " slow immersion	·68
" " " in vacuo	·89
Crushing strength, lbs. per sq. in. dry (a)	30,165·
" " " " " (b)	33,710·
" " " " " (c)	30,666·
" " " " " (d)	28,323·
" " " " " (average)	32,288·
Transverse strength, lbs. per sq. in.	1,453·
Shearing strength, lbs. per sq. in.	1,393·
Loss on corrosion, grams per sq. in.	·000702
Drilling factor, mm.	7·4

In quarrying the heavy sheets, even breaks up to 100 feet in length on the grain are made by sinking 2-inch holes half way through the sheets, and firing with about $4\frac{1}{2}$ quarts of powder. On the hardway two such holes are made 8 inches apart and rimmed. On grain and rift the stone splits with nearly equal facility. Blocks 10 × 5 × 5 feet may be split evenly in these directions by plug and feathers in 3-inch holes placed 6 inches apart on both sides and end of block along the desired plane of cleavage.

A brief summary of the equipment follows:—

5 25-ton derricks with steam hoists and separate boilers.

1 loading derrick with steam hoist.

Gravity tramway with drum, cable and cars.

1 Ingersol-Rand compressor, 250 ft. free air per minute.

1 Canadian Rand compressor, 500 ft. free air per minute.

1 Canadian Rand compressor, 300 ft. free air per minute, operated by 1 Fairbanks Morse gasoline engine.

1 125 h.p. boiler furnishing steam for 2 compressors and loading derrick.

1 compressor, 150 ft. free air per minute, operated by steam from one of the hoist boilers.

36 plug drills D.B. 15.

7 "sluggers" D.B. 19.

1 Burleigh rock drill.

Several buildings including boiler house, compressor house, offices, boarding houses and dwellings.

About 100 men are employed. The scale of wages kindly furnished by the company is as follows:—

Quarrymen—$3.75 per 8-hour day.

Labourers—$3 per 8-hour day.

Engineers—$4.25 per 8-hour day.

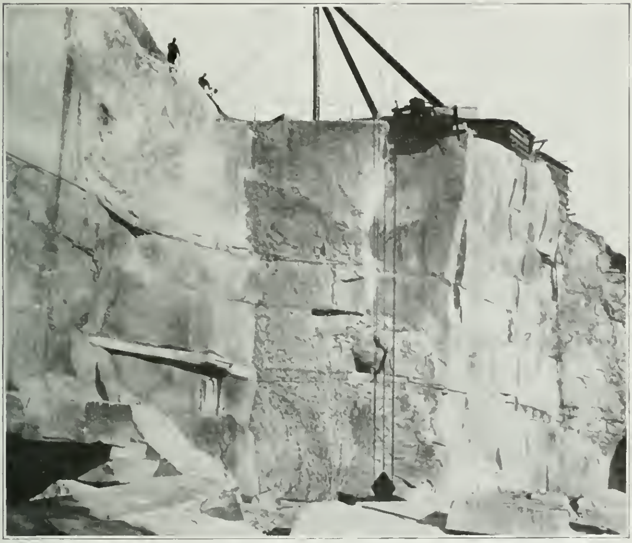
All employees are paid at one and a half times this scale for overtime, and at double this scale for Sundays and holidays.

The island is owned by J. M. McKinnon who receives 5 cents a yard royalty from the company. Practically all the stone has been sent to the breakwater at Victoria, the contract for which called for 1,250,000 cubic feet, but I understand that 1,512,441 feet had been delivered by the end of May, 1916. This stone is all in roughly squared blocks of large size, up to 20 tons in weight. I am informed also that Hardy Island granite is specified for the proposed Great Northern depot in Vancouver.

Prince Rupert Area.

One granite quarry has actually been worked and several claims have been located as granite-quarrying sites on the islands off the mouth of the Skeena river. The line of the Grand Trunk Pacific railway shows numerous exposures of the Coast Range rocks from Sockeye at the mouth of the river

PLATE XXIII.



Granite quarry of the Sechelt Granite Co., Hardy island, B.C.

eastward to beyond Nicol. The granites are interrupted by bands of basic schists and are overlaid in places by the Kitsalas formation of Triassic age.

"Along the Skeena river, the Coast Range section is made up of wide bands of light and dark grey granodiorites, alternating with bands of dark basic schists, the largest 6 miles across. The granodiorites in this section show a more or less pronounced gneissic structure everywhere. Along their western margin the schistosity conforms generally in dip and strike with that of the bordering easterly dipping altered sedimentaries. Farther on, the direction and angle of dip varies from point to point, and in a few places the lines of schistosity are sharply plicated. The gneissic structure is considered to have been assumed during the cooling of the granitic magma, and not to be a product of subsequent dynamic deformation.

"In the Skeena section there is no clear evidence of more than one period of intrusion, and the granodiorites, except for slight difference in coloration and an occasional banded arrangement due to the concentration of the dark minerals, have a very uniform character across the range. They are medium to coarse-grained rocks, occasionally showing a porphyritic structure, made up of plagioclase feldspar usually andesine, orthoclase, microcline, quartz and either or both biotite and hornblende. Apatite, titanite, and magnetite are common accessories, and epidote and, less frequently, pyrite and garnet are conspicuous secondary minerals."[1]

The most accessible exposures occur between Sockeye and a point to the eastward of Tyee where Mr. Alfred Gardé has acquired a quarrying site. The Prince Rupert Granite Company operated for crushed granite on the easterly side of Smith island, and the Recorder's office in Prince Rupert shows that the following claims have been taken with the object of quarrying granite:—

Lot 1388, range 5, 39·95 acres, small island in Hecate strait.

F. J. Coleman and J. J. Lee (1568).

At Falls river, Prince Rupert Hydro Electro Co. (1569).

Before proceeding to a detailed description of the more important properties the stones mentioned above will be briefly described.

The stone: No. 1568.—A fine-grained granodiorite with a slightly gneissoid structure: it is almost identical with No. 1577 from Smith island, but slightly lighter and with a purer white colour in the light components. Judging by the specimen only, this seems to be a very desirable stone.

No. 1569.—This is a medium-grained granodiorite or quartz diorite comparable with the stone from Tyee described as No. 1578 on page 98. It resembles that stone in the preponderance of hornblende and the presence of epidote, and differs in its finer grain and less gneissoid structure. Judging from the specimen only this is a very desirable building stone, but the

[1] Thirteenth Int. Geol. Cong., Guide-book 10, p. 19, 1913.

presence of small black knots indicates that larger imperfections of this kind may occur in the quarry.

Prince Rupert Granite Co.; Williams & Manson, Solicitors, Helgerson block, Prince Rupert, B.C.

This company has operated for crushed granite on the easterly side of Smith island in the mouth of the Skeena river; as far as I am aware, no attempt has been made to use the stone for structural purposes.

The quarry is of small dimensions and has been opened at a point 30 feet above water level, in the face of a steep declivity which rises to a height of about 75 feet. Above this, granite is exposed in precipitous cliffs to a much greater height.

The face of the quarry bears S. 40° E. The strike of the sheeting is parallel to this direction with a dip of 15° to the northeast. The sheets are heavy—at least 4 or 5 feet thick and possibly more. Nearly vertical joints cross N. 20° W.; they are not closely spaced on the whole, but in places they are aggregated into narrow fractured headings. Cross joints are infrequent at W. 15° S. Very large blocks are undoubtedly obtainable in the present quarry, and the overlying ledges seem to be capable of yielding blocks of any reasonable dimensions.

The granite is of fine grain and dark colour with very few black knots; it works easily and seems to have a good rift vertical in direction and approximately parallel to the cross joints. In breaking the stone I found many incipient diagonal "knives" but I am unable to say to what extent this intimate fracturing affects the entire formation. On the whole, one is impressed with the possibilities of this granite for fine building or even for monumental purposes.

The stone: No. 1577.—This rock belongs to the series, 1454, 1577, 1578, and 1512; it is coarser in grain than No. 1454 from Agassiz and finer than the other two. The dark minerals range up to 3 mm. in diameter and are less abundant than in No. 1454. The rock is a medium to fine-grained grey granodiorite.

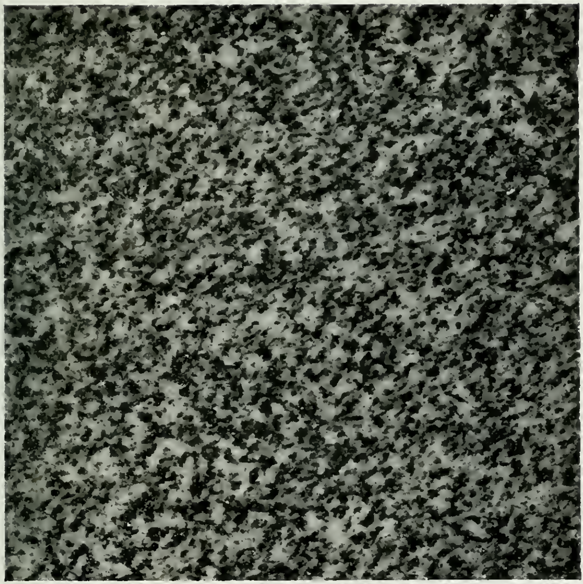
Microscopically the stone shows fresh feldspar with the orthoclase in excess of the plagioclase, a less amount of quartz, hornblende, and a little biotite. The rock is fresher than No. 1454 and contains much less plagioclase and more orthoclase and quartz. An analysis shows 0·039 per cent of sulphur which is considerably more than in the Jervis Inlet stones.

The grain and colour of this stone recommend it for use as a building material and as a monumental stone (Plate XXIV).

The physical properties follow:—

Specific gravity..................................	2·79
Weight per cubic foot, lbs..........................	174·168

PLATE XXIV.



Smith Island granite, quarry of Prince Rupert Granite Co., Smith island, B.C.

Pore space per cent	·91
Ratio of absorption, per cent, one hour	·201
" " " two hours	·208
" " " slow immersion	·232
" " " in vacuo	·300
" " " under pressure	·328
Coefficient of saturation, one hour	·61
" " " two hours	·63
" " " slow immersion	·70
" " " in vacuo	·91
Crushing strength, lbs. per sq. in., dry (a)	26,870·
" " " " " (b)	25,730·
" " " " " (c)	23,593·
" " " " " (average)	25,374·
Transverse strength, lbs. per sq. in	1,476·
Shearing strength, lbs. per sq. in	1,425·
Loss on corrosion, grams per sq. in	·000486
Drilling factor, mm	6·4

The product of the quarry was crushed in a small plant still on the property and was used for concrete in Prince Rupert. A few blocks were removed by plug and feathers but I have not learned the use that was made of them.

Alfred C. Gardé, 315 Second Avenue, Prince Rupert, B.C.

The line of the Grand Trunk Pacific railway cuts the base of a granitic mountain for more than a mile to the eastward of Tyee station (27 miles from Prince Rupert). This cut affords a means of ascertaining, in a general way, the structural features of an inexhaustible and accessible supply of material.

About 1½ miles east of Tyee, the railway company has opened a pit for the purpose of obtaining stone for fills along the line. The railway here runs N. 20° E. and the sheeting of the granite dips away from the track, i.e., northwest at about 15°. A distinct series of joints at fairly wide intervals dips towards the track at 35°. Heavy stone can doubtless be obtained between these two series of partings.

The rock is all dark, coarse-grained, and somewhat gneissoid in structure. Scattered knots are present as well as dark, fine-grained bands and whitish veinlets: the latter have a fairly constant strike of N. 60° W. with a dip of 80° to the southwest.

Westward from the pit, similar conditions prevail showing places in which diagonal and discontinuous jointing is more apparent. A separate spur of the mountain is cut by the railway, beginning at a point a half mile east of Tyee and continuing to the west for a distance of about 1,400 feet.

On this spur Mr. Gardé has leased a property of 63·2 acres (L. 5103 R. V.; 20 chains east and west, 40 chains north and south on the west side, 14·86 chains north and south on the east side).

The granite is well exposed and rises gradually to a height of 1,000 feet within the limits of the property. The sheeting, while distinct, is rather discontinuous and of changing dip, varying from 15° to more than 20° in a direction N. 75° W. On the whole, the sheeting is heavy—up to 8 or 10 feet thickness. The joints are rather difficult to describe without going into unwarranted detail. At the east end a system of joints strikes N. 30° W. and dips 60° to northeast. At the west end there is a pronounced jointing N. 35° W. with a dip of 80° to the northeast; this probably represents the same system with a variation in the dip. The partings are widely spaced with intervals of 5 to 20 feet. Viewed from the southwest aspect the exposure shows a third set of joints striking with the sheeting, and dipping at right angles to it. The sheeting and jointing is all fairly heavy and would not interfere with the extraction of large stone. It is to be remembered, however, that the first two sets of joints are diagonally disposed to the sheeting and, therefore, would cause considerable loss in dressing the stone to rectangular form.

The stone is dark and coarse in grain with gneissoid structure more or less apparent. The lamination appears to strike about N. 20° W. with a low dip to the northeast: it does not seem to be in accord with any of the systems of parting. Knots are not very abundant but occasional large elongated knots or streaks would have to be avoided in preparing dressed stone. Veinlets are not so abundant as in the more easterly outcrops, but some occur with a rather persistent strike W. 25° N. and vertical dip.

The stone: No. 1578.—This rock belongs to the series of "granites" in which black and glassy white components in strong contrast make up the bulk of the rock. The series is typically represented in this report by Nos. 1454, 1577, 1578, and 1512, including quartz-diorite, monzonite, and granodiorite. The present example is coarser than Nos. 1454 and 1577 and about equal in grain to No. 1512 from Coryell. The white minerals are sometimes 6 mm. long, and aggregates of dark minerals were observed reaching a length of 12 mm. with a width of 3 or 4 mm. The black minerals are rather less abundant than in No. 1512 and the general effect is therefore somewhat lighter. Gneissoid structure is more or less apparent, but the stone exposed on the face of the quarry varies greatly in this respect, some parts being almost free from this structure (No. 5 Plate XLVII).

A microscopic examination shows both feldspars with the plagioclase predominating. Quartz is less abundant than the feldspars. The dark mineral is chiefly strongly pleochroic green hornblende. Epidote and black mica are present in small amount. The rock is a quartz diorite rather than a granodiorite on account of the excess of plagioclase over orthoclase; in this respect it differs from the stone from Smith island (No. 1577).

The rock polishes well and is not disfigured on old surfaces by iron stains. The strength tests are all probably a little below the maximum as it was impossible to prepare material strictly parallel to the rift of the stone on account of the unfortunate shape of the specimen obtained.

Corrosion results in a pitting of the dark minerals and in the production of a more distinct yellow in the epidote. Sulphur is present to the extent of 0·027 per cent indicating less pyrite than in the Smith Island stone, but considerably more than in the Jervis Inlet granites.

The physical properties follow:—

Specific gravity	2·777
Weight per cubic foot, lbs.	171·95
Pore space, per cent	·812
Ratio of absorption, per cent, one hour	·161
" " " two hours	·164
" " " slow immersion	·197
" " " in vacuo	·285
" " " under pressure	·294
Coefficient of saturation, one hour	·55
" " " two hours	·56
" " " slow immersion	·67
" " " in vacuo	·97
Crushing strength, lbs. per sq. in., dry	26,106·
Transverse strength, lbs. per sq. in.	1,646·
Shearing strength, lbs. per sq. in.	1,535·
Loss on corrosion, grams per sq. in.	·000373
Drilling factor, mm.	6·2

Very little work has yet been done on the property, but Mr. Gardé proposes to open a quarry on the westerly side where a ravine with a small stream affords an opportunity of attacking the formation from the rear, thus making possible the exploitation of the sheets up the dip instead of down the dip which would be necessary if a quarry were located on the exposure facing the railway.

Mr. Gardé estimates that the above mentioned stream has a flow of 4 cubic feet per second, that it may be harnessed under the head of 460 feet, and that it would furnish all the power required for a large quarrying and crushing plant.

The siding at Tyee could be connected with the quarry by an extension of 1,000 feet and I understand that the railway company is prepared to execute this work as soon as a reasonable amount of freight is assured. The rate of transport to Prince Rupert is placed at 55 cents per ton on crushed stone, and $1 per ton on dressed dimension stone.

It is hardly necessary to mention that the proximity of the Skeena river affords another means of cheap transport.

Other Occurrences of Coast Range Granites.

The various reports dealing with the coast and islands of British Columbia refer to the granite of certain localities as suitable for building purposes. The chief references, in some cases supplemented by notes of my own, are as follows:—

Walsh cove, West Redonda island[1].

"In Walsh cove, on the eastern shore of West Redonda island, there is an exposure of beautiful pink granite, which is so traversed by joint planes that quarrying should be relatively easy. The harbour facilities are good, the water remaining deep quite near the shore. It is a coarse-grained biotite granite, containing two feldspars. This granite is somewhat similar to the celebrated Baveno granite from the vicinity of Lago de Maggiore, in Italy, but the shade of pink is more delicate and its general appearance even more pleasing."

The stone exposed at the head of the cove is pinkish but of variable colour. Near the water, material of small size could be procured, but the stone is too severely jointed for systematic quarrying, although its rectangular arrangement is favourable (1546). Inland, the rock rises in a high bluff which is too precipitous for quarrying.

North of the cove the same stone rises in ledges which would yield blocks of fair size, but not dimension stone. On the channel to the north are further heavy ledges, vertically jointed parallel to the face. The sheeting is variable and inclined and the fracturing rather severe, but prospecting would probably reveal workable ledges. Between this exposure and Dean point the rock is more severely shattered. At the point most of the low-lying stone is severely fractured but some ledges a short distance inland are more promising (1547).

The stone throughout varies somewhat in grain, colour, and brilliancy; it is practically free from knots, but the formation is cut by dikes of later igneous rocks. The quality of the stone justifies careful prospecting for suitable ledges on which to open a quarry, but I would hazard the opinion, based on a very cursory examination, that ledges of sufficient solidity and uniformity for commercial operations have not yet been observed.

Some fairly heavy ledges of greyish granite were observed on the north shore of West Redonda island, and along Lewis channel to the north of Junction point.

The stone: No. 1546.—This stone is a granite or granodiorite of general pinkish tone, and with a grain comparable with that of the best varieties

[1] Geol. Sur. Can., Memoir 23, Pub. No. 1188, p. 142.

of Jervis Inlet stone. It consists of pink and white feldspar, less quartz, and a relatively small amount of black minerals, both biotite and hornblende. The pink and the white feldspars are sharply defined resulting in a clean, attractive polished surface. The rock is not as pink as the example from Okanagan lake, described as No. 1497 on page 67, but it has more of the pink element than No. 1467 from the paving stone quarry of the Vancouver company on Nelson island; it might well be described as intermediate between these two types.

No. 1547.—This rock differs very little from No. 1546, but is a little cleaner and more "lively" in appearance. As both samples were taken from the surface it is likely that the difference observed is due only to a variation in the extent to which alteration has proceeded.

Squirrel Cove, Cortes Island.[1]

On the south side of Squirrel cove near the Indian village a pinkish granite is exposed for a quarter mile along the shore; it rises into a sloping ridge of about 50 feet elevation presenting step-like ledges of rock. The strike of the sheets is about S. 10° E. with a low but varying dip westward, i.e., inland, which would necessitate working down the dip. Vertical joints occur parallel to the strike of the sheets. Cross joints are variable but average about N. 30° E. They are closely set in places, forming fractured headings between which very solid rock is encountered. In one place I observed a stretch of 18 feet without a cross joint. There is no doubt that very heavy stone could be quarried in the unfractured zones between the headings.

Throughout the exposure the stone is fairly uniform in grain and colour and is practically free from knots. Long exposed surfaces are dull and lighter than the fresh stone and present a slight cast of pink.

The stone: No. 1550.—This stone is a pinkish granite or granodiorite of the same general colour as Nos. 1546 and 1547 from Redonda island. The grain is considerably coarser and the dark minerals are more sharply defined and relatively less abundant. From No. 1467 the present example differs in a slightly coarser grain and a duller and more opaque appearance in the light-coloured minerals; this may be due to the fact that we are dealing with a specimen from the surface.

Quarrying could easily be carried on at this point as the exposures are not precipitous, the major jointing conforms with the strike of the sheets, and Squirrel cove affords an excellent harbour with deep water close to the shore.

Head of Pendrell Sound, East Redonda island.

Bancroft states (*op. cit.*) that a granite similar to that of Walsh cove occurs near the head of Pendrell sound, but I was unable to locate the

[1] Geol. Sur. Can., Mem. 23, Pub. No. 1188, p. 143.

outcrop to which he refers. The rocks immediately at the head of the sound are dark and variable in colour and much cut by veinlets. While some large blocks might be quarried in places, the colour and toughness of the stone do not recommend it for building, and the variability in colour, together with the veinlets, unfit it for monumental work (1545).

The rocks exposed along the west side of Pendrell sound and along the shores of Waddington channel are rough, fractured, and precipitous; they do not look at all favourable from our point of view. The rocks on the east side of Pendrell sound are rendered unfit for building purposes by the profusion of little veins of aplitic matter and by the presence of knots; the latter are so abundant at the point in the middle of this stretch of water as to give the rock the appearance of a conglomerate when viewed from a little distance.

The bold cliffs on West Redonda island, east of Waddington channel, would furnish fairly large stone but it is knotty and of variable structure. On Durham point the rock is shattered, rough, very knotty, and cut by numerous dikes.

The stone: No. 1545.—This rock is of medium grain resembling in this respect the average stone from Jervis inlet. The black mineral is chiefly biotite with some hornblende. The light-coloured minerals are very impure with a dull greyish colour which entirely removes the element of "liveliness" from the stone. Under the microscope the main constituent is seen to be fairly fresh plagioclase in crystals up to 5 mm. in length. Orthoclase is much less abundant and there is very little quartz. The dark minerals are greenish hornblende and brown biotite. The rock ranges close to a true diorite.

W. S. McDonald, 1571 Main street, Vancouver, B.C.

Mr. McDonald holds a lease on a property of 40 acres situated on the west side of Melanie cove near its head. A small amount of work has been done here.

The stone is disposed in heavy ledges (sheets) of 4 to 10 feet in thickness. The strike is N. 50° E. and the dip 40° to the northwest. Widely spaced joints cross at N. 20° E. vertically, and irregular joints run in the opposite direction. The hill rises to 100 feet or more and presents many places at which very large stone could easily be obtained.

The stone works easily under the hammer and is said to split with great facility. Unfortunately it is very knotty, no face of any extent being free from this objectionable feature, which unfits the stone for use in fine building or for monuments.

The outermost of the small islands off this cove shows heavy ledges of a similar stone in a highly inclined position. Dimension blocks could doubtless be quarried but the stone is very knotty.

The stone: No. 1544.—This rock is of rather coarse grain with sharply defined black minerals in a groundmass of white. The dark mineral is nearly all hornblende in crystals up to 10 mm. in length. The white minerals are quartz and feldspar of pure white colour. The polished surface would be distinctive by reason of the sharp contrast in colour between the fairly coarse constituents. A microscopic examination was not made but the stone is probably nearer to the quartz diorites than to the typical granodiorites of Jervis inlet.

Bute Inlet.[1]

"At a distance of about 27 miles within Bute inlet, the massive Granite mountain rises, almost devoid of vegetation from the water's edge to an altitude of 6,653 feet. It is composed of a medium-grained biotite granite of a greyish-white colour, which would be a very serviceable and satisfactory building stone."

Port Harvey.[2]

"Grey hornblende granite occurs on the west shore of Port Harvey of such good quality that it would make attractive building stone and so situated that it may be quarried with moderate ease."

Kwatsi Bay, Thompson Sound.[3]

"Grey hornblende granite occurs on the southern shore of Kwatsi bay on Thompson sound of such good quality that it would make attractive building stone and so situated that it may be quarried with moderate ease."

Bones Bay, Cracroft Island.[4]

A pink granite similar to that at Squirrel cove is reported by Bancroft at Bones bay on the northern shore of Cracroft island.

Otter Cove, Discovery Passage.[5]

"The granitic rocks appear on the west side of the passage, a mile and a quarter south of Otter cove.....In Otter cove the granite has a pale pinkish tinge, and contains a white triclinic feldspar, with a pink orthoclase. The grain is uniform and the stone is free from injurious jointage-planes. It is moderately easy to dress and work, and takes a good polish, and might be quarried to advantage on the island in the mouth of the cove,

[1] Geol. Sur. Can., Mem. 23, Pub. No. 1188, p. 143.
[2] Idem.
[3] Idem.
[4] Idem.
[5] Geol. Sur. Can., Ann. Rep., Vol. 2, p. 45. B.

or elsewhere around its shores. Chatham point, to the north of the cove, shows a highly hornblendic and darker coloured variety of granite.........

"On the inner side of the small island nearly opposite Chatham point to the north, a quarry might advantageously be opened, the stone resembling that of Otter cove, and being favourably situated to work."

Lund and Vicinity.

A very small amount of granite has been quarried near Lund for local use. Immediately north of the town the stone is of pinkish colour (1552) and is rather knotty. Accessible stone, even in thin sheets, occurs in cliffs 30 to 50 feet high a short distance farther north. Building stone in small but fairly rectangular blocks could easily be quarried here, but there is no indication of sufficient solidity for a regular quarry.

The shore northward to Sarah point shows greyish granite, fractured and knotty. In certain places the even character of the sheeting would permit the quarrying of common building stone.

From Sarah point to the head of Melanie cove the rock is rough and knotty with many secondary veinlets. On the west side of Deep bay the stone is of darker colour; it is intimately checked and has a profusion of knots (1543). Bold head is composed of similar rock.

Three and one-half miles south of Lund the granite is pinkish in colour and evenly but thinly bedded (1553). Diagonal but clean cut joints would permit the removal of small blocks. This rock fades northward into a fine-grained phase which has been suggested as an ornamental stone (1554); it could be obtained only in small pieces and presents little or no economic possibilities. Stone of a similar nature, but even more fractured, occurs on the small island at the mouth of Blind bay, Cortes island (1551).

White Rock island would yield some greyish granite in blocks of large dimensions, but the island is small, storm-swept, and devoid of water.

The stone: No. 1552.—A pink-grey granite or granodiorite of medium grain; it resembles the stone from Redonda island, but contains less pink feldspar, and the dark minerals are more sharply defined. Small fine-grained aggregate in which the pink feldspar is lacking are scattered through the stone.

No. 1543.—A grey granodiorite or quartz diorite of fine grain. It resembles No. 1577 from Smith island but it is coarser in grain; on the other hand, it is finer than No. 1542 which it also resembles except for a more opaque white in the light-coloured components. This rock is a fine-grained phase of No. 1544 from Melanie cove. It is to be observed that these stones are of much darker colour than the typical Jervis inlet granodiorites which have been described in detail.

No. 1553.—A pink granite or granodiorite not essentially different in grain or colour from No. 1547 from Redonda island.

No. 1554.—A light pinkish granite of much finer grain than No. 1553; it is characterized also by a paucity of dark-coloured minerals.

No. 1551.—A granite like No. 1554 but rather coarser in grain and with more red in the feldspars; it is probably the most red of the pink granites from the coast.

Summary—Granites of the Coast Range.

The most important building and monumental stone of British Columbia is furnished by the great range of mountains which extends for nearly 1,000 miles along the coast and is known as the Coast range.

The general rock of these mountains is a greyish granodiorite varying to quartz diorite or even to dark basic phases such as gabbro. The best known commercial stone is the grey granodiorite of Jervis inlet which is quarried on Nelson, Hardy, Fox, and Granite islands. A generalized account of this stone is given on page 82, and a representative specimen is figured in Plate XVIII.

Stone from these quarries has been extensively used for building purposes in Victoria and Vancouver, and has been shipped abroad; it has also been employed for monument bases, and the darker type from Granite island has been in demand for monuments.

The following are good examples of buildings constructed of Coast Range granite from Jervis inlet.

Base of Parliament Buildings and the sea-wall, Victoria (Frontispiece).

First Baptist church, Vancouver.

Bank of Montreal, Victoria (Plate XIX).

Post-office and Winch building, Vancouver (Plate XXII).

Canadian Bank of Commerce, Vancouver.

Stone not essentially different from the Jervis inlet type has been quarried to a very small extent on Pitt lake and near Agassiz on the main line of the Canadian Pacific railway. Darker coloured stones of less granitic appearance occur on the islands off the Skeena river and also along the line of the Grand Trunk Pacific railway. Pinkish granites of varying grain are of common occurrence on many of the islands in the Strait of Georgia.

Literature:—

Report of the Minister of Mines of British Columbia for 1904, pp. 248-251.

Thirteenth International Geological Congress, Guide-books 8, 9, and 10.

Geological Sur. Can., Memoir 23, Publication No. 1188.

Geological Sur. Can. Ann. Rep., Vol. 2.

Geological Survey of Canada, Publication No. 996, 1908.

Granites of Late Jurassic or Post-Jurassic Age.

Contemporaneous with the intrusion of the Coast Range batholith, or following that intrusion in Lower Cretaceous time, or later, a number of lesser granitic and granodioritic stocks and batholiths of related composition appeared. Confining ourselves to those which have received some attention as possible sources of building stone, we may conveniently arrange them for purposes of description as follows:—

Granites of Vancouver Island.
Granites of the Nelson batholith.
Granites of the Greenwood area.
Granites of the Little Canyon area.
Syenites of the Ice River area.

Granites of Vancouver Island.

The main axis of Vancouver island is composed of a series of batholithic masses and is therefore comparable in structure with the Coast range of the mainland.

"It is probable that all the plutonic rocks were erupted during one general period of batholithic intrusion, but in detail they may be divided into the three main types which were erupted in a definite sequence. The three types are, in the probable order of their eruption: Wark diorite and quartz diorite gneisses, Beale diorite, and Saanich granodiorite and quartz diorite."[1]

"The most important of these rocks and the only one that has attracted any attention as a building stone is the Saanich granodiorite which is thus described by Clapp. "The plutonic rocks of the Saanich type range from a granite to a quartz diorite. The main type is transitional between a granodiorite and a quartz diorite, and cannot be definitely classified without a chemical analysis, but will be referred to ordinarily as a granodiorite."[2]

"The rocks are well exposed on Saltspring island, in the Saanich peninsula, and at various points in a northwesterly direction along the axis of the island. No quarrying has been done, but the possibility of obtaining a dark type of building stone is referred to by Clapp as follows. "The fractured and sheared character of the rocks of southern Vancouver island renders most of them unfit for building purposes. Near the Alberni canal, to the north of Franklin river, the basic granite or granodiorite is fairly regularly jointed and comparatively free from small fractures, and moderately large and sound blocks could probably be quarried."[3]

[1] Geol. Sur. Can., Memoir 13, Pub. No. 1121, p 95, 1912.
[2] Idem, p. 101.
[3] Idem, p. 201.

In view of Clapp's remarks, no definite attempt was made to examine exposures of the Saanich granodiorite. Incidentally, a specimen was obtained from a small stock on Esquimalt harbour; it is described below.

The stone: No. 1400.—A greyish rock of distinctly crystalline structure and slightly gneissoid aspect: it is hard and rough, filled with flaws, iron-stained in places, and of no promise as a building material.

The stone is of medium grain and is composed of glassy feldspar of both varieties, quartz, and semi-decomposed hornblende in much less amount than the light-coloured minerals. A microscopic examination was not made, but the stone resembles a quartz diorite more than it does the typical granodiorites of the Coast range.

Granites of the Nelson Batholith. Nelson Area.

"The Nelson granodiorite batholith has a very extensive development in West Kootenay district and also extends into East Kootenay and the Boundary district. The granodiorite is intrusive in all the older formations from the Shuswap to the Rossland group. The main mass centres in the vicinity of Nelson while in the outlying areas the batholith is represented by smaller masses and cupola stocks. The rocks composing it vary from light grey granite to dark grey quartz diorite and even more basic types."[1]

The Nelson granite is of so wide distribution and is accessible at so many points that a complete description of even the recorded outcrops is beyond the scope of this work. Quarries have been worked at several points near Nelson; these will be described in detail, and, together with certain sections along the railways, will serve to illustrate the formation.

A typical section is exposed along the railway between Castlegar and Nelson. Grey and rather granitic rocks are cut by the railway immediately east of the crossing of the Columbia. From here to South Slocan, actual cuttings are few, but the neighbouring mountains are of coarse grain and gneissoid structure with many aplitic veinlets. From South Slocan to beyond Bonnington falls the rocks are rough and coarse-grained, of both granitic and gneissoid types of little promise. From this point to the crossing of the Kootenay rivers the prevailing stone is of coarse grain and dark colour, and represents a basic phase of the batholith. Between the Kootenay River bridge and Nelson the stone is of better quality, and although coarse and gneissoid in places, and excessively shattered in others, it would be possible to obtain a greyish type of granite at many points. The quarry of the Canadian Pacific Railway Company, at Granite, and that of the Canadian Marble and Granite Works, a short distance west of Nelson, will serve to illustrate the type of stone occurring along this stretch.

Many exposures of the granite may be seen along the Proctor branch of the Canadian Pacific railway and on the line of the Great Northern railway,

[1] Thirteenth Int. Geol. Cong., Guide-book 9, p. 64, 1913.

as far as Mountain station above Nelson. The stone is essentially similar to No. 1514 described on page 112, but varies in the degree to which gneissoid and porphyritic structure is developed. The stone of many of the outcrops visible from the railway is much too coarse in grain for structural purposes, but more desirable material might be quarried at many points along the line. Beyond Mountain station the rock is very gneissoid, much injected with veinlets, and at a short distance gives place to the schistose, and shattered rocks of the Rossland group.

About a mile north of Salmo the line of the Great Northern railway lies close to exposures of the batholithic rocks which are here of a pinkish colour and are disposed in fairly heavy sheets tilted at high angles. A cursory examination indicates that stone of considerable size could be quarried in certain parts of these exposures.

Good outcrops of the Nelson granite may also be seen along the Canadian Pacific railway between Tunnel and a point three miles north of Coryell.

The actual quarries in the Nelson batholith are confined to the immediate vicinity of Nelson, where operations have been conducted by the Canadian Pacific Railway Co., the Canadian Marble and Granite Works, and the Kootenay Granite and Monumental Co.

Canadian Pacific Railway Company; Nelson quarry.

A considerable amount of stone was quarried by the company at Granite about 3 miles west of Nelson. The workings are very irregular and extend for about 280 yards with a face of nearly 100 feet; above this the mountain gradually ascends to greater altitudes. The general trend of the face is W. 20° S. The sheeting is dome-like, with a northward dip in the middle, a northwesterly dip at the west end, and a northeasterly dip at the east end. The major jointing is vertical at N. 60° E. A second set crosses at S. 35° E. with a dip of 85° to the southwest. Irregular fracturing in addition to the above more defined series is much in evidence in certain parts of the workings. The sheeting is fairly heavy—8 to 10 feet in places—and does not interfere with the winning of large blocks. On the other hand, the jointing is frequently excessive, resulting in fractured headings which have been left standing between the belts of less fractured rock now removed. This procedure has resulted in a very irregular and unsystematic quarry.

The best part of the quarry is in the middle where a better system of sheeting and jointing permits a more defined description. The sheeting here dips towards the lake at about 45° with parting planes 6 to 8 feet apart. The major joints strike E. 40° S. nearly vertically and are as much as 50 feet apart. A more troublesome set of joints strikes S. 40° W. and dips at a high angle to the northwest. Large stone can be obtained here.

The stone throughout the quarry is fairly uniform in grain and colour, but no considerable surface is free from knots which are frequently of large size. Light-coloured veinlets are not uncommon but they are not so universally distributed as the black knots.

The stone: No. 1523.—This granodiorite is finer in grain and much darker than No. 1514 from Three-mile point: it is very similar in grain and colour to the Granite Island stone described as No. 1453 on page 89. The present example, however, is rather darker with more black mica disposed in a more feathery manner; it may also be distinguished by the presence of large crystals of feldspar which include some of the normal finer-grained components. The rock differs from No. 1524 from the Canadian Marble and Granite Company's quarry, in the possession of a slightly coarser grain and cleaner colour. Under the microscope the components are seen to be all in a fresh condition with the plagioclase in excess of the orthoclase. Quartz is present in some abundance and the dark minerals are chiefly biotite with a little hornblende and a few grains of augite.

"The Nelson granite is a sort of granite representative of the monzonite group of rocks, intermediate between the alkali and the lime-soda series of rocks, and about on the boundary between granite and diorite. Its composition is as follows:—

	per cent		per cent
Silica	66·46	Soda	4·86
Alumina	15·34	Potash	4·58
Ferric oxide	1·68	Titanium oxide	0·27
Ferrous oxide	1·83	Phosphoric acid	0·08
Lime	3·43	Water	0·29[1]
Magnesia	1·11		

The physical properties follow:—

Specific gravity	2·705
Weight per cubic foot, lbs.	167·13
Pore space, per cent	1·03
Ratio of absorption. per cent, one hour	·264
" " " two hours	·277
" " " slow immersion	·324
" " " in vacuo	·368
" " " under pressure	·385
Coefficient of saturation, one hour	·69
" " " two hours	·72
" " " slow immersion	·84
" " " in vacuo	·95
Crushing strength, lbs. per sq. in., dry, (a)	35,788·
" " " " " (b)	35,236·
" " " " " (average)	35,512·

[1]Geol. Sur. Can., Ann Rep. Vol. XV, p. 101A, 1906.

Transverse strength, lbs. per sq. in.	2,543·
Shearing strength, lbs. per sq. in.	1,418·
Loss on corrosion, grams per sq. in.	·00217
Drilling factor, mm.	4·6"

Quarrying at this point has been discontinued by the railway company, but 5 derricks in a state of disrepair are still on the property. The stone was used for culverts, bridge piers, etc., along the line of railway, also to a limited extent for building purposes in Nelson. The prevalence of black knots unfits the stone for purposes of fine construction.

Canadian Marble and Granite Works, P. O. Box 903, Nelson, B.C.; James Carruthers, Montreal, president; G. B. Wilson, Nelson, manager.

The company holds 4 acres of quarry lands on the highway, 1¼ miles west of Nelson.

The sheeting strikes with the highway due southwest and dips 15° to the southeast, *i.e.*, away from the road, necessitating an advance down the dip if the quarry is extended. The partings are discontinuous but the sheets are heavy and would permit the quarrying of large stone. The major jointing is particularly favourable as it strikes with the sheets and dips at right angles to them. Cross joints, more closely set, strike S. 5° W. and dip 85° to the west. Large stone of rectangular shape can easily be procured. The knoll is about 50 feet high, but does not pass immediately into the mountain, and consequently affords a convenient quarry site.

The stone varies a little in colour and is marred by numerous black knots which, however, are usually of small size. Brown oxidized zones are common on old faces and brown spotting is observed on surfaces of more recent exposure.

The stone: No. 1524.—This rock is a grey granodiorite of fine grain very similar to the stone from the quarry on the railway nearby, which has been described as No. 1523 on page 109. The stone is finer in grain than No. 1523, but it is less clean, as brownish stains are apparent and the microscopic section shows that the feldspars are in a semi-decomposed condition. An analysis gave 0·013 per cent of sulphur. It is to be remembered that this is surface stone, whereas the stone from the quarry on the railway was obtained at considerable depth.

The physical properties follow:—

Specific gravity	2·676
Weight per cubic foot, lbs.	164·62
Pore space, per cent	1·41
Ratio of absorption, per cent, one hour	·323
" " " two hours	·335
" " " slow immerison	·389
" " " in vacuo	·52
" " " under pressure	·528

Coefficient of saturation, one hour		·61
„ „ „ two hours		·63
„ „ „ slow immersion		·72
„ „ „ in vacuo		·99
Crushing strength, lbs. per sq. in., dry (a)	37,827·	
„ „ „ „ „ (b)	35,390·	
„ „ „ „ „ (average)	36,608·	
Transverse strength, lbs. per sq. in	2,158·	
Shearing strength, lbs. per sq. in	2,610·	
Loss on corrosion, grams per sq. in		·000663
Drilling factor, mm		3·5

The production from this location is very small; a few blocks were used for monument bases, but I have not learned of any building in which the stone may be examined.

Kootenay Granite and Monumental Company, Limited; 507 Front street, Nelson; Andro. Brncich, president; Frank Sarar, secretary-treasurer; post-office box 1001, Nelson, B.C.

The quarry is situated at Three-mile point, Kootenay lake, on the Proctor subdivision of the Canadian Pacific railway. The property consists of 2 acres of lot 1361, group I, Kootenay district; it is leased by the company from Henry Hammond at a yearly rental of $200.

All along the mountain side from Nelson to the site of the quarry and beyond, are great ledges of granite, varying in the degree of shattering and in the extent to which porphyritic structure is developed. Both on the Canadian Pacific railway and on the Great Northern railway at a greater altitude are numerous localities at which more or less desirable granite is accessible. The present location was doubtless selected as presenting the most promise, therefore, it may be regarded as typical of the district.

The quarry was first opened near the railway track at more than one point, later, a more defined opening was made above the older workings. This newer quarry is about 50 feet long and the face slopes 50 feet up the hill in a series of steps. The major joints strike N. 10° W. vertically and form successive faces as the quarry is advanced. Cross joints are not developed in any regular manner, but irregular partings occur at varying intervals. The sheeting is very pronounced with a strike at right angles to the major joints, *i.e.*, E. 10° N. with a dip of 45° northward. The sheeting planes are not quite parallel and the sheets vary in thickness up to about 4 feet. The rift of the stone is said to be parallel to the major joints, and the grain at right angles to this direction; consequently, the horizontal plane must represent the hardway. It is stated by the workmen that very little difference in cleave is noticed in the three directions. The high inclination of the sheets, the lack of parallelism in the divisional planes, and the fact that the vertical rift crosses the sheeting at about 45°, occasion a large amount of waste. Nevertheless, owing to the infrequency of cross joints, pieces up to 25 feet in length have been quarried.

The stone is uniform and varies only in the occurrence of patches of coarser grain and the presence of scattered porphyritic crystals of feldspar. Black knots of small size occur sparingly. Enormous quantities are available.

The stone: No. 1514.—The three Nelson granodiorites, Nos. 1514, 1523, and 1524, resemble the Coast Range types in a general way. The present example is the lightest in colour of any of the series, and differs from Nos. 1523 and 1524 more than they do from the Coast Range types. The grain is medium to coarse and the general colour decidedly light owing to the sparing development of dark minerals. The feldspars are white, but the quartz is pinkish imparting to the whole stone a slightly pinkish colour (Plate XXV).

The microscope shows fairly fresh plagioclase, rather less orthoclase in a fresh condition, considerable quartz, a small amount of biotite, and a few grains of magnetite and sphene. The grain is about the same as in the stone from the paving stone quarry of the Vancouver Granite Company on Nelson island (No. 1467). The content of sulphur is 0·019 per cent.

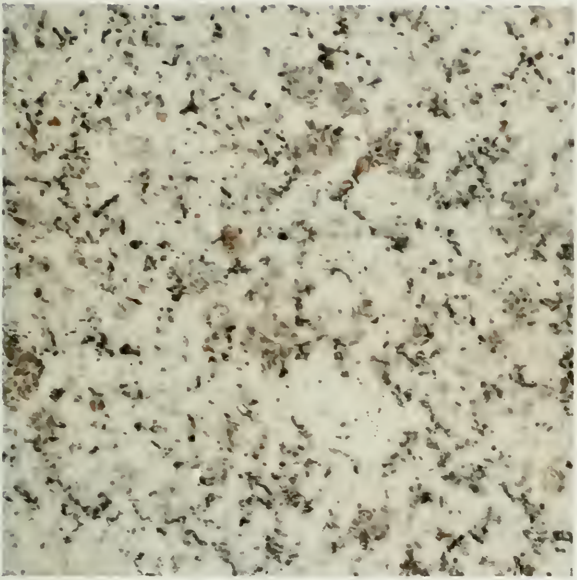
The physical properties of this stone follow:—

Specific gravity	2·656
Weight per cubic foot, lbs.	163·63
Pore space, per cent	1·432
Ratio of absorption per cent, one hour	·329
" " " two hours	·339
" " " slow immersion	·407
" " " in vacuo	·53
" " " under pressure	·547
Coefficient of saturation, one hour	·60
" " " two hours	·62
" " " slow immersion	·74
" " " in vacuo	·97
Crushing strength, lbs. per sq. in. dry (a)	27,014·
" " " " " (b)	31,798·
" " " " " (average)	29,406·
Transverse strength, lbs. per sq. in	1,708·
Shearing strength, lbs. per sq. in	1,790·
Loss on corrosion, grams per sq. in	·00138
Drilling factor, mm	6·5

The company holds a lease from the Canadian Pacific Railway Company for sites for buildings and for a spur 276 feet long. The equipment is as follows:—

1 80 h.p. boiler.

PLATE XXV.



Nelson granite, quarry of Kootenay Granite and Monumental Co., Three-mile point, Kootenay lake, B.C.

1 Canadian Rand compressor.

2 surfacers, Geo. Oldham and Sons Co.

4 plug drills.

1 rock drill.

2 derricks with steam hoists.

Several small buildings and also a mill in Nelson, 40 ft. by 40 ft.

A maximum of 35 men have been employed. At the time of my visit 18 men were at work.

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

Squared quarry blocks—50 cents per cubic foot.

Random coursing, rock-face, bedded and jointed—50 cents per square foot.

Regular coursing, rock-face—75 cents per square foot.

Regular coursing, bushed face, 8-point—$1.75 per square foot.

Sills, 2-brick, rock-face, bushed top and bottom—$1.10 per lineal foot.

Sills, 2-brick, bushed all faces—$1.50 per lineal foot.

Lintels, 8-inch, rock-face, bushed top and bottom—$1.10 per lineal foot.

Steps, 10 or 12 inch tread, bushed face and top—$1.50 per lineal foot.

The company is engaged in cutting stone for the Church of Jesus Christ of Latter Day Saints at Cardston, Alberta; this work calls for stone to the value of $50,000. The product has also been used for monument bases, for the Houston monument in Nelson, for the court house in Revelstoke, and for the post-office in Grand Forks (part). The Houston monument shows the possibility of quarrying large stone. The base is 4 × 4 × 4 feet, and the shaft 8 feet high; the horse trough is 6 × 2½ × 2 feet.

Granites of the Greenwood Area.

Dark rocks of the granodiorite class are exposed on the Kettle Valley railway between Taurus and Greenwood: they seem to be seriously shattered and to give little promise as building stone. Similar rocks have been quarried locally in Greenwood to a very small extent. Buildings are of a greyish-green aspect, and the stone shows flow structure, numerous veinlets, and a lack of uniformity; it may be seen in the L. A. Smith block in Greenwood.

Greenwood, B. C.

The mountains to the southward of Greenwood rise at a gradual slope and the rock is disposed in ledges which offer many opportunities for the easy locating of quarries. In rear of the school, to the eastward of the town, a small amount of quarrying has been done. The formation is very seriously and irregularly shattered with the most pronounced series of joints striking N. 65° E. almost vertically: these joints seldom exceed 2 or 3 feet in interval. The second set strikes with the face of the mountain

S. 40° E. and is more widely spaced. Horizontal partings also occur as well as irregular diagonal breaks.

The stone is not uniform in grain and is frequently cut by veinlets (1500). The location is hopeless except for the production of a hard, rough type of stone in comparatively small pieces.

Farther east, near the hospital, the major jointing is nearly east and west with a dip of 55° to the north. Blocks 2 feet thick might be procured here. Still farther east, at the Greenwood-Phoenix tramway tunnel, the jointing is more even and it would not be difficult to quarry material of sufficient size for ordinary building. The stone here is rather darker with a greater amount of the ferro-magnesian constituent.

North of the railway the mountain side is more precipitous and offers less opportunity for quarrying, nevertheless, some stone was obtained from near the smelter and was used for rough construction in Greenwood.

The stone: No. 1500.—This rock is a hard, tough, granodiorite of medium grain. The light minerals are rather impure in colour and the dark minerals are greenish giving a cast of green to the whole stone. The original dark mineral seems to have been hornblende, but decomposition has proceeded far, resulting in dull green spots and greenish staining in the surrounding light minerals. As a building material this rock, irrespective of the formational disadvantages is not to be compared with the better varieties of grey granodiorites described in this report.

Granites of the Little Canyon Area.

Terrace, B. C.

In the vicinity of Little Canyon, about a mile east of Terrace, the line of the Grand Trunk Pacific railway passes through several rock-cuts in a granitic stock which is considered to be of later age than the Coast Range batholith. The first three cuts show a reddish and altered type of granite in a much shattered condition; the fourth cut presents a more promising outcrop from our point of view.

The sheeting is ill-defined but fairly heavy and would not prevent the quarrying of large stone. Three sets of joints are developed with different intensity in different parts of the exposure. In places the parting planes are aggregated into fractured headings rendering a large amount of stone worthless. On the whole however, it would be possible to quarry good blocks up to 20 feet in length. The general trend of the rock-cut is N. 10° E. The first set of joints strikes N. 20° W. and dips 70° to the southwest; the partings are even and sharply defined at intervals up to 8 feet. The second set strikes W. 10° S. and dips 60° to the southward. The third set which is less defined strikes N. 20° E. and dips 80° to the northwest. It will be observed that the joints are not well disposed for the winning of rectangular blocks.

The mountain spur which occasions the rock-cut runs up to great altitudes to the north and west. Along its western border some heavy ledges are in accessible position, but beyond these the formation is much cut by stringers and is less promising.

The rock is a grey granite of medium grain, practically free from knots, but showing gneissoid structure in places (1589). The stone in the cuts nearer Terrace is reddish, more fractured and generally less promising (1590).

The stone: No. 1589.—In grain, colour, texture, and structure, this rock is so remarkably like the stone from Cathmar on the main line of the Canadian Pacific railway that no further account is required. The Cathmar stone has been described in detail as quartz diorite porphyrite, a variety of igneous rock far removed from a granite (No. 1493, page 76). It is rather remarkable that a unique type of stone such as this should be found at points so widely separated. A specimen of this rock was submitted by John Bremner for the proposed court house in Prince Rupert.

No. 1590.—A medium-grained reddish granite of dull appearance. Both pink and white feldspars occur and a less amount of clear quartz. The dark mineral is sparingly developed and is much decomposed, appearing as ill-defined, small, light greenish spots.

Syenites of the Ice River Area.

Dr. J. A. Allan reports a large mass of light grey syenite in the Ice River valley near Field; his impression as to its economic value may be learned from the following extracts:—

"The normal syenite, which is comparatively free from fractures, would make a good stone, either for building or ornamental purposes. The amount of this material is unlimited and it occurs along either side of the bottom of Ice River valley.

"As this is the only large mass of igneous rock of value for building purposes in the vicinity of the main line of the Canadian Pacific railway in the Rocky mountains, a market for the material would soon be established, either in Calgary and eastwards, or if of suitable quality, it might be profitably shipped to Vancouver and the Pacific coast."[1]

Summary—Granites of Late Jurassic or Post-Jurassic Age

In Vancouver island and on the mainland to the east of the great masses of the Coast range occur stocks and batholiths of igneous rocks which, in the general terms adopted for this report, are called granite, although none of them are granite in the strict sense of the word.

The only commercially important quarries are situated near Nelson where a greyish granodiorite, somewhat similar to that of Jervis inlet,

[1] Geol. Sur. Can., Memoir 55, Pub. 1370, p. 242, 1914.

has been worked to a considerable extent. This stone is described on pages 109, 110, and 112, and is figured in Plate XXV.

A greenish granodiorite of very inferior quality has been used locally at Greenwood; a peculiar rock (quartz diorite porphyrite) is proposed for structural purposes at Little Canyon on the Grand Trunk Pacific railway; and some of the masses of southern Vancouver island are thought to be capable of yielding structural stone.

Literature:—

Geol. Sur. Can., Memoir 13, Pub. No. 1121, 1912.
Thirteenth International Geological Congress, Guide-book No. 9, 1913.
Geol. Sur. Can., Memoir 55, Pub. No. 1370, 1914.
Geol. Sur. Can., Memoir 38, 1912.

CHAPTER V

THE "BLACK GRANITES" OF THE PROVINCE OF BRITISH COLUMBIA.

The term "Black Granite" is used by quarrymen and monument makers to designate any dark-coloured igneous rock of granitic texture. None of these rocks are granite in the proper sense of the word but "black granite," nevertheless, is a useful expression in classifying building and ornamental stone from the commercial point of view. Under this head are included those igneous rocks of a very dark colour which are unfitted for building purposes, but made valuable for monumental purposes by reason of the dark colour.

Few of the stones described in the previous chapter are granites, but they approach more nearly, at least in general appearance, to typical stone of that class. The dividing line between "granite" and "black granite," as used herein, is arbitrarily drawn for the purpose of facilitating classification and is quite indefensible from a scientific point of view.

Stones of this type have received very little attention in British Columbia although the province contains numerous sources of possible supply. Among these may be mentioned the dark, basic phases of the Coast Range batholith, exposed on numerous islands of the Strait of Georgia, and the masses of dark igneous rocks described by Daly along the international boundary, and referred to in numerous reports on the mining districts of the southern parts of the province.

The only stones of this class to which my attention has been directed are as follows:—

Porphyritic monzonite of Rossland.

Monzonite of Coryell.

Monzonite of Ymir.

Orbicular hornblende gabbro near Midsummer island, Queen Charlotte sound.

Gabbros of the Coast range.

Rossland Area.

Rossland, B.C.

East of Rossland, in the vicinity of the derailing switch on the Canadian Pacific railway, is an area of about 25 acres of a dark-coloured porphyritic monzonite which has been quarried to a small extent for building purposes and for use as a monumental stone.

Immediately east of the railway yards the rock is exposed to a maximum height of 20 feet in a cut about 100 yards long. Towards the east end of the cut, distinct sheeting is observed dipping east and a little south. Towards the west end, the sheeting is less distinct but the dip is in the opposite direction, indicating that the sheeting conforms to the contour of a ridge of which the northern end is crossed by the railway. The sheets vary in thickness, but stone 4 feet thick could be procured in places. A small quarry has been opened on the extremity of the ridge north of the track. Here the sheeting is the same as in the cut and the jointing is less obscured by the shattering of explosives. The most pronounced series of joints strikes E. 40° S. with a steep but variable dip to the eastward. Cross joints occur very irregularly. A limited amount of stone is available here,but along the axis of the ridge (S. 40-50° E.) much material is accessible (1515).

About 800 feet south and east along the track and at a lower level, a second quarry has been opened exposing an upper heavy sheet of fully 4 feet with others of undetermined thickness below. The formation is not excessively shattered and fair sized stone can doubtless be obtained without undue loss. Farther south to the limit of the exposure, about 400 feet, finer-grained phases of the same stone are to be seen, but no work has been done to reveal the condition of the formation.

The stone:—This type of rock is not confined to the present locality but occurs in other places in the vicinity of Rossland. The following description is given by Drysdale:—

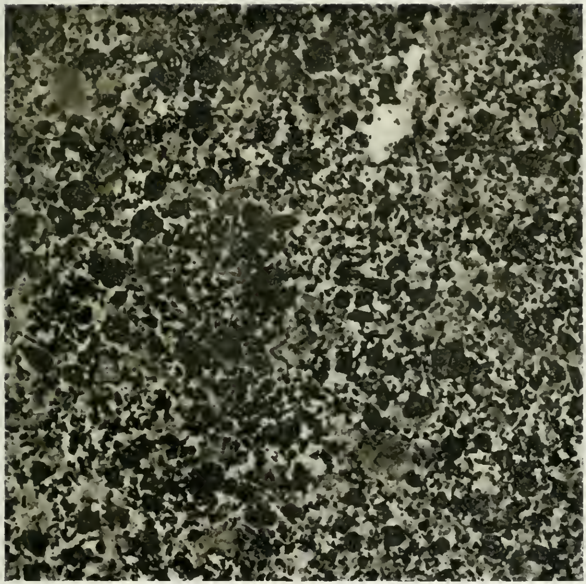
"The porphyritic monzonite of most of these localities has a rather characteristic appearance and within any one body is remarkably uniform. Typically the rock is of a light grey colour, coarse-grained and composed of rather large, stout prisms of dark-green pyroxene and secondary hornblende, countless small rounded or hexagonal flakes of brown biotite, and abundant feldspar. The crystals commonly measure between one-eighth and one-quarter of an inch in length and occasionally attain even larger dimensions. The pyroxene and the small biotite flakes, the latter seldom over one-fortieth of an inch in diameter, are evenly distributed through the light feldspars which exceed the coloured constituents in amount though because of the dark colours of the latter, the reverse often seems to be the case. The feldspars have less regular crystal forms than the other constituents and vary much in size: the larger grains not uncommonly have cleavage faces nearly one-quarter of an inch in length."[1]

No. 1515.—This monzonite is distinctly a dark-coloured rock with dark-greenish glistening spots up to 8 mm. in diameter but averaging about 4 or 5 mm. in diameter. In addition there are more sharply defined, smaller black grains. These dark minerals are enclosed in a lighter crystalline groundmass which does not exceed one-half of the whole surface (Plate XXVI).

Under the microscope the large greenish spots are seen to be hornblende which has developed from the alteration of pyroxene of which some traces are still left. The glistening black spots are mica which is brown in

[1] Geol. Sur. Can., Mem. 77, No. 1520, p. 233, 1915.

PLATE XXVI.



Porphyritic monzonite, Rossland, B.C.

transmitted light. The larger crystals of the light-coloured minerals are orthoclase enclosing small columnar crystals of plagioclase. The presence of the two feldspars in the absence of quartz makes the rock a monzonite, and the relatively large size of the hornblende crystals imparts the porphyritic structure which justifies the name "porphyritic monzonite."

On fresh fracture the rock dulls in a few years and a longer exposure renders the surface reddish. Polished surfaces are very attractive, but the tendency to alteration on exposure will restrict the use of the stone as a monumental material. The corrosion test, however, was not of sufficient duration to produce any effect beyond slightly increasing the contrast between the component minerals. It is significant, however, that the actual loss under this experiment is higher than in any other igneous rock tested. The content of sulphur is 0·078 per cent indicating a greater amount of pyrite than was observed in any other of the stones examined.

The physical properties follow:—

Specific gravity	2·882
Weight per cubic foot, lbs.	177·56
Pore space, per cent	1·304
Ratio of absorption, per cent, one hour	·303
" " " two hours	·322
" " " slow immersion	·368
" " " in vacuo	·427
" " " under pressure	·458
Coefficient of saturation, one hour	·67
" " " two hours	·70
" " " slow immersion	·80
" " " in vacuo	·93
Crushing strength, lbs. per sq. in., dry (a)	27,498·
" " " " " (b)	27,662·
" " " " " (c)	29,343·
" " " " " (average)	28,167·
Transverse strength, lbs. per sq. in.	1,692·
Shearing strength, lbs. per sq. in.	1,053·
Loss on corrosion, grams per sq. in.	·00474
Drilling factor, mm.	6·7

This stone was used in the construction of the base of the Bank of Montreal and for the lower storey of the post-office in Rossland; it has also been employed for monuments. The buildings show a rather dark colour but the stone is very uniform and entirely free from knots. The only blemish is the occasional presence of ill-defined whitish lines due to the failure of the dark-coloured minerals (Plate XXVII). For decorative or monumental purposes the stone has a distinct value as its uniform grain and dark colour, together with a fair susceptibility to polishing, are important features in its favour from this point of view.

Coryell Area.

A large batholithic mass, fully 15 miles in diameter, lies north of the international boundary at about lat. 118° W. Its margin is cut by the Canadian Pacific railway (Nelson-Midway branch) near Coryell and in consequence it has been named the "Coryell batholith" by Daly who ascribes it to middle Tertiary age. Other authors include these rocks in the Nelson batholith which is of late Jurassic or Post-Jurassic age.

The main mass of the batholith is a "medium-grained, occasionally somewhat porphyritic, light reddish to pinkish brown rock of typical syenitic habit—hornblende-biotite pulaskite."[1] This rock has attracted no attention as a possible building stone but the margins of the batholith show a darker rock of different mineral composition which has been quarried by the Canadian Pacific Railway company at a point about one and a quarter miles west of Coryell.

Canadian Pacific Railway Company: Coryell quarry.

The excavation is about 100 feet long parallel to the face of the mountain (S. 20° W.) and has been worked into the mountain-side to a distance of about 50 feet. The sheeting and jointing is so irregular that description is difficult. An ill-defined and discontinuous sheeting seems to dip at about 30° towards the track. Vertical jointing parallel to the strike of the mountain-face is to be seen in places as well as irregular cross jointing. On the whole it may be said that the formation is rather badly shattered but that very large stone is nevertheless obtainable in places. Higher up the mountain-side are good ledges of apparently solid stone. There is no doubt that an unlimited quantity of the material could be obtained in the vicinity. The stone is fairly uniform in grain but it is marred, in part, by the presence of fine whitish stringers (1512).

The stone: No. 1512.—This rock is of general dark colour and coarse grain with light and dark components arranged in a more or less pronounced gneissoid manner. It resembles in a general way Nos. 1454, 1577, and 1578, but it is coarser in grain and darker in colour than any of these. The rock occurs in the basic edge of the Coryell pulaskite batholith and has been determined by Daly as augite-biotite-hornblende monzonite.[2] This stone might with equal reason have been included with the granites as it is no darker in colour than Nos. 1577 and 1578: it is placed here only on account of its more basic composition (No. 6, Plate XLVII).

[1] Geol. Sur. Can., Memoir No. 38, p. 359.
[2] Geol Sur. Can., Memoir No. 38, pp. 360-361.

PLATE XXVII.

Rossland monzonite. Base of post-office, Rossland, B.C.

The smoothed surface shows white minerals up to 12 mm. in diameter and dark minerals of two kinds—jet black and greenish. Under the microscope one sees orthoclase, andesite, and micro-perthite, all slightly decomposed, diopside (pyroxene) partially altered to green hornblende, biotite of brown colour in transmitted light, and a few grains of magnetite. The presence of the two kinds of feldspar together with the dark-coloured minerals constitutes this rock a monzonite, and the absence of quartz distinguishes it from the stones of similar appearance mentioned above which are referred to the quartz diorite series.

The physical properties of this stone follow:—

Specific gravity	2·901
Weight per cubic foot, lbs.	179·29
Pore space, per cent	1·007
Ratio of absorption, per cent, one hour	·208
" " " two hours	·211
" " " slow immersion	·246
" " " in vacuo	·33
" " " under pressure	·351
Coefficient of saturation, one hour	·59
" " " two hours	·60
" " " slow immersion	·70
" " " in vacuo	·94
Crushing strength, lbs. per sq. in., dry, (a)	23,600·
" " " " " (b)	22,967·
" " " " " (c)	23,305·
" " " " " (average)	23,291·
Transverse strength, lbs. per sq. in.	2,278·
Shearing strength, lbs. per sq. in.	2,752·
Loss on corrosion, grams per sq. in.	·001635
Drilling factor, mm.	9·2

Systematic quarrying for building stone was never carried on at this site; the operations seem to have consisted in blasting large masses from the face and subsequently cutting them up by plug and feathers. The product was used for retaining walls, culverts, tunnels, bridge piers, etc., along the line of railway, also for structural purposes in Grand Forks, Greenwood, and other places in the vicinity. The post-office in Greenwood is probably the best example of the use of this stone for building. This structure presents a dark and decidedly speckled appearance owing to the coarse grain of the stone and the strong contrast between the constituent minerals. The black mica is conspicuous and produces a glistening effect. Gneissoid structure is apparent in many blocks, porphyritic feldspar crystals are pronounced in others, and still others are marred by the fine whitish veinlets. On the whole it must be concluded that this stone is of a rough and dark nature which makes it more suited for purposes of heavy construction than for use in buildings of architectural pretensions.

Ymir Area.

Ymir, B.C.

About a mile south of Ymir on the Nelson and Fort Sheppard railway a stock of porphyritic monzonite is crossed by the railway in a rock-cut about 300 yards long in a north and south direction. The belt seems to bear about E. 10° N. West of the track are accessible exposures running up to a height of 100 feet before pinching out in the higher mountain at a probable distance of less than a mile. East of the track the exposures are lower and appear in knolls for a short distance only. Both sheeting and jointing are very irregular; the only set of joints at all possible of description run east and west with a dip of 80° to the north. Much loss would be caused by shattering in any attempt at systematic quarrying but nevertheless some large blocks could be obtained, particularly towards the north of the exposure where the sheeting is heavy and better defined, with a low dip to the west and south.

The stone is very uniform in grain and there is a complete absence of knots, flow structure, or other blemishes. Old surfaces are grey and dull and broken pieces seem rather prone to decay; on fresh fractures large, glistening crystals are prominent and are disposed vertically in a north and south direction indicating the existence of a well developed rift.

The stone: No. 1521.—Drysdale thus describes the Ymir monzonite which is referred to a Tertiary, possibly Oligocene, age:—

"The Salmon River monzonite is a dark greenish grey, coarsely granular rock with stout prisms of augite and biotite in a feldspar matrix, the contrast between the two giving it a mottled appearance that is characteristic. The larger crystals of feldspar schillerize in sky-blue colours which are particularly brilliant on wet surfaces.

"Under the microscope the augite appears as the pale green, almost colourless diopside and the crystals commonly measure between one-eighth and one-quarter of an inch or more in length. The orthoclase is a soda variety and the plagioclase which is present in relatively small crystals is labradorite. Apatite and magnetite are present as accessory constituents and chlorite as alteration products."[1]

For our purpose the coarse grain and the lack of purity in the light-coloured constituents are not favourable. While regular knots are not present the stone shows, in places, fine-grained patches with which a considerable amount of pyrite is associated. On fresh fractures the large brownish-

[1] Geol. Sur. Can., Memoir 94, Pub. No. 1651, p. 38, 1917.

black mica crystals are prominent and the augite presents a rather dull and unattractive appearance.

A small amount of stone was quarried in the rock-cut and was used for monumental purposes. When freshly polished the stone is of good appearance but it is prone to become rapidly dulled on exposure. As a building stone the rock is too dark to meet with approval.

Coast Range Area.

Island north of Fire island and west of Midsummer island, at the south end of Queen Charlotte sound.

Dr. G. M. Dawson first drew attention to the occurrence of a remarkable type of rock at this point in the following words. "Dark, highly hornblendic rocks, of granitoid structure, also appear in several places. On one of the small islets, west of the end of Midsummer island, a dark rock of this character assumes a beautiful spheroidal concretionary structure, which is well shown on glaciated surfaces. The spheroidal masses are closely crowded together, their diameters being from 2 to 4 inches."[1]

Dr. J. A. Bancroft devotes several pages to a detailed description of this rock. The following extracts are taken from his report:—"The greater part of this island and the immediately adjacent islands are composed of dark basic rocks (1557a), which vary both in their composition and texture and are frequently penetrated by apophyses and dikes of granite. That portion of the intrusive body of rock, which is distinguished by the development of the orbicular structure, has a length, in a north and south direction, of 55 feet. Its maximum width is 15 feet, the western and southern boundaries being completely exposed, while to the east and north it is partially masked by a thin covering of soil which bears a lowly growth of shrubbery. Within the area thus outlined the orbules are so closely congregated that they are contiguous with each other . . . . (1558).

"The orbicular hornblende-gabbro would furnish a unique and very beautiful building stone."[2]

The limited extent of the exposure and the fact that it rises only 6 or 8 feet above high water makes very doubtful the possibility of quarrying the stone on a commercial scale. As the formation is rather severely fractured there is no immediate evidence that blocks of large size could be obtained. Nevertheless, it would be possible to secure pieces of sufficient dimensions for the making of small bases, pedestals, and other objects of a like nature.

The stone: No. 1557a.—This rock is to be considered merely as an example of the many phases of dark, basic rocks exposed in this vicinity. It is a tough, hard, igneous rock of fairly coarse grain and greenish-grey to black colour. The dark crystals are augite or hornblende and the light crystals,

[1] Geol. Sur. Can., Ann. Rep., Vol. 11, p. 53B, 1886.
[2] Geol. Sur. Can., Memoir 23, Pub. No. 1188, p. 95, p. 96, p. 144, 1913.

in this case much less abundant, are plagioclase feldspar. Rocks of this type are too hard and tough to be worked profitably for building stone; their only value lies in the possibility of employing them for monumental purposes.

No. 1558.—This peculiar stone is sufficiently defined by the description already given. The polished surface, reduced one-half, is reproduced in Plate XXVIII.

Summary Black Granites of British Columbia.

The term "Black Granite" is commonly applied by quarrymen and monument-makers to all types of dark-coloured igneous rocks; the expression has no definite scientific meaning.

Many of the eruptive rocks of the mining districts of the southern part of the province may be of possible value as monumental stone, but the only examples which have attracted any attention are the monzonites of Rossland, Coryell, and Ymir.

Monzonite is a dark rock consisting essentially of orthoclase, plagioclase, and a dark ferro-magnesian mineral such as hornblende. The Rossland stone has been used for monuments and for buildings; it is described on pages 118-119, and is shown in Plate XXVI. The Coryell stone is a coarser and rougher type; it has been quarried for rough masonry and for building. This rock is described in detail on pages 120-121. The Ymir stone is a coarse-grained variety with glistening mica as a characteristic feature; it has not been systematically quarried but a few blocks have been taken out for monuments.

Phases of the Coast Range batholithic rocks are dark enough to be included here, particularly the gabbros on some of the islands of the Strait of Georgia, Queen Charlotte sound, and Hecate strait. A peculiar orbicular gabbro, shown in Plate XXVIII, has attracted attention as a possible decorative stone; it occurs on a small island off Midsummer island in the southern part of Queen Charlotte sound.

The Coast Range "granite" as exposed along the line of the Grand Trunk Pacific railway is usually of a dark type and might be considered under the present category.

There is no literature dealing primarily with these rocks from our point of view but most of the reports on mining regions contain references to stones of possible value. The more important publications are as follows:—

Geol. Sur. Can., Memoir 38. (49th Parallel).
Geol. Sur. Can., Memoir 23. (Coast and Islands).
Geol. Sur. Can., Memoir 21. (Phoenix-Boundary).
Geol. Sur. Can., Memoir 77. (Rossland).
Geol. Sur. Can., Publication No. 996. (Coast and Islands).
Geol. Sur. Can., Publication No. 939 (Rossland).
Geol. Sur. Can., Memoir 94. (Ymir).

Orbicular hornblende gabbro, small island near Midsummer island, B.C. (One-half natural size.)

CHAPTER VI

MARBLES OF THE PROVINCE OF BRITISH COLUMBIA.

Limestone which by alteration due to natural agencies has become crystalline, is called "crystalline limestone"; and this, when possessed of a certain fineness of grain or other qualities giving it a handsome appearance, is called "marble." In some cases limestones are classed as marble, although crystalline structure is absent or but slightly developed, if the stone is of sufficient beauty for use as ornamental material.

Owing to the intense metamorphism to which the rocks of British Columbia have been submitted, practically all the limestones have been rendered crystalline, but the application of the purely commercial term "marble" is a question for further investigation. No general attempt will be made in this chapter to distinguish between crystalline limestone and marble; the distinction can be made only in those individual cases which have been more fully investigated from the economic point of view.

British Columbia does not rank high as a producer of stone of this class; actual production has been confined to the following localities:—

Marblehead, north of Kootenay lake.

Nootka sound, Vancouver island.

Northern Texada island.

Southern Texada island.

Grant Brook, Grand Trunk Pacific railway.

Of these, only the Marblehead quarries and those of southern Texada island have shipped any stone beyond a few blocks for experimental purposes. The list may be extended, however, by the addition of a few localities which have produced a coarse crystalline limestone, suitable only for building purposes and which could scarcely be included in the category of marble: the chief of these are:—

Kootenay lake, opposite Kaslo.

Grand Forks.

Sheep Creek.

Bands of crystalline limestone occur in practically all the sedimentary formations from the Shuswap terrane to the latest Mesozoic strata. The localities of occurrence, therefore, are so numerous that it would be futile to attempt a categorical list in a work of this kind. By reason of accessibility, or because of having attracted some attention from the economic point of view, a restricted number of localities are tabulated below and an attempt is made to ascribe them to their proper place in the geological column. This table is arranged in ascending order, *i.e.*, the oldest formation is at the top, and the youngest at the bottom.

Table Showing the Geological Age of the Chief Occurrences of Marble in British Columbia.

System	Formation	Locality	Reference
Pre-Cambrian	Shuswap	Marblehead Kaslo Arrowhead Grand Forks Okanagan lake Shuswap lake	This report, p. 128 " p. 135 " p. 139 " p. 140. G.S.C., Ann. Rep. 1877–78, p. 164B. Idem. p. 163B.
	Beltian (Nakimu)	Prairie hills	13th Int. Geol. Cong., Guide-book 8, part 2.
Cambrian		Vermilion pass White Man's pass Yoho river Grant brook	This report, p. 141 " p. 141 " p. 142 " p. 143
Carboniferous	Pend d'Oreille	Sheep creek	This report, p. 147
	Rossland	Fife	This report, p. 148
	Wardner	Wardner	13th Int. Geol. Cong., Guide-book 9, p. 51.
	Cache Creek	S. Thompson river N. Thompson river Hope Agassiz	G.S.C., Ann. Rep., Vol. III, p. 160R. Idem. G.S.C., Ann. Rep., Vol. III, p. 159R. Idem.
		Boundary creek	G.S.C., Ann. Rep., Vol. XV, p. 133A
Triassic	Nitinat	Southern Vancouver island	This report, p. 149
	Nicola	Nicola lake	G.S.C., Ann. Rep., Vol. III, p. 160R.
	Anderson Bay	Southern Texada island	This report, p. 149
	Open Bay	Harbledown island	This report, p. 155
Jurassic	Sutton	Southern Vancouver island	This report, p. 156
	Marble Bay	Northern Texada island W. Redonda island Knight inlet Bute inlet S. Valdes island Dinner rock	This report, p. 159 " p. 162 " p. 162 G.S.C., Mem. 23, p. 67 Idem. p. 65 Idem. p. 66

System	Formation	Locality	Reference
		Nootka sound, V. I	This report, p. 163
		Tofino inlet, V. I	Information received.
		Nimpkish lakes, V. I	G.S.C., Ann. Rep., Vol. III, p. 158R.
		Horne lake, V. I	G.S.C., Rep. 1873-74, p. 101.
Undetermined		Murray brook	G.S.C., Ann. Rep., Vol. XV, p. 51AA.
		Effingham inlet	Idem. p. 65A.
Devono-Carboniferous to Jurassic		Dease river	G.S.C., Ann. Rep., Vol. III, p. 33B.
		Shames, G.T.P.Ry	This report, p. 175
		Beaver cove, V.I.	„ p. 171
		White Cliff island	„ p. 174
		Digby island	„ p. 173
		Smith island	„ p. 172
		Khutzeymateen inlet.	„ p. 172
		Banks island	„ p. 172
		Elliott island	„ p. 172
		Rivers inlet	„ p. 172
		Kum-ea-lon inlet	„ p. 172
		Porcher island	„ p. 172
		Gurd island	„ p. 172
		Princess Royal island	„ p. 172
		Columbia valley, 30 miles south of Windermere	Information received.

Many of the localities listed above, and numerous others which might be cited, have no immediate economic significance and will not be referred to further. The more important occurrences including all those which have received any attention from the present point of view may be arranged as follows:—

- Marbles of the Shuswap terrane.
  - Kootenay Lake area.
    - Marblehead.
    - Kaslo.
  - Arrow Lakes area.
    - Arrowhead.
    - Arrow lake.
  - Grand Forks area.
    - Grand Forks.
- Marbles of the Beltian series.
- Marbles of the Cambrian system.
  - White Man's and Vermilion Pass area.
  - Yoho River area.
  - Grant Brook area.
- Marbles of the Carboniferous system.
  - Sheep Creek area.
  - Fife area.

Marbles of the Triassic system.

Southern Vancouver island area (Nitinat formation).

Southern Texada Island area (Anderson Bay formation).

Harbledown Island area (Open Bay formation).

Marbles of the Jurassic system.

Southern Vancouver Island area (Sutton formation).

Northern Texada Island area (Marble Bay formation).

Redonda Island area.

Marbles of undetermined age, probably Devono-Carboniferous.

Nootka Sound area.

Prince Rupert area.

Digby island.

White Cliff island.

Beaver Cove area.

Shames area.

Much of the marble being used at the present time in British Columbia is supplied from the quarries of the Vermont Marble Company in the Ketchikan mining district, Alaska. The stone is a white variety, clouded rather than veined with blue, and is known under the trade name "Tokeen." The company maintains a mill in Vancouver.

Marbles of the Shuswap Terrane.

The rocks of the Shuswap terrane are largely of sedimentary origin and doubtless were originally sand, gravel, limestone, and clay. Intense metamorphism has altered the whole series into crystalline, more or less schistose rocks. The limestones have all been converted into the crystalline form: many of the known bands are very impure and the formation is generally so excessively shattered that quarrying of marble is impossible. So numerous are the actual exposures of this stone that the locations which have been worked are too few to justify sweeping deductions as to the possibilities of the Shuswap terrane as a producer of marble.

Kootenay Lake Area.

Canadian Marble and Granite Works, P.O. Box 903, Nelson, B.C.; James Carruthers, Montreal, president; G. B. Wilson, Nelson, manager.

The marble quarries of this company are situated near Marblehead on the Trout Lake branch of the Canadian Pacific railway, 8 miles north of Lardeau.

A short distance north of Lardeau crystalline limestones interbanded with schists crop out in the mountain-side to the west of the railway; they are succeeded northward by interlaminated schists and quartzites. At the third mile the railway leaves the immediate vicinity of the mountain, but the hills, viewed from the distance, do not seem to contain limestone strata. Near Marblehead (La Blanche), the railway again approaches the mountain and a dark type of crystalline limestone is exposed in a cut north of the station (1525). The beds here strike N. 40° W. and dip 35° to the northeast. One set of joints is vertical and parallel to the strike of the formation, and a second set strikes S. 10° W. with a dip of 85° to the east. About 100 yards north of the cut the limestone is lighter and more massive. The original quarry of the company was opened at this point to a length of 90 feet and a width of 50 feet. The work was done by channellers and consisted in the removal of six 4-foot tiers leaving a vertical face of 24 feet. Above the face the hill rises at a steep angle for another 20 feet beyond which it is talus-covered. The beds strike N. 40° W. and dip 40° to the northeast. Pronounced joints parallel to the strike of the beds dip at right angles to the strata, *i.e.*, 50° to the southwest. Irregular shattering is also observed but I was unable to make out any distinct set of cross joints. It will be observed that the horizontal quarry floor is at a high angle to the dip of both the beds and the major joints. Most of the stone is light-coloured (1529) but darker bands occur towards the bottom. The following statement gives a more complete subdivision of the types of marble, but I am doubtful of the advisability of establishing so minute a subdivision, at least on a commercial basis.

"It is estimated that the deposit of marble is approximately 700 feet in thickness. The top layer is about 50 feet thick of a light-coloured, crystalline marble, similar to the Georgia "Cherokee" marble. Then there is about 10 feet, also crystalline, like the Georgia "Dark Creole." Next follows 6 feet of light blue, and then 2 feet similar in appearance to Italian statuary marble. Other layers include various shades of blue marble, from light to very dark.

"The marble is described as being somewhat harder than the average Vermont marble, but it takes a better polish and retains it. The deposit is large, free from flaws and cracks, and so unbroken that blocks can be taken out in size up to any dimensions that it is practicable to get machinery to lift the blocks with."[1]

This quarry was abandoned by the new management, on account of the presence of secondary veinlets of calcite, and another was opened about 800 yards farther north. In this case, tunnelling methods were adopted with the production of an excavation which has substantially the following dimensions:—

Portal: 36 ft. long (S. 50° W.), 30 ft. wide, 18 ft. high.

Quarry: 75 ft. long, (N. 40° W.), 60 ft. wide, 18 ft. high.

The upper 6 ft. have been removed by explosives and the lower 12 feet have been taken out in two tiers of 6 feet each by channellers. The floor of the quarry is level with the portal for the central 45 feet of its length, but the lower 6-foot tier has not been removed for 15 feet at either end.

[1] Ann. Rep. Min. of Mines, Prov. of B.C., p. 197, 1908.

An extra tier, 6 feet deep and 5 feet wide, has been taken out along the northwest side of the portal and thence across the quarry.

The bedding is the same as in the quarry last described and consequently the quarry floor is at a high angle to the bedding and the gang blocks have the lamination disposed diagonally. The jointing is approximately vertical at about N. 50° W. and also at right angles to that direction. Neither set is uniform or well defined, but the partings are spaced widely enough to permit the extraction of large blocks, not however, without considerable waste (Plate XXIX).

The general run of the stone is the light-coloured variety (1526) which, however, fades imperceptibly into a type in which the dark bands are more pronounced (1527). The light stone is much more abundant and is known as "Light Kootenay" while the dark type is called "Dark Kootenay." Intermediate varieties naturally occur and I question if the dark type can be obtained sufficiently uniform and in sufficient quantity to meet the wishes of contractors.

South of the quarry and at 50 feet greater elevation a small amount of quarrying has been done in darker stone (1528). Here and at the portal of the large quarry the stone appears to be severely fractured and gives no indication of the much greater solidity encountered as the work progressed.

The stone: Two examples of typical commercial stone from the mill will be first described, and the samples collected in the quarries will be determined by comparison with these.

No. 1530.—This stone is white crystalline limestone of medium grain, the individual crystals being about 2 or 3 mm. in average diameter but occasionally reaching dimensions of 4 mm. The stone is almost identical with No. 1424 from Nootka sound described on page 166. The only difference is that the present stone is scarcely as pure, as all pieces of any considerable size show more or less faint blue cloudiness.

Like most of the marbles this rock lies within the zone of danger of injury by frost as the coefficient of saturation is ·85; the freezing test, however, shows little visible effect and the actual loss of strength is too slight to be determined by our methods. The cube subjected to corrosion was considerably etched and rendered opaque white; several small grains of pyrite, not observed on the rubbed face, were made visible by the process.

The physical properties follow:—

Specific gravity	2·718
Weight per cubic foot, lbs.	168·7
Pore space, per cent	·572
Ratio of absorption, per cent, one hour	·136
" " " two hours	·144
" " " slow immersion	·179
" " " in vacuo	·198

Marble blocks and portal of quarry of the Canadian Marble and Granite Works, Marblehead, B.C.

Ratio of absorption, per cent, under pressure	·212
Coefficient of saturation, one hour	·64
„ „ „ two hours	·68
„ „ „ slow immersion	·85
„ „ „ in vacuo	·93
Crushing strength, lbs. per sq.in., dry (a)	12,486·
„ „ „ „ „ (b)	13,103·
„ „ „ „ wet	11,978·
„ „ „ „ „ after freezing	9,362·
Transverse strength, lbs. per sq. in	2,127·
Shearing strength, lbs. per sq. in	1,156·
Loss on corrosion, grams per sq. in	·1346
Drilling factor, mm	22·2
Chiselling factor, grams (I)	·9
„ „ (II)	4·3

This rock is an almost pure crystalline limestone with very little magnesia, iron, or foreign matter. An analysis by Leverin follows:—

	per cent
Insoluble matter	·36
Soluble silica	·22
Lime[1]	54·42
Magnesia[2]	·37
Ferrous oxide	·11
Ferric oxide	trace
Alumina	·03
Sulphur	·01
[1] Equivalent to calcium carbonate	97·18
[2] Equivalent to magnesium carbonate	·78

No. 1531.—This is a light bluish-grey crystalline limestone of medium grain but slightly coarser than No. 1530. It is banded in lighter and darker colours, but the banding is not strongly pronounced, as the components are not strikingly different and fade into one another. The rock is not essentially different from No. 1533 from Kootenay lake. It is scarcely as strong as that example but it chisels more easily although the drilling factor is lower. The slight differences in the crushing strength, dry, wet, and frozen, are within the range of instrumental error and indicate that the stone is not appreciably affected by these experiments. The corrosion test causes a whitening and etching of the surface and produces a sharper contrast between the semi-translucent and consequently darkish crystals and the opaque white crystals. No pyrite was revealed in this case (Plate XXXII).

The physical properties follow:—

Specific gravity	2·719

Weight per cubic foot, lbs.		169·05
Pore space, per cent		·438
Ratio of absorption, per cent, one hour		·093
" " " two hours		·108
" " " slow immersion		·119
" " " in vacuo		·135
" " " under pressure		·162
Coefficient of saturation, one hour		·57
" " " two hours		·66
" " " slow immersion		·73
" " " in vacuo		·83
Crushing strength, lbs. per sq. in., dry, (a)	11,471·	
" " " " " " (b)	11,172·	
" " " " " " (c)	13,188·	
" " " " " " (average)	11,710·	
" " " " " wet	10,691·	
" " " " " wet after freezing	11,069·	
Transverse strength, lbs. per sq. in	1,577·	
Shearing strength, lbs. per sq. in	1,248·	
Loss on corrosion, grams per sq. in		·1116
Drilling factor, mm		17·2
Chiselling factor, grams (I)		2·0
" " " (II)		8·2

An analysis by Leverin shows that this stone, despite the colouring matter, is even purer than the white variety No. 1530. Although no pyrite was observed on the smoothed surfaces, the stone contains more sulphur, and presumably more pyrite, than No. 1530.

The analysis follows:—

	per cent
Insoluble matter	·12
Soluble silica	·26
Lime[1]	54·51
Magnesia[2]	·44
Ferrous oxide	·06
Ferric oxide	trace
Alumina	·06
Sulphur	·024
[1]Equivalent to calcium carbonate	97·34
[2]Equivalent to magnesium carbonate	·92

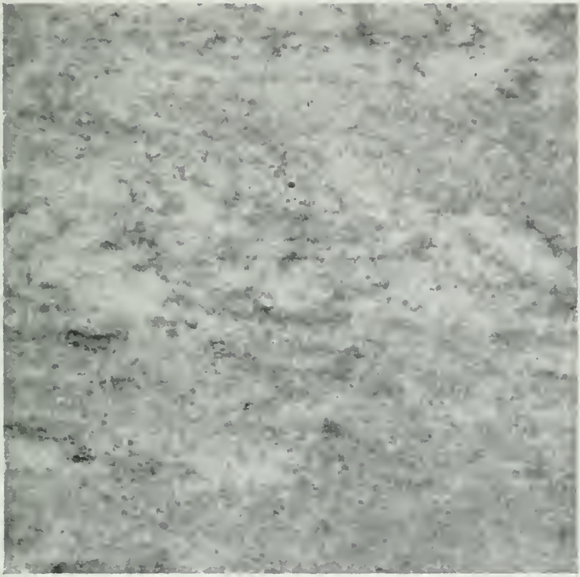
An analysis, published by the company, indicates a stone of even greater purity as follows:—

	per cent
Silica	·30

Plant of the Canadian Granite and Marble Works, Marblehead, B.C.

Kootenay marble, Canadian Granite and Marble Works, Marblehead, B.C.
(About one-fourteenth natural size.)

Plate XXXII.



Dark Kootenay marble, Canadian Granite and Marble Works, Marblehead, B.C.

	per cent.
Ferric oxide and alumina..	·20
Magnesium carbonate......	·30
Calcium carbonate.........	99·40

No. 1525.—A blue crystalline limestone of medium grain, banded and blotched with white. The banding is more pronounced than in No. 1531 and resembles more closely the type of interlamination seen in some of the specimens from Sheep creek, e.g., No. 1517 page 130.

No. 1526.—Essentially the same as No. 1524 but of less solidity due to planes of shearing having been developed by terrestrial strains.

No. 1527.—Identical with No. 1531.

No. 1528.—A distinctly laminated blue and white variety of lighter colour and slightly coarser grain than No. 1525.

No. 1529.—A white type like No. 1524. It shows faint blue cloudiness in which the blue is due more to a greater translucency of certain areas than to the presence of foreign colouring matter.

The company holds 400 acres in fee simple; of this, 112 acres are in quarry lands and the balance in millsite etc. The quarrying plant consists of the following apparatus:

At new quarry:—

2 Sullivan swivel-head channellers.
1 quarry bar.
1 derrick with separate boiler and hoist.
2 boilers.
Small buildings, cars, track minor appliances.

At old quarry:—

1 portable boiler.
1 dismantled compressor.
Minor appliances.

The company has installed a complete mill, boarding house, offices, and other buildings at La Blanche station. The mill consists of two buildings with a yard between. The gang mill is 54 feet by 45 feet and contains 4 single-pitman gang saws with concrete foundations and hoppers and with the ordinary equipment of distributors, sand pumps, etc. This building has an annex, 45 feet by 36 feet, which contains a fairly complete machine shop, and an engine connected to a dynamo which supplies power for the whole plant. The boiler is in a small separate annex.

The finishing mill is 45 feet by 75 feet, with an annex for offices; it contains:—

1 Patch planer.
1 diamond saw.

1 rubbing bed.
1 derrick.
1 Patch polisher.
1 crane.

This machinery is operated from a line shaft which is actuated by motor.

The yard between the two mills is provided with tracks and transfer cars permitting the gang cars to be placed in any desired position in either mill. The buildings are all of substantial structure and the equipment, including a complete electric lighting plant, is modern and in excellent repair (Plate XXX).

The following prices are quoted, all f.o.b. Marblehead.

Rough squared blocks, per cubic foot..................$1.00 to $2.00.

Bases, polished face and top edge, per lineal ft.

6 inch	·50
8 inch	·60
10 inch	·75
12 inch	·90

Treads and platforms, fine sand-rubbed, front edges rounded, boxed, per square foot.

	Light Kootenay	Dark Kootenay
$1\frac{1}{8}$ or $1\frac{1}{2}$ in. thick	$0.85	$0.70
$1\frac{1}{2}$ in. thick	.95	.85
2 in. thick	1.20	1.00

Floor tiling, 8 in. by 8 in. to 2 ft. by 1 ft., per sq. ft.........$0.50 to $0.60

The plant is said to have a capacity of 25 tons of finished marble per day, but, owing to the depression caused by the war, it was idle at the time of my visit in July, 1916. The following figures, taken from the Report of the Minister of Mines of British Columbia, indicate the value of the production for certain years estimated in the form of slabs.

1908—$50,000.

1909—$30,000.

Kootenay marble has been used in the construction of the following buildings:—

Bank of Commerce, Nelson (Plate XXXIV).

Entrance to theatre, McKennan building, Strathcona, Alberta (Dark Kootenay).

Maglio block, Nelson.

Great West Life Assurance Company's building, Winnipeg (Plate XXXIII).

School, Kaslo, B.C.

Court house, Revelstoke, B.C.

PLATE XXXIII.

Kootenay marble. Building of Great West Life Assurance Co., Winnipeg, Manitoba.

PLATE XXXIV

Kootenay marble. Bank of Commerce, Nelson, B.C.

W. G. Gillette, Fort George, B.C.

Mr. Gillette holds 141 acres (Lot 2278) under lease, but subject to purchase, on the east side of Kootenay lake opposite Kaslo.

The prevailing schists and gneisses (1534) of the district form a prominent cliff with about 50 feet of vertical exposure facing the lake. Immediately to the north of this cliff a band of marble underlies the gneiss, and a short distance farther north micaceous gneisses are again seen underlying the marble. The exact thickness of the marble belt was not determined but it is of sufficient extent to answer all practical requirements. The strike of the formation is N. 40° W. and the dip is about 35° southwest or towards the lake.

The quarry is about 60 feet long and 45 feet wide with a maximum face of 25 feet; it is opened between two prominent joints striking N. 35° E. with almost vertical dip. Other joints of this system with a varying dip to the northwest are seen on the face; in the upper stone they are pronounced, but in the lower levels they are less frequent. Other joints occur approximately parallel to the lake shore, but they are very irregular and incapable of being ascribed to a distinct system. In addition, much of the heavier stone is cut by fine diagonal dries. The bedding is heavy with no tendency to split on the planes of stratification. In fact, artificial floors have to be made in the process of quarrying. The jointing is a more serious objection, for while some large stone can be obtained there is considerable waste from this cause.

The stone is essentially a white to blue-banded crystalline limestone of coarse grain. The dark bands are more pronounced in some places than in others, but large blocks of white stone without some blue banding are scarcely to be obtained. Much of the stone is charged with tremolite in large crystals and of so white a colour that it can scarcely be observed on freshly fractured surfaces: the tendency of this mineral to turn yellow, and later brown, is to be observed on all blocks which have weathered for a considerable time, but a limited exposure does not seem to have a serious effect on the colour.

The stone: No. 1532.—This example represents the lighter type of marble from this locality; it is a coarse white crystalline limestone with individual crystals up to 15 mm. in diameter. Owing to the very white colour of the included tremolite its presence would not be suspected on a freshly fractured surface, but a detailed examination reveals crystals of this mineral throughout the specimen.

The wet crushing strength is anomalous, but in view of the slight porosity it is within the range of instrumental error. One may conclude that the rock is slightly weakened by wetting and is not seriously affected by freezing. This property is commonly observed in very coarse-grained crystalline limestone, *e.g.*, the stone from Haleys in Ontario described on page 313 of the first volume of this report. The low transverse strength as compared with the shearing strength is due to the coarse grain. Had the experiment been made on a larger specimen the result would have been higher. The corrosion test produces a whitening and etching of the surface and distinctly reveals large crystals of tremolite which assume a yellowish tint. The pure white colour of this mineral on natural fractures makes its detection almost impossible either with the naked eye or the hand lens.

The physical properties follow:—

Specific gravity	2·752
Weight per cubic foot, lbs	171·36
Pore space, per cent	·313
Ratio of absorption, per cent, one hour	·072
" " " two hours	·079
" " " slow immersion	·099
" " " in vacuo	·101
" " " under pressure	·114
Coefficient of saturation, one hour	·63
" " " two hours	·69
" " " slow immersion	·87
" " " in vacuo	·88
Crushing strength, lbs. per sq. in., dry	13,987·
" " " " wet	10,158·
" " " " wet after freezing	11,560·
Transverse strength, lbs. per sq. in	1,254·
Shearing strength, lbs. per sq. in	1,688·
Loss on corrosion, grams per sq. in	·103
Drilling factor, mm	15·4
Chiselling factor, grams (I)	·4
" " " (II)	6·3

An analysis by Leverin shows this stone to contain considerably more carbonate of magnesia and foreign insoluble matter than the white stone from Marblehead. The sulphur content, while slightly greater than in the white Marblehead stone, is less than in the grey stone from that locality. The analysis follows:—

	per cent
Insoluble matter	2·16
Soluble silica	·28
Lime[1]	52·10
Magnesia[2]	2·08
Ferrous oxide	·11
Ferric oxide	trace
Alumina	·03

	per cent.
Sulphur	·018
[1]Equivalent to calcium carbonate	93·04
[2]Equivalent to magnesium carbonate	4·37

No. 1533.—This is a medium-grained, blue-banded, crystalline limestone very similar in general appearance to No. 1531 from Marblehead. The difference in grain between this stone and No. 1532 is remarkable, but I am not prepared to say that this difference holds throughout the quarry. As commonly occurs with marbles of low porosity the comparative figures for dry, wet, and frozen crushing strength are unsatisfactory. There is a decided anomaly in this instance of which I have no explanation. One must conclude that the stone is not greatly affected by wetting and freezing.

Corrosion results in strong etching and whitening of the surface, the production of greater contrast between the component crystals, and the revealing of crystals of tremolite.

The physical properties follow:—

Specific gravity	2·759
Weight per cubic foot, lbs	171·81
Pore space, per cent	·304
Ratio of absorption, per cent, one hour	·063
„ „ „ two hours	·076
„ „ „ slow immersion	·084
„ „ „ in vacuo	·095
„ „ „ under pressure	·110
Coefficient of saturation, one hour	·57
„ „ „ two hours	·69
„ „ „ slow immersion	·76
„ „ „ in vacuo	·86
Crushing strength, lbs. per sq. in., dry	13,267·
„ „ „ „ wet	16,530·
„ „ „ „ wet after freezing	13,250·
Transverse strength, lbs. per sq. in	1,581·
Shearing strength, lbs. per sq. in	1,097·
Loss on corrosion, grams per sq. in	·0934
Drilling factor, mm	27·4
Chiselling factor, grams (I)	·4
„ „ „ (II)	7·6

No. 1534.—A greenish, rusty-weathering, strongly laminated gneiss, characterized by the presence of much brown mica and scattered pyrites.

A dismantled derrick is on the property and a small building with a boiler, a steam hoist, and a small compressor by the Chicago Pneumatic Tool Company.

Stone from this quarry is of too coarse grain and too filled with tremolite to be adapted to slabbing and polishing or to fine carved work; it is essentially a building marble suited to rock-face work. The chief output was used for the post-office and for the court house in Nelson; it may also be seen in the Provincial Government buildings in Kaslo and Grand Forks and in the Arena rink in Vancouver (Plate XXXV).

Frederick Archer and E. Timms, Kaslo, B.C.

This firm holds a marble property on the south fork of Kaslo creek, about 5 miles from Kaslo, and a short distance from the line of the Kaslo-Nakusp branch of the Canadian Pacific railway.

Marble is exposed near the level of the creek and on the mountain-side at an elevation of about 500 feet above the stream. The lower outcrop offers little opportunity to form conclusions as to the nature of the formation as it is imperfectly exposed for a short distance only. The creek and the face of the exposure bear about E. 5° N. Down stream the stone is a fine blue limestone imperfectly marmorized, and excessively shattered by sharp diagonal dries. The beds seem to strike E. 20° S. and to dip 40° to the northeast. 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 surface is hidden for the most part by a deposit of secondary calcite which has filled the fractures and rendered difficult any conclusions as to solidity (1537).

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 mountain-side. Actual bedding is difficult to determine in a cursory examination as it is masked by the development of a well-defined and close-set jointing. These joints are nearly vertical at S. 30° W., and seem to be due to stresses which have affected the whole mass of the rock. If this conclusion is correct it is hopeless to look for greater solidity at depth. Another set of partings which may possibly represent the original bedding occurs at E. 10° S. with a dip of 35° to the northeast. The western part of the outcrop, for more than half the distance of its total length, is of fine-grained, white stone (1538). The central part presents a mottled type (1539), which gradually passes into the blue variety at the east end (1540).

The grain and colour of the samples obtained from these outcrops indicate that the material is a highly desirable marble for purposes of fine decoration. On the other hand, there is no present evidence that mill blocks could be quarried. The condition of the surface cannot be described otherwise than as unsatisfactory, and while further development might

PLATE XXXV.

Kaslo marble. Court house, Nelson, B.C. (The monument to the left is of Nelson granite from Three-mile point, Kootenay lake.)

reveal a solid formation at depth, the character of the jointing, in my opinion, does not justify high hopes in this respect.

The stone: No. 1536.—This rock is a hard, bluish, mottled limestone of exceedingly fine grain. Although of crystalline structure, the grain is so fine that the stone looks non-crystalline to the naked eye. The specimen is seriously cut by incipient diagonal fractures.

No. 1537.—A light bluish-white crystalline limestone of exceedingly fine grain. The crystalline structure is more apparent than in No. 1536.

No. 1538.—This is a white crystalline limestone of fine and even grain; it is slightly coarser than Nos. 1536 and 1537, and is more distinctly a marble in the commercial sense. The colour is not pure white; polished faces would probably show faint mottling in bluish and yellowish tones. In itself, the material is doubtless of decorative value.

No. 1539.—A very fine-grained, white crystalline limestone, blotched and banded with blue. Polished surfaces are of handsome appearance. Intrinsically the stone is a commercial marble on account of its fine grain and delicate colouration.

No. 1540.—A strongly laminated type of the fine-grained blue and white varieties.

A. T. Garland, Kalso, B.C.

A marble band, interbedded with the prevailing schists, crops out on the shore of Kootenay lake about a mile south of Kaslo. The formation is essentially the same as at the quarry on the east shore, but the stone is somewhat finer in grain (1535). A small amount of stone was quarried here for flux and a few blocks were shipped for monumental purposes.

The stone: No. 1535.—This rock is a bluish-white, laminated, crystalline limestone of medium grain. The laminae are marked by numerous flakes of glistening white mica and minute grains of graphite. The location was not visited but the present sample offers little encouragement as an ornamental stone.

Arrow Lakes Area.

Mrs. Lila Howieson, Arrowhead, B.C.

This property of 80 acres is legal subdivision 15, section 28, township 20, range 29, west of the fifth meridian. It is situated east of the line of the Canadian Pacific railway from Revelstoke to Arrowhead, at a point about 4 miles north of Arrowhead.

The formation strikes N. 10° W. and dips 35° to the eastward and is so disposed with respect to the configuration of the country that it is accessible up a gradual incline to a height of 300 feet. The actual thickness is not determinable without an accurate instrumental examination, but it is not less than 50 feet. The natural face presents a cliff of 50 feet in height striking S. 30° E. which, therefore, gives a section almost parallel to the strike of the formation. The major joints are strong at N. 40° E. with a dip of 80° to the northwest. A second set of joints strikes W. 30° N. with a dip of 80° to the northeast. Both sets are closely spaced in places, but in others they are sufficiently separated to permit the extraction of fair-sized stone. The outcrop is not sufficiently exposed to justify any general conclusions as to its ability of yielding quarry blocks.

The stone is fine-grained, white, crystalline limestone resembling the marble from Kaslo creek described on page 139. Blue banding parallel to the stratification of the formation is developed irregularly resulting in various types of marble ranging from almost pure white to distinctly banded examples. Several samples are described below as No. 1540a.

Mrs. Howieson also holds a lease on a marble property of 147·2 acres situated on the west side of Okanagan lake, 22 miles from Arrowhead and 2 miles below Pingston creek (Legal subdivision 11329).

The belt runs a little north of west and shows a marble resembling No. 1540a but of slightly coarser grain. Certain parts of the formation show a clouding and banding in pink. I was unable to examine this outcrop personally.

The stone: No. 1540a.—The white type is a crystalline limestone of medium grain and slightly clouded appearance owing to varying translucency and tinges of colour. A considerable amount of pyrite occurs on the planes of parting but little was observed in the interior of the stone. Other examples show varying grain, and the ordinary blue cloudiness and interbanding. Another type presents an exceedingly fine grain and an alabaster-like appearance of considerable beauty; this would be a very desirable marble could it be procured in quantity.

Grand Forks Area.

Grand Forks, B.C.

An extensive band of crystalline limestone is exposed in the side of the mountain on the left bank of the Kettle river, about two and a half miles below Grand Forks. The limestone is overlaid by a great series of schistose rocks and appears only where a pronounced anticline has brought up the lower strata. This anticline is fractured and cut through by a lateral ravine on both sides of which the limestone is visible. The quarry is near the junction of this ravine with the valley of Kettle river on the side farthest from Grand Forks.

The bedding is rather obscure but it seems to strike E. 20° S. with a dip of 75° to the southward at the quarry, while on the other side of the ravine the dip is to the north. Vertical jointing, parallel to the face of the mountain, is pronounced, and a less defined set of partings crosses the formation in an opposite direction. The limestone probably rises to a height of several hundred feet and is accessible for a long way along the mountain-side which is rough and cut by numerous dikes.

The quarry is very small and has been made by prying off blocks between the joints. Immense quantities of stone are easily obtainable, but there is no present evidence of the suitability of the location for the quarrying of mill blocks on a commercial scale.

The stone is all very coarse in grain and is marked throughout by brownish or greenish spots; it is fairly resistant to weathering as the broken pieces in the quarry attest, but long continued exposure results in the development of a pulverulent condition on the surface (1503).

The product makes a very good building stone for rock-face work and may be seen in a house near the quarry and in the fence surrounding the court house in Grand Forks. These structures show little evidence of weathering and no development of iron-staining. The stone is too coarse in grain to be used for chiselled work or for purposes of decoration.

The stone: No. 1503.—This stone is a very coarse-grained, white crystalline limestone with scattered yellow spots due to the presence of foreign mineral matter. On weathered surfaces and on planes of parting in the stone, this yellow material is more pronounced.

Marbles of the Beltian Series.

This great series of rocks, the extent of which has already been briefly stated on page 22, contains numerous bands of crystalline limestone, particularly in the upper part. The economic possibilities of these bands as producers of marble are practically unknown.

Marbles of the Cambrian System.

The limestone members of the Cambrian strata of the Rocky mountains are frequently marmorized over wide extents of country: nevertheless, but little attention has been directed to them as sources of supply. The reason probably lies in the inaccessibility of many of the known exposures and the general fracturing to which the rocks have been subjected during the progress of mountain-making.

The marbles of this age which require mention in a work of this sort may be conveniently considered under the following areas:—

White Man's and Vermilion Pass area.

Yoho River area.

Grant Brook area.

White Man's and Vermilion Pass Area.

This area lies south of the main line of the Canadian Pacific railway in the eastern ranges of the Rocky mountains. At present the region is inaccessible but the construction of the proposed highway through the Vermilion pass will greatly increase the facilities of transportation.

White marble occurs in great masses in the Vermilion pass but it is much shattered and seems to contain an undue amount of pyrite. The locality was not visited but a somewhat fuller description is given in the fourth volume of this report.

Dr. Dawson thus refers to the marble of White Man's pass:—

"From the immediate vicinity of the summit of the pass, westward to the mouth of the North Fork, the limestones, both in the bottom of the valley and as far as could be observed, to the tops of the adjacent mountains, have been changed to marble, which is in some cases very coarsely crystalline. In colour, the marble generally varies from white to yellowish shades, but blotched grey and white, and brown and white varieties were also observed. More or less pyrite and grains of magnetite are generally disseminated through the rock. The marble is of no economic importance owing to the inaccessible character of that part of the region."[1]

Yoho River Area.

"Claims have been staked for marble in the Yoho valley in 1911. A cross-section of this band of marble is exposed at the switch-back on the Yoho road, 2 miles from the mouth of this river. At this point the band is between 350-400 feet thick. The rock is a dolomitic marble and varies largely in both colour and texture. In colour it is grey, mottled grey with white spots, or vice versa, light grey, white with greyish bands a fraction of an inch in width, and pure white. The last two varieties occur toward the top of the band and are of most economic importance. The rock takes a smooth polish. The grained material can be readily carved and will take a sharp edge. The band of marble extends along the west slope of Mt. Ogden so that the quantity of material is large.

"The exposed surface of the marble is badly fractured so that it would be hard to get large blocks, but this fractured zone may not be very deep. The presence of small cavities in certain layers is also detrimental to the value of the marble. Pyrite is only sparingly scattered through certain layers which might be avoided in quarrying.

"During the summer of 1913 diamond drilling was being carried on to find out the extent and quality of the marble.

"The beds are lying almost horizontal with a maximum dip of 12 degrees. The railway is less than 2 miles distant at the mouth of the valley and is on the same elevation."[2]

Claims have been staked as follows:—

Robert Kidney, Field, B.C. Part of section 3, township 29, range 18, west of the fifth meridian.

[1] Geol. Sur. Can., Ann. Rep., Vol. I, pp. 116B and 169B, 1886.

[2] Geol. Sur. Can., Memoir No. 55, Pub. 1370 pp. 236-237, 1914.

R. J. Gordon.—Part of the southwest quarter of section 2, and of the southeast quarter of section 3, township 29, range 18 west of the fifth meridian.

J. C. Kirkpatrick.—Part of the southeast quarter of section 3, township 29, range 18 west of the fifth meridian. Part of the northeast quarter of section 34, township 28, range 18 west of the fifth meridian.

Grant Brook Area.

Grant Brook Marble Co., Grant Brook, B.C.; F. H. Beniker, Edmonton, Alta.

One and a half miles east of Grant Brook, near the British Columbia-Alberta boundary, extensive outcrops of marble are known in the mountain-side to the north of the line of the Grand Trunk Pacific railway.

Quarrying which never passed the experimental stage was attempted here some years ago by this company. Considerable sums were spent in development and in the construction of an inclined tramway from the railway to the outcrops of marble at a height of several hundred feet. This tramway and such machinery as had been installed is now in a state of disrepair.

The general strike of the formation is a little south of east. The lowest rocks observed above the heavy talus are thin-bedded dark crystalline limestones (1246) dipping 30° to the northward where first seen but assuming a much steeper dip at higher and consequently more northern outcrops. These rocks are succeeded by banded whitish marbles in beds of gradually increasing thickness; at a height of six feet some of these beds are fully a foot thick (1247). A talus-covered interval of about 20 feet follows to the foot of the almost perpendicular ledges of heavy-bedded marbles which strike east and west and dip almost vertically.

The outer or more southerly ledge varies from 10 to 50 feet in width and rises to a height of nearly 50 feet. The stone of this ledge is fairly massive and generally of a reddish colour (1249). In places it is strongly laminated, in others it is interbanded with white, in others it shows white blotches (1252) or greenish blotches and veinlets (1251). All these varieties are very desirable marbles, but the possibility of obtaining enough of any one type to comply with the demands of a contractor has not been established.

A second ledge rises to the north, and consists chiefly of white marble which continues down to the talus-covered slope at the west of the exposure where the red ledge has been eroded (1250).

A third ledge to the northward rises still higher and consists of a generally white marble but with reddish bands in places.

The bedding throughout the exposure is heavy; in places there is no sign of divisional planes across the whole 50 feet of width of the outer ledge. In consequence of the vertical dip of the formation the bedding planes are co-incident with the perpendicular faces of the ledges.

Jointing is pronounced and variable. The main series strikes a little west of north and dips at greatly varying angles to the westward. A second series with the same strike, dips in the opposite direction and cuts the first series approximately at right angles. Minor diagonal jointing is also present in varying intensity. The major jointing would undoubtedly permit the winning of large blocks, but there would be a large amount of waste. The minor fracturing is likely to prove a very serious objection, especially in attempts to saw the stone into slabs. It is impossible in the present state of the quarry to determine to what extent this finer fracturing is due to surface agencies.

The stone: No. 1247.—A fine-grained, very hard and compact crystalline dolomite of general white colour but slightly banded with blue.

No. 1248.—A dark blue, strongly laminated, hard crystalline dolomite of very fine grain.

No. 1249.—This marble is fine in grain, rather hard, rose-coloured, somewhat variable in tint, and with a mottled aspect (Plate XXXVI). It is a very strong stone of low porosity and should prove of good weathering properties, but it would be hard to work. The dolomitic character of the stone is shown by its high specific gravity and weight per cubic foot and by the slight loss under the corrosion test relative to the marbles from other localities. This test produces but slight etching and scarcely any change in colour.

The physical properties were not determined in full but the chief constants are listed below:—

Specific gravity	2·855
Weight per cubic foot, lbs	177·32
Pore space, per cent	·57
Ratio of absorption, per cent, one hour	·150
" " " two hours	·153
" " " slow immersion	·157
" " " in vacuo	·185
" " " under pressure	·201
Coefficient of saturation, one hour	·74
" " " two hours	·76
" " " slow immersion	·78
" " " in vacuo	·92
Crushing strength, lbs. per sq. in., dry (a)	25,114.
" " " " " (b)	23,700·
" " " " " (average)	24,407·
Loss on corrosion, grams per sq. in	·00586

The analysis reveals the highly dolomitic character of the stone and its impurity as indicated by the high percentage of insoluble material. The

PLATE XXXVI

Grant Brook pink marble, Grant Brook, B.C.

ferric oxide, while much greater than in any other of the marbles tested, is not very high considering the red colour of the stone. It is probable that the red colour is due to the insoluble portion rather than to the content of iron in the carbonates.

The analysis follows:—

	per cent
Insoluble residue	11·52
Soluble silica	·08
Lime[1]	27·62
Magnesia[2]	18·60
Ferrous oxide	·64
Ferric oxide	·20
Alumina	·14
Sulphur	·013
[1] Equivalent to calcium carbonate	49.32
[2] Equivalent to magnesium carbonate	39·06

No. 1250.—This is essentially a very fine-grained white marble. The colour, however, is seldom pure white, but generally shows a cast of pink or blue, consequently there is nearly always a more or less pronounced mottling in faint tones of colour. In the quarry it is doubtful if a sharp line could be drawn between this variety and the pink type No. 1249.

The block of stone brought as a specimen proved very unsatisfactory as test material as it was found to be full of flaws. The great difference in the two determinations of crushing strength is due to this cause. A more fortunate sample would doubtless have resulted in higher and less divergent figures.

The high specific gravity and the slight loss on corrosion are indicative of the dolomitic nature of the stone. Etching is scarcely apparent under the latter test, and no change in colour is produced beyond a slight accentuation of the delicate mottling. Although the pore space is greater than in the red stone, No. 1249, the coefficients of saturation are lower indicating a stone of better frost-resisting properties.

The physical properties were not determined in full, but the chief constants are listed below:—

Specific gravity	2·868
Weight per cubic foot, lbs	177·79
Pore space, per cent	·699
Ratio of absorption, per cent, one hour	·161
" " " two hours	·161
" " " slow immersion	·172
" " " in vacuo	·231
" " " under pressure	·247

Coefficient of saturation one hour		·65
„ „ „ two hours		·65
„ „ „ slow immersion		·69
„ „ „ in vacuo		·93
Crushing strength, lbs. per sq. in., dry (a)	34,670.	
„ „ „ „ „ (b)	26,811.	
„ „ „ „ „ (average)	30,704.	
Loss on corrosion, grams per sq. in.		.00599

The analysis indicates a stone with a dolomitic base similar to that of the red stone (No. 1249). The greater purity of the present example is shown by the less amount of insoluble material but this is still sufficiently high to remove the stone from the category of pure dolomites; this does not necessarily affect the value as ornamental material. The analysis follows:—

	per cent
Insoluble matter	3·42
Soluble silica	·12
Lime[1]	29·23
Magnesia[2]	20·86
Ferrous oxide	·65
Ferric oxide	·05
Alumina	·15
Sulphur	·013
[1] Equivalent to calcium carbonate	52·20
[2] Equivalent to magnesium carbonate	43·81

No. 1251.—A hard, fine-grained, rose-coloured marble like No. 1249 but interbanded with the whitish variety, blotched with white, and more particularly with pronounced greenish spots due to the presence of soft secondary greenish mica. The material would make a handsome decorative stone but I fear that the great difference in hardness between the pink and green components would result unfortunately on polished surfaces.

No. 1252.—This marble is of a somewhat deeper rose-colour than No. 1249 but it is more variable, showing tinges of different depth of colour in some cases fading into white. It is a handsome stone and would be valuable if procurable in quantity.

Stanley Washburn, Minneapolis, Minn.; F. H. Reading, Edmonton, Alberta.

Claims have been located on ledges of pink marble about 7 miles up Grant brook from the railway. The stone is said to occur in a massive formation and to closely resemble the pink variety described as No. 1249, on page 144.

Wm. Blackwood, Nelson, B.C.

Mr. Blackwood holds the claim adjoining that of the Grant Brook Marble Company. No work has been done on the property.

Marbles of the Carboniferous System.

The Carboniferous strata of the southern mainland to the west of the Columbian mountains occur in rather isolated areas in the prevailing volcanic rocks. Limestones are of common occurrence in these patches of sedimentaries; they are nearly always crystalline, but frequently impure and siliceous.

The limestones of the Cache Creek group have been worked for lime near Yale, Agassiz, and Hope, and many localities of occurrence are reported along the Thompson river, but I have found nothing in the literature to indicate that these stones are at all promising from our point of view.

The Pend d'Oreille group, typically exposed in the southeast part of the Trail Mining Division has numerous bands of crystalline limestone and one of these has been definitely worked for building stone on Sheep creek, a few miles above Salmo.

The Rossland group is largely composed of igneous rocks but some sedimentaries are present among which are bands of crystalline limestone. One of these bands is worked for flux near Fife, but I know of no attempt to use the stone for structural purposes.

Crystalline limestone associated with altered sediments and volcanics are of common occurrence along the coast. Owing to a lack of fossils by which the age of the rocks may be accurately determined, some doubt exists as to the proper place of many of these stones in the geological column. The most important limestone-bearing formation is the Marble Bay which is typically exposed in the northern part of Texada island. This formation has been determined as Jura-Triassic in age by McConnell but other authors regard it as Devono-Carboniferous. In consequence of this doubt the formation will not be considered here. It is probable also that most of the marbles listed as of undetermined age are to be ascribed to Carboniferous or Devono-Carboniferous time.

Sheep Creek Area.

Sheep Creek, B.C.

On the south side of Sheep creek, about 7 miles above Salmo, a small amount of quarrying for marble was done by Wm. McArthur of Portland; the product was used in the post-office at Nelson, but that building is mainly constructed of stone from Kootenay lake opposite Kaslo.

The limestone formation is encountered at the base of the mountain which is cut S. 50° W. by the valley of Sheep creek. The beds strike S. 20° W. and dip 60-70° to the southeast. It is apparent that the ravine crosses the beds at an angle of 30°; in this direction the exposure is about 200 yards across. The limestone formation runs up to a high altitude to the southwest, and the same or a parallel series is seen on the property of the Hudson Bay Mining Co. across Sheep creek to the northeast.

A general examination across the exposure shows that much of the stone is impossible from our point of view, for the limestone is seriously interbanded with quartz, and veinlets of this mineral traverse the more compact limestone bands. In places, however, this objectionable feature is less pronounced, or even absent for short distances across the strike.

Towards the northeast boundary of the marble belt, a small quarry, about 50 feet across, was opened in the most promising quartz-free portion of the marble. The strike here is S. 20° W. and the dip is 65° to the southeast. Irregular joints cross at N. 75° E. and form the face of the quarry which is about 20 feet high. These joints are not very closely set, but they are very curving and would occasion much loss in quarrying. Parting on the bedding planes is not pronounced except locally, but a distinct set of joints striking almost parallel to the first set dips 40° to the northwest. On the whole the formation is rather badly shattered; while fair sized building stone is obtainable, I see no immediate evidence of the possibility of securing gang-saw blocks. On the easterly side of the quarry the rock is dark and less thoroughly crystallized, while on the westerly side it is filled with quartz bands and stringers. The general run of the quarry is a rather coarse-grained, white and grey banded, crystalline limestone: three types may be recognized—light (1516), dark (1517), and intermediate (1518), but it would require careful selection to secure any variety in sufficient size or quantity for a work of any magnitude. The stone is desirable for rock-face building, but I doubt its suitability to slabbing or polishing. The material lying in the quarry shows little sign of deterioration and there is no evidence of iron-staining.

The stone: No. 1516.—This is a medium-grained crystalline limestone of the glistening type. The component crystals average about 3 mm. in diameter and on account of a facile cleavage show glistening facets. The colour is normally white, but some traces of blue cloudiness are apparent.

No. 1517.—This rock is a dark-blue crystalline limestone of rather finer grain than No. 1516: it is distinctly and evenly banded, with very fine white lines indicating the original bedding of the stone. The rock is soft, not prone to excessive weathering, and apparently free from pyrite. It is of the same colour, but slightly coarser in grain than No. 1524 from Marblehead, and differs also in the more pronounced banding.

No. 1518.—This rock is merely an example of many varieties which show interbanding of light and dark components in varying amount. The banding is usually even and parallel and is not to be confused with cloudiness.

Fife Area.

Fife, B.C.

Crystalline limestone has been quarried at this point for use as flux in metallurgical operations. The quarry is quite extensive and the outcrop considerable, but the stone is of poor quality for our purposes, and the excessive shattering of the formation would make the quarrying of building stone practically impossible.

The stone: No. 1513.—A medium-grained crystalline limestone of white colour, but stained in dirty shades and filled with checks and coloured spots: it is of no promise for our purposes.

Marbles of the Triassic System.

Marbles of this age occur in the southern part of Vancouver island and on the islands of the Strait of Georgia. In the absence of the certain evidence afforded by fossils, the age of many of the marble bands is not determinable; in consequence, it is possible that other occurrences should be included here. The more important formations are as follows:—

Nitinat formation of southern Vancouver island.

Anderson Bay formation of southern Texada island.

Open Bay formation of Harbledown island.

Nitinat Formation of Southern Vancouver Island.

The Nitinat formation is extensively developed in southern Vancouver island. where it presents many bands of crystalline limestone particularly on the shore of Nitinat lake.

"The rocks of the Nitinat formation are calcareous or have been derived from calcareous rocks. There are many areas of white, usually coarsely crystalline limestone or marble, but the larger portion of the original limestone appears to have been profoundly altered by invading magmas."[1]

Clapp is not enthusiastic regarding the value of these stones as structural marble, for the excessive fracturing exhibited by most of the exposures leads to the conclusion that only in rare instances could they be of value.

The following analysis of a specimen from Nitinat lake is taken from Clapp's report:—

Calcium carbonate	96·89
Magnesium carbonate	0·42
Ferric oxide and alumina	0·40
Insoluble matter	2·64
Sulphur	0·01
Phosphorus	trace
	100·36

Anderson Bay Formation of Southern Texada Island.

The occurrence of marble in the southern part of Texada island is referred to by Dr. Geo. M. Dawson in the following words:—

[1] Geol. Sur. Can., Memoir 13, p. 44.

"At the base of Mount Dick of the chart, on the east shore, near the southern extreme of the island, is a small broken and shattered anticlinal, including a bed of purplish, pinkish and variegated marble, with a maximum thickness of about 20 feet."[1]

McConnell ascribes these marbles to the Anderson Bay formation which he considers to be of Triassic age, and therefore slightly older geologically than the Marble Bay limestone of the northern part of the island.

"Limestones occur near Henderson bay with altered argillaceous rocks, and on the west coast with dark slaty quartzites. They are coarsely crystalline rocks, greyish or light pinkish in colour, and in most of the sections occur in heavy beds or bands. Thin sections show large individuals of calcite in a fine-grained calcite ground mass. In the pink variety the large individuals are often bordered by films of hematite.

"The Henderson Bay lens has a length of half a mile, a maximum surface width of 300 feet, and a thickness, measured at right angles to the dip, of 180 feet. The west coast lenses are much smaller and have also been partially destroyed by the intrusion of the Texada porphyrites."[2]

The first location was made on the northerly end of the limestone lens by Mr. A. Henderson of Nanaimo: this property (Lot 26, C.G.) was afterwards sold to the Nootka Marble Co. South and west of this claim the Malaspina Marble Quarries Co. hold Lot 339, and still farther south and west, Wm. Astley of Vancouver holds Lot 340 on the south-west shore of the island.

Malaspina Marble Quarries Company, Limited; 914-915 Credit Foncier building, 850 Hastings St. West, Vancouver; Wm. Astley, president; James S. Taylor, secretary; Joseph Astley, manager and vice president.

This company holds Lot 339, Group 1, New Westminster district, on the marble ridge to the west of Anderson bay in the southern part of Texada island. The property is half a mile east and west by a mile north and south. The country rock is the Anderson Bay formation consisting of alternating series of slates, quartzites, conglomerates, marbles, tuffs, agglomerates, and reddish, lead-coloured and green schists. A belt of marble outcrops near the northeast corner of the property and is said to extend to the southwest angle and beyond to the west shore of the island. This continuity of the marble as a single band is scarcely to be accepted as proved. My observations on the strike of the beds at the quarry, and statements made by others who have examined the property, would indicate rather that a series of marble lenses exist of which the actual strike is southeasterly and the general trend of the series to the southwest. Mr. E. A. Haggen, reporting for the company, states:—

[1] Geol. Sur. Can., Ann. Rep. Vol. II, p. 33B, 1887. ("East shore" should probably read "West shore.")
[2] Geol. Sur. Can., Memo. 58, Publication No. 1386, p. 15, 1914.

"The deposit has a strike of N. 30° W. (mag.) and a dip of about 60° W. The deposit is strong and well defined. We traced its outcrop for a distance of half a mile." Professor W. H. Zuber in a report to the company says:—"The ledge dips towards the west, and in places it is covered with soil, vegetation, and boulders, but it can be traced for a distance of some miles on a line paralleling the shore."

The quarry is situated near the northeast corner of the property at a point 350 feet above Anderson bay and 850 feet inland in a straight line. The length of the present opening is about 60 feet along the strike of the beds and its width 35 feet.

The strike of the beds is S. 30° E. and the dip 58° to the southwest. Insufficient stripping has been done to clearly reveal the character of the different beds forming the marble ledge, but the following section is substantially correct; it was measured from northeast to southwest at right angles to the dip, and therefore expresses the true thickness of the beds:—

20 ft.—Light-coloured marble (1472).

21 ft.—Dark red crinoidal marble (1468).

15 ft.—Lighter red marble fading into the above, and somewhat banded with green and white (1469).

50 ft.—Heavily blotched and variable marbles in light and very dark tones (1470).

60 ft.—Banded crinoidal marble resembling No. 1468 (1473).

40 ft.—Reddish and mottled marbles fading to lighter colour towards the southwest margin (1471).

Most of the marble is distinctly laminated parallel to the bedding, but there is no marked tendency to split in this direction: it is not difficult to obtain material of 2 to 3 feet in thickness. Systematic jointing is difficult to discover, but irregular cracking is in evidence. Nevertheless, some large stone is obtainable even from the surface; it is stated that a block $9 \times 4\frac{1}{2} \times 4$ feet was quarried from which slabs were cut measuring 7 ft. 6 in. by 3 ft. 6 in. The absence of formational jointing and the presence of superficial cracking only gives reason to believe that greater solidity would be encountered at depth.

The stone: No. 1472.—This marble is of white colour delicately veined and banded with pink; it is of medium grain, but has occasional larger crystals. It is capable of a good polish and would make an excellent decorative stone for interior work where delicacy of colouring is a chief feature. The trade name for this stone is "Tenas" when cut parallel to the grain and "Tenasti" when cut across the grain.

No. 1468.—This marble (Plate XXXVII) is probably the most uniform and certainly the most developed of the various types shown in the locality. When cut parallel to the grain it is known as "Pil" and when cut across the grain as "Pilti."

The stone is distinctly a crinoidal marble with a red to chocolate-coloured base filled with the white crystalline remains of sea-lilies. The white fragments range from small size up to 10 or more millimetres in extent. Secondary veinlets of white calcite also add to the beauty of the stone.

The porosity of the stone is very low and consequently the freezing experiment results in no visible change. Corrosion produces a pitted effect and causes the development of whitish lines in the red part. When wet the red colour is enhanced and a sharper contrast between the red and white elements is developed.

The stone is rather harder to cut than the average of the crystalline marbles; the irregular grain naturally makes it less suitable for fine carving and accounts for the "jumpy" track obtained under the chiselling test.

The wet crushing test is not recorded in the accompanying table The actual figure obtained was 13,586 lbs. which can scarcely be accepted without verification as the strength after freezing is much greater. The cube probably failed along one of the secondary veinlets giving an abnormally low result.

The physical properties are as follows:—

Specific gravity	2·712
Weight per cubic foot, lbs.	169·00
Pore space, per cent	·177
Ratio of absorption, per cent, one hour	·034
" " " two hours	·036
" " " slow immersion	·052
" " " in vacuo	·051
" " " under pressure	·065
Coefficient of saturation, one hour	·51
" " " two hours	·55
" " " slow immersion	·80
" " " in vacuo	·93
Crushing strength, lbs. per sq. in., dry	18,518·
" " " " wet	
" " " " " after freezing	17,213·
Transverse strength, lbs. per sq. in	2,466·
Shearing strength, lbs. per sq. in	1,182·
Loss on corrosion, grams per sq. in	·1236
Drilling factor mm	16·00
Chiselling factor, grams (I)	·4
" " " (II)	5·6

This rock is essentially calcium carbonate with very little magnesium carbonate, but with a considerable amount of insoluble foreign matter.

Plate XXXVII.

Malaspina "Pilti" marble, Malaspina Marble Quarries Co., Texada island, B.C.

The red colour is not due to the iron contained in the soluble carbonates but to the colour of the insoluble silicates. The analysis by Leverin is given below:—

	per cent
Insoluble matter	4·00
Soluble silica	·26
Lime[1]	52·20
Magnesia[2]	·46
Ferrous oxide	·15
Ferric oxide	·06
Alumina	·08
Sulphur	·011
[1]Equivalent to calcium carbonate	93·21
[2]Equivalent to magnesium carbonate	·97

No. 1469.—This marble is very similar to No. 1468 and gradually fades into that variety. On the whole it is of lighter colour and shows, in places, bands that are nearly white, and in others greenish streaks. The stone is more distinctly banded than No. 1468 and consequently presents greater differences between the slabs cut parallel to the bedding (Tyee) and those cut vertical to it (Tyeeti).

No. 1470.—The stones of this belt differ greatly. Too little work has been done to enable one to properly classify the types. Broadly speaking the fifty feet of width is made up of white, pink, greenish, and very dark chocolate-coloured parts which are not regularly interbedded but occur in boulder-like masses of varying extent. It would probably be difficult to obtain a large amount of any one kind. The variety, more particularly described under this number is the dark chocolate type (Klake and Klaketi) which is a harder stone consisting of a fairly uniform dark reddish base cut by numerous stringers of white calcite. In places it shows bands closely resembling Nos. 1468 and 1469. It probably represents a part of the original strata in which crinoidal fragments were less abundant. The white component of this belt is not so desirable a stone; it is coarse in grain, rather hard, and the colour is not clean.

No. 1473.—This stone is not essentially different from No. 1468; it is perhaps a little lighter and more banded, but some of the samples are indistinguishable from No. 1468.

No. 1471.—This marble is of a general pink colour and banded structure; on the whole, it is darker than No. 1472, but lighter than Nos. 1468 and 1473. Considerable variation is to be observed in different parts of the belt. For the typical pinkish stone the company has adopted the names "Tzum" and "Tzumti" according to the parallel or vertical position of the slab with respect to the bedding.

That beautiful and unique marbles occur on this property and that their extent, if less than has been claimed, is sufficient to satisfy all possible demands is unquestionable. The solidity of the formation beneath the zone of superficial weathering is as yet unproved and the important question of continuous uniformity in the various layers awaits further development.

Anderson bay is a good harbour with deep water near the shore. A small wharf has been constructed here and it is proposed to build an inclined tramway from the quarry to this point. At the time of my visit (June, 1916) there was no equipment at the quarry, but I understand that the company proposes to continue the development on an extensive scale at an early date.

The stone already quarried was obtained by the Continental Marble Co., 588 Rogers block, Vancouver. This company quarried 1265 cubic feet, paying the Malaspina company $1 per cubic foot. The marble has been used for interior finishings in the following buildings:—

Postal station C, corner of Main and 15th streets, Vancouver (Plate XXXVIII).

Post-office, Victoria.

Post-office, Nanaimo.

Merchants Bank, Granville and Pender streets, Vancouver.

Victoria theatre, Victoria.

I understand also that Malaspina marble is specified for the new Canadian Northern and Great Northern railway stations in Vancouver.

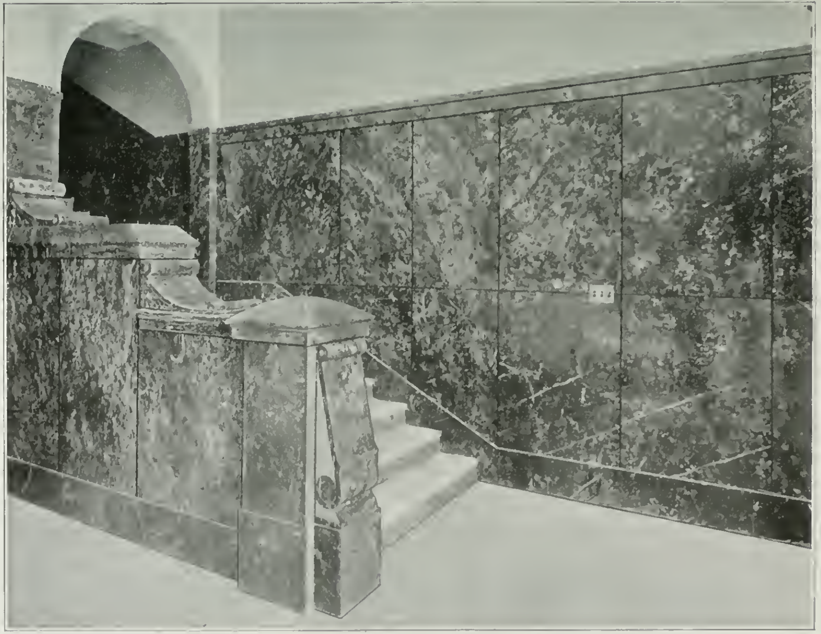
Nootka Quarries Limited; A. W. McCurdy, Victoria, president.

This company holds lot 26 immediately to the north of the Malaspina company's property in southern Texada island. The claim was originally located by Mr. A. Henderson of Nanaimo who erected a wharf and tramway and did a certain amount of development without fortunate results. The failure is said to have been due to improper methods in opening the quarry.

The marble ledge is thought to be the same as that worked by the Malaspina company, but as the intervening country is covered, further work is required before this point can be considered proved.

McConnell described the outcrop in the following terms:—

"The marble at Anderson bay occurs in a lens about half a mile long and 180 feet thick, enclosed in lead-coloured and pink schists belonging to the Anderson Bay formation. The lower part of the lens consists of a nearly massive band 40 feet thick of whitish, coarsely crystalline limestone, irregularly marked in places with yellowish lines. This is overlaid by 33 feet of pinkish marble showing some distinct partings parallel to the dip of the lens. This rock is made up of lens-shaped areas of pink marble, usually from 1 to 3 inches in thickness and 2 to 6 feet in length, separated by narrow bands of the white variety. The smaller pink lenses have wavy



Malaspina marble. Interior work, post-office at corner of Main and 15th streets, Vancouver, B.C.

courses, and are often outlined in the surface by micaceous lines. The upper part of the lens is more shaly, and is too broken up to be of commercial value as a marble.

"The most valuable part of the lens is the central variegated pink and white band. The colouring of this rock is very effective, but is due to reddish hematite scales, and this will probably restrict its use to inside work, as surfaces exposed to the weather soon tarnish.

"The quarry is situated 100 feet above sea-level and about 900 feet from the head of Henderson bay. A tramway was built to the coast and some buildings erected when work was in progress, but these are now in a ruinous condition."[1]

Wm. Astley, 914-915 *Credit Foncier building, Vancouver.*

Mr. Astley holds lot 340 to the southwest of the property of the Malaspina Marble Quarries Company. Reddish marbles occur here on the southeastward extension of the series of lenses already described. No work has been done to ascertain the extent or quality of the deposits.

Open Bay Formation of Harbledown Island.

Harbledown island, Johnstone strait.

The occurrence of marble on Harbledown island has been referred to by many authors but no work has ever been done to test the character of the deposits. The most important band crops out for a distance of 300 yards on the south shore, one-half mile west of the extreme east point of the island.

The exposure shows cliffs of 50 feet covered by soil beneath which the limestone probably runs up to much greater altitudes in a northwesterly direction. An examination of the exposed face shows that the beds are highly inclined with a varying dip and strike. At the east end the beds strike N. 60° E. and dip at 20° to the northwest; at the west end the dip is greater and in a southwest direction. It is apparent therefore that the formation (Open Bay) has been very severely contorted. Systematic jointing can not be made out but severe and irregular fracturing is much in evidence, as well as numerous dikes and blebs of injected igneous rocks.

The storm-worn face of the cliff shows a prevailing, medium-grained, greyish, crystalline limestone of extremely friable nature. Whitish bands occur in places, but the general run of the stone is grey (1559). Somewhat more compact specimens were obtained at the top of the cliff, but nothing sufficiently coherent to suggest the use of the stone for decorative purposes. Judging by a comparison with other marble outcrops, similarly exposed,

[1] Geol. Sur. Can., Mem. 58, Publication No. 1386, pp. 96-97, 1914.

one is forced to the conclusion that this stone is primarily soft and friable. In any event, there is nothing promising in the deposit in its present entirely undeveloped condition.

The stone: No. 1559.—A soft, dark blue, somewhat laminated crystalline limestone of fine to medium grain: it is the most uniform in colour and the darkest in tone of the crystalline limestones examined.

Marbles of the Jurassic System.

Jurassic rocks are exposed in Vancouver island and on many of the islands along the coast. Limestone bands are not uncommon, but in many cases the age of the rocks is in some doubt owing to the absence of characteristic fossils. The following formations and localities are the only ones of certain determination and of economic importance:—

Sutton formation of southern Vancouver island.
Marble Bay formation of northern Texada island.
Redonda Island area.

Sutton Formation of Southern Vancouver Island.

The Sutton formation consists of "lentils of crystalline limestone intercalated with the Vancouver volcanics." These small lenses of limestone occur at many points throughout southern Vancouver island; their distribution is well indicated on Clapp's map, No. 1123 of the Geological Survey of Canada. Some of these bands have been worked for lime-burning, particularly at Rosebank, near Victoria, and on the Alberni canal. In the vicinity of Saanich inlet, the stone has been extensively quarried in connexion with the Portland cement industry. Being of fair appearance in small specimens, the stone has naturally attracted attention as a possible building material and even as an ornamental marble. In consequence it was thought advisable to examine the more important workings with the object of ascertaining whether the formational features there revealed indicate any possibilities from the present point of view. Briefly it may be said that stone in small pieces and more or less suitable for building might be obtained from any of the quarries but that operations for building stone *per se* would not be financially successful, and that marble quarrying is quite impossible. In all cases observed the formation is so excessively shattered and so mixed with volcanics that we are forced to the unsatisfactory conclusion stated above.

The following locations were examined and are herein described as typical of the Sutton crystalline limestone:—

W. J. McTavish, Rosebank (lime).
T. Exton, Rosebank (lime).
Vancouver Portland Cement Company, Brentwood.
Associated Cement Company (Canada), Bamberton

Vancouver Portland Cement Co., R. F. Butchart, president, Board of Trade building, Victoria.

This company obtains the carbonate of lime required for cement-making from a narrow band of crystalline limestone of the Sutton formation which outcrops near Brentwood on Saanich inlet. Several openings have been made and abandoned on the exhaustion of the available stone. The quarry now being worked lies to the east of the track of the British Columbia Electric Railway about a quarter mile south of Brentwood station; it is about 500 feet long and 150 feet wide and presents a face of 30 feet. The surface is very uneven with a consequent variable stripping, in some places as great as 50 feet. This is not a serious inconvenience to the company as much of the overburden is utilized for the clay element in cement-making.

The limestone formation strikes W. 30° N. and dips at varying angles to the southwest. More apparent than the actual bedding of the stone is a major jointing which strikes with the formation and dips at a much higher angle, 70°, in the same direction. Irregular fractures showing evidence of gliding cross in a general direction at right angles to the major jointing. The rock is excessively shattered and cut by numerous dikes (1409, p. 186). The stone on the northeast wall is dolomitic and the same feature is making itself apparent on the southwest side; in consequence it is unlikely that the quarry will be further extended across the strike. The general run of the stone is dark and bluish in colour (1410), but lighter bands occur in places. As stated in general terms on page 156, there is no possibility, even in the deeper parts of the quarry, of obtaining building stone on a commercial scale.

The stone: No. 1410.—This stone is a hard, brittle, and fine-grained limestone of dark grey colour: it has been so excessively shattered and recemented that it is traversed in all directions by a multitude of fine white veinlets of secondary calcite. Although of crystalline structure, the stone is not of marble grade.

The quarry equipment consists of the following appliances:—

1 Marion steam shovel.

3 Ingersol-Rand drills.

1 compressor.

1 Browning orange-peel stripper.

1 aerial line with buckets to convey stone to crusher.

The company was producing 1,000 barrels of cement a day at the time of my visit, June, 1916.

Associated Cement Co. (Canada) Limited; Hon. Colonel Stanley, president, London; Edwin Tomlin, secretary and treasurer, Winch building, Victoria; H. Anderson, works manager, Bamberton, B.C.

The quarry of this company is situated on one of the lens-shaped masses of Sutton crystalline limestone which impinges on the west shore of

Saanich inlet at Bamberton. The excavation has been made at a point 74 feet above high water. The width is about 250 feet and the workings have been carried a like distance into the hill. The face has gradually increased from nothing to 106 feet.

The strike of the formation is irregular but averages about W. 30° N. with an almost vertical dip. The formation is severely shattered and the limestone is irregularly mingled with volcanics. The quarry has been advanced across the strike exposing the following series of rocks:—

80 ft.—Limestone.
15 ft.—Volcanics.
10 ft.—Limestone.
20 ft.—Volcanics.
20 ft.—Limestone.
15 ft.—Volcanics.
8 ft.—Limestone.
— .—Thin sheet of volcanics.
— .—Limestone now being worked. Mr. Anderson states that this extends for 200 feet.

Three types of stone are quarried—average crystalline limestone (1411), dolomitic limestone (1412) which occurs in small amount, and the volcanic rock (1413, p. 186).

The stone: No. 1411.—This rock is indistinguishable, except by local differences in colour, from No. 1410 described on page 157.

No. 1412.—A light, whitish-grey, dolomitic limestone of fine grain: it is hard and splintery and shows a faint mottling and banding in darker tones. The rock is less fractured than No. 1411 and might be used for building purposes could it be procured in pieces of sufficient size. Intrinsically it is a desirable marble, but the formational features of the deposit would not permit the obtaining of quarry blocks.

The equipment at the quarry is as follows:—

1 Bucyrus shovel (electric, $1\frac{1}{4}$ yard bucket).
2 Ingersol-Rand drills, $43\frac{1}{4}$B.
1 compressor by Alley and McLelland, Glasgow.
Cars, track, and electric haulage gear.

The capacity of the plant is 2,000 barrels a day. Sixty men are at present on the pay roll; 12 of these are quarrymen.

W. J. McTavish, 604 Sayward building, Victoria.

A quarry is operated for lime-burning on a belt of crystalline limestone at Rosebank near Victoria: it is about a quarter mile from tide water and is opened in the top of a minor hill to a depth of 50 feet. The excavation is about 400 feet long and 200 feet wide. Other openings have been made farther inland along the strike of the formation, W. 20° N. The limestone beds, with the above strike, dip 70° southwesterly: they are excessively shattered, cut by volcanic dikes, and disturbed by faulting. The general run of the stone is blue (1406) which is more or less banded with white (1407, 1408), and in places is traversed by fine white veinlets. Small blocks of building marble could be procured, but there is no hope for the establishment of a regular building stone quarry.

The stone: No. 1406.—A dark grey, fine-grained crystalline limestone. Shearing forces have induced a pronounced laminated structure giving to the specimen an almost slaty aspect: this unfits the stone for use as marble.

No. 1407.—This specimen shows the dark grey marble, described above, interbanded with a less amount of rather coarser-grained white. The slaty appearance is evident here also.

No. 1408.—Like No. 1407, but lighter in colour and with less contrast between the light and the dark components.

T. Exton; Jones & Rance, agents; Victoria.

A small quarry for lime-burning has been opened at the point where the Rosebank ridge meets the highway from Victoria to Albert head. The stone is essentially the same as Nos. 1406, 1407 and 1408 described above.

Marble Bay Formation of Northern Texada Island.

The Marble Bay formation of the northern part of Texada island is thus described by McConnell:—

"The limestones of the Marble Bay formation are confined to the northern portion of the island. They occur in two large and a multitude of small areas, some only a few feet across separated by igneous rocks. The largest area extends from the north end of the island in a band from 1 mile to 1½ miles in width, southeastward along the coast for a distance of 6½ miles, then bending southward crosses the island to the iron range on the west coast. This area covers approximately 14 square miles.

"A second considerable area occurs close to the west coast in the vicinity of Davis bay. Limestone is exposed here over an area about 4 miles in length following the direction of the island, and 1 mile in width. The country is mostly drift-covered and the exact contact of the limestone with the bordering rocks is rarely seen. The limestone band is enclosed in porphyrite, except at the northern end, where it passed under Cretaceous beds.

"In addition to the two large areas, numerous limestone inclusions mostly too small to map, occur in the porphyrites from Davis bay northward to Crescent bay . . . . .

"The Marble Bay formation as developed on Texada island consists entirely of limestone, mostly calcareous, but with some magnesian bands. Both varieties have been crystallized more or less completely by repeated igneous invasions, and the mineralizing agents which accompanied and succeeded them"[1]

Bancroft, LeRoy, and others consider the Marble Bay formation to be of Devono-Carboniferous age.[2]

Considerable interest in this formation has been shown by marble cutters in Vancouver and Victoria and several attempts have been made to utilize the material for monumental purposes. It may be fairly said that these attempts have not met with any striking measure of success.

The formation has been worked for lime-burning by the Pacific Lime Company on Blubber bay and by the Tacoma Steel Company on Limekiln bay. Actual operations for marble have been attempted on Marble and Sturt bays on the east shore. From all of these localities occasional blocks have been shipped for monumental purposes.

The average stone is a fine-grained, greyish to bluish, semi-crystalline limestone showing considerable variation in colour in different localities (1474). Near the contacts with the numerous dikes this stone is more thoroughly marbleized and is normally white (1475). This type does not seem to occur in quantity but is confined to rather narrow zones near the eruptives. Naturally, transitional stages occur of which the varieties are numerous (1476); also greenish and reddish clouded and banded examples are found, particularly in the vicinity of the copper mines, but these are not proven to occur on a scale to make quarrying possible.

The bedding of the limestone is obscure and the strata are generally disposed in low folds although in places they are almost vertical in position. Thin-bedding is not one of the chief disqualifying features of the stone. Jointing is pronounced throughout the formation and is generally so excessive that the quarrying of large blocks is almost impossible. In this connexion it was noticed also that the stone possesses a strong tendency to diagonal fracture which makes the preparation of even small hand specimens very difficult. The almost universal presence of dikes of eruptive rock seriously cut up the limestone beds and would interfere greatly with attempts at systematic quarrying.

The above rather pessimistic remarks are founded on McConnell's statements, and on my own rather restricted observations: it is not to be concluded that the formation presents no possibilities from our point of view, but that no area which could be regarded favourably as a quarry site has yet been located. Blocks of average size have been quarried for monumental purposes on Marble bay and similar material has been produced incidentally at the quarries on Blubber and Limekiln bays. Monu-

[1] Geol. Sur. Can., Memoir 58, Publication No. 1386, pp. 17-18, 1914.
[2] Geol. Sur. Can., Memoir 23, p. 64, 1913.

ment-makers inform me that the stone is capable of a fair polish but that the gloss is very rapidly dulled on exposure to the weather.

As typical of the formation a short description of the quarry of the Pacific Lime Co. on Blubber bay is given below.

The bedding of the limestone is roughly horizontal and the planes of stratification are very obscure. Dikes of eruptive rocks cut the formation in all directions: of these, two prominent examples, one striking E. 10° S. and the other at right angles, form the southeast angle of the quarry. The jointing is excessive and so irregular as to defy description. The average stone is a rather dark, fine grained, greyish-blue, semi-crystalline limestone. This rock is marmorized and assumes a white colour near the volcanics. Transitional stages occur, as well as bands in which the ordinary rock is filled with stringers of white crystalline calcite. Despite the excessive shattering, fair sized blocks may be obtained in places, but there is no possibility for the systematic quarrying of mill blocks. The dark average stone is hard, breaks with a conchoidal fracture, and is prone to part on incipient diagonal flaws. The central part of the face shows 75 feet of magnesian limestone not differing in appearance from the overlying and underlying greyish-blue stone.

Near Van Anda the same bluish-grey, fine-grained type alternates with the white, more thoroughly crystallized bands. The formation both here and on the road to Blubber bay seems to be excessively shattered, but it must be remembered that only surface material was available for inspection.

On Marble bay the same fine-grained greyish stone prevails and all gradations from this type to the white, more thoroughly crystallized variety were observed (1477).

The stone: No. 1474.—This is a fine-grained, greyish-white crystalline limestone: it varies greatly in different exposures, in some cases being quite grey (blue) and with the crystalline structure so fine that it is not observable with the naked eye. Magnesian and non-magnesian bands occur: they are so similar in appearance that they can scarcely be differentiated without analysis. McConnell gives analyses of the two varieties as follows:—

	Magnesian variety	Ordinary variety
Calcium carbonate	85·00	98·39
Magnesium carbonate	11·32	0·71
Ferric oxide and alumina	2·16	0·30
Insoluble matter	1·26	0·20[1]
	99·74	99·60

[1] Geol. Sur. Can., Memoir 58, p. 98, 1914.

No. 1475.—A very fine-grained, white crystalline limestone faintly clouded with blue. The blue parts are finer in grain and represent the less altered portions of the original limestone (No. 1474) from which this type has been derived. This stone, considered apart from the formational features, is a desirable marble of very fine grain and delicate coloration.

No. 1476.—This stone is merely an example of a number of varieties showing intermediate stages between the nearly pure white stone and the greyish, less altered variety. The specimen shows white bands differing in grain and in the degree to which a semi-translucent property is developed. The white portions are streaked and banded with darker parts which owe their colour, in part at least, to greater transparency and the consequent diminished reflection. This stone is not as delicate a material as No. 1475.

No. 1477.—Several specimens showing transitions from a dark bluish fine-grained, crystalline type to lighter-coloured varieties of coarser grain, streaked, banded, or mottled with blue, and in extreme cases strongly veined with very dark material which usually shows grains of pyrite. Any of these stones are of decorative value could they be procured in blocks of sufficient size and free from the prevailing shattering.

Redonda Island Area.

A band of crystalline limestone on the north shore of West Redonda island near George point has been quarried for use in the pulp mills of Howe sound. The bulk of the stone is a white (1549) or grey (1548) marble which in places is handsomely mottled, and in small pieces would be pronounced a desirable ornamental stone. The formation is so severely shattered that no hope can be entertained of quarrying commercial blocks.

The stone: No. 1548.—A hard, medium-grained, light blue crystalline limestone varying considerably in grain and colour in different parts of the quarry.

No. 1549.—A medium to coarse-grained, rather glassy, crystalline limestone with secondary lamination due to shearing. The mottled varieties referred to above are special phases of this stone in which rather delicate and unique cloudings of blue occur.

Marble bands of this age are of frequent occurrence on the islands and inlets of this vicinity. The outcrops on Bute and Knight inlets have attracted a certain amount of attention and have been examined with negative results by persons interested in the industry. (See G.S.C. Memoir 23).

Marbles of Undetermined Age.

Detailed geological information is not available regarding the precise age of the marbles considered below. It is probable, however, that they belong to Devono-Carboniferous formations. The only location that has received any serious attention is that of the Nootka Quarries, Limited, on

Nootka sound, Vancouver island, but a number of prospects have been located at points along the coast, and a large mass of crystalline limestone occurs north of the line of the Grand Trunk Pacific railway, about 80 miles to the east of Prince Rupert.

These occurrences will be considered under the following areas:—

Nootka Sound area.

Prince Rupert area.

Beaver Cove area.

Shames area.

Nootka Sound Area.

A great belt of limestone more or less altered into marble crops out on the east side of Tahsis canal. Beginning at a point opposite Esperanza narrows it forms the east shore nearly to the head of the canal and rises into mountains of 3000 feet elevation with a general southeasterly trend. The formation also occurs on the west side of the canal at its head and appears to continue far to the north and west. South and east the belt extends across Tlupana arm with a great width and is easily accessible at a number of points.

The general average of the stone as exposed on the east side of Tahsis canal is a bluish limestone with a pronounced tendency to diagonal fracturing (1418). The stone on Tlupana arm is essentially the same (1424), but it is more mingled with harder dolomitic bands (1427) which weather lighter and with a characteristic checked appearance. The limestone (1424a), on the other hand, weathers bluish and seems to be more granular and absorbent. The formation is intersected by numerous dikes of volcanic rock, and near these a more or less complete marmorization has resulted. The possibilities of the belt as a producer of marble are probably great, but they have not yet been established by extensive prospecting. At two points only has any attempt been made to ascertain the character of the marbleized bands. A very small amount of work was done by Gore and McGregor of Victoria on the outcrop west of the head of Tahsis canal; more extensive development was carried on by Nootka Quarries, Limited, on the exposures of Tlupana arm. Just how far the facts established by these operations are to be applied to the whole belt is very questionable as too few of the possible localities have been opened to constitute a reasonable average, and the choice of the site of the Nootka quarry does not seem to have been governed by the ripest experience.

The stone: No. 1418.—This rock is a hard, very dark grey to black limestone, crystalline in structure, but of so fine grain as to appear homogeneous to the naked eye. The formation is so extensively fractured that it is very difficult to obtain a fair-shaped specimen by reason of the diagonal planes of induced cleavage. The rock has been recemented along the fracture planes by white calcite; in consequence it is traversed by fine white veinlets and closely resembles the dark limestone from the cement quarries at the head of Saanich arm (Nos. 1410 and 1411, pp. 157-158).

No. 1424 (a).—This stone is a dark-grey, crystalline limestone of medium to fine grain: it is more distinctly crystalline, coarser, lighter, and much softer than No. 1418. Light bands occur in places but the stone is less seriously checked and is without the diagonal veinlets so characteristic of the less marmorized rock, No. 1418. It is essentially the same as No. 1425 described in detail on page 165.

No. 1427.—A medium to fine-grained, white crystalline dolomitic limestone; in the purer parts it has a slightly bluish tinge. Large white crystals of tremolite are scattered through the matrix. On fresh fracture these are not very apparent but the tendency of this mineral to turn yellow soon manifests itself on exposure. The exposed stone, therefore, is usually rather dirty and blotched with yellow. The diagonal fracturing characteristic of the unaltered limestone is apparent on weathered surfaces, but is somewhat masked in the interior.

Nootka Quarries, Limited; A. W. McCurdy, president, Victoria.

This company holds a considerable block of land on the limestone belt at the point where it crosses Deserted creek on Tlupana arm of Nootka sound. The properties include sections 8 and 17.

The formation is exposed for more than a mile along both shores of Deserted creek and is evidently intercalated between volcanics. The general run of the stone is a granular, absorbent limestone (No. 1424a, above) interbanded with a whiter dolomitic type which weathers less rapidly and stands up in the form of distinct ridges with a peculiar checked surface (No. 1427, above). On the east side of the inlet the ordinary limestone prevails as far north as the site of the more southerly of the company's buildings. From this point to the quarry the common stone is interbanded with the dolomites and more or less marmorized by intersecting dikes.

The original bedding of the formation is more or less obscured by secondary induced lamination parallel to the dikes. Near the building referred to above the strike is N. 50° E., and the dip is 45° northwest. A short distance farther north the strike is distinctly N. 75° E. and the dip 26° southeasterly. Between these two points a pronounced lamination is observed striking N. 40° W. with a steep dip. Parallel to this direction are white dolomitized bands and veinlets. On the west side of the inlet a strike of N. 10° E. and a dip of 70° westwardly were observed. On the whole there is considerable variation in the strike and dip but there is no doubt of a general northeasterly trend of the bedding planes; this is not in accord with the general bearing of the formation as a whole.

Work has been done at several places on the southwest side of the "creek" and a much greater amount on the northeast side, where the quarry proper has been opened. This point is near the northwest corner of section 8, and here the workings lie at an elevation of 10 feet above mean tide and 60 feet in from the shore which has here a general bearing of N. 10° W. The excavation is 50 feet square, N. and S. and E. and W. mag. As the opening has been made in a sloping hillside the eastern wall rises 20 feet above the top of the west wall; below this level is a channelled quarry, 5 feet deep, 48 feet E. and W. and 33 feet N. and S. Within this opening is a deeper channelled section, 5 feet deep, 25 ft. 6 in. N. and S. and 32 ft. 6 in. E. and W. The floor of this section has been cut by channeller into strips 5 feet wide which extend in an east and west direction. Two of these strips have been removed to a depth of 5 feet. Exclusive of the upper wall on the east side, the actual quarry is therefore of a maximum depth of 15 feet. The lower part of the excavation is full of water which rises and falls with the tides, indicating a free underground communication. The hill to the east rises gradually at first and then more abruptly to a height of about 800 feet within the distance of a quarter mile. The neighbouring mountains attain an average elevation of 2,500 to 3,000 feet.

The actual bedding of the limestone in the quarry is difficult to determine as it is masked by an induced lamination parallel to intersecting dikes: it probably is about N. 75° E. with a low dip, 15° to 20°, to the southeast. The upper part of the south face seems to represent a curved and irregular joint plane on which a faint indication of dome-like bedding is to be observed.

The rock at the quarry and in the immediate vicinity is much cut by dikes, and to this cause is no doubt due the more perfect marmorization of the stone. A two-foot dike of dark-coloured stone (1423, p. 186) enters the quarry at its southwest angle: this does not extend directly downwards but bifurcates—one branch passing across the quarry and intersecting the east wall at about its central point. The other branch follows the south wall and breaks up into thin, dome-shaped masses. The two branches are connected at the level of the upper floor of the quarry by a horizontal sill. Below this level this system of dikes probably fails. At the north side of the quarry a 4-foot dike strikes E. and W. across the excavation and a parallel, but much smaller dike occurs within the quarry, 5 feet to the south. Outside the quarry proper and 12 feet farther north is still another dike which is connected by arching sills with that previously described.

This system of dikes is described in some detail because it indicates that the molten rock was not injected into well defined fissures in the limestone, but that it found its way along joints and bedding planes filling the whole mass of limestone with a reticulation of dikes and sills. The conclusion is obvious that in actual quarrying the dikes observed on the surface give no indication of the conditions at depth and consequently a very uncertain factor is present which must be reckoned with in any attempt at quarrying. The quarry shows evidence also of breaks and movements in the stone subsequent to the introduction of the volcanics.

The general base of the limestone is a medium-grained, greyish, crystalline type (1425): this is blotched and laminated with white (1424) with a pronounced parallelism to the various sills and dikes of the volcanic intrusion. Naturally, many types occur intermediate between the two extremes and show varying degrees of interbanding of grey and white (1426).

Despite the numerous dikes and flaws the Company has succeeded in quarrying a considerable number of satisfactory blocks; those now on the property show the characteristic grey and white lamination in all directions. There is no indication of iron-staining on the exposed surfaces but many of the blocks show flaws which would prevent successful slabbing. Nevertheless, slabs 5 feet by 5 or even 6 feet have been successfully sawn, probably from blocks obtained at the bottom of the quarry. A four-inch drill core has proved the continuity of similar stone to a considerable depth: pieces of the core up to 5 feet in length were observed.

On the opposite shore of Deserted creek at a point distant about three-fourths of a mile in a direction S. 30° E. from the quarry a small opening has been made in grey and white banded stone, which, although irregularly jointed, seems to be capable of yielding blocks of fair size. Some hard dolomitic bands at this point have a peculiar spotted appearance. The spots are dark when fresh, but on weathering they become white and soft. (1428). A little farther south another small hole has been made in the common bluish stone and just beyond this point the limestone belt is cut off by volcanics.

The stone: No. 1424.—In the hand specimen this rock is a white crystalline limestone with the individual crystals averaging about 3 mm. in diameter. There is a slight tinge of blue and this colour is more pronounced in places, giving the stone a faintly clouded appearance. It so closely resembles the white stone from Marblehead, No. 1530, page 130, that one has difficulty in differentiating them. This stone, however, is more compact and harder as it has a higher crushing strength and a lower factor for both chiselling and drilling. It is stronger and considerably harder than the grey Nootka stone No. 1425.

The corrosion test produces an opaque white and etched effect with an accentuation of the contrast between the constituent crystals. Small grains of tremolite, not before suspected, were revealed by the experiment. As in the case of the white Marblehead stone the coefficient of saturation is unfortunately high.

The physical properties are as follows:—

Specific gravity	2·72
Weight per cubic foot, lbs.	169·27
Pore space, per cent	·312
Ratio of absorption, per cent, one hour	·072
" " " two hours	·074
" " " slow immersion	·105
" " " in vacuo	·114
" " " under pressure	·115(?)
Coefficient of saturation, one hour	·63
" " " two hours	·64
" " " slow immersion	·91
" " " in vacuo	·99
Crushing strength, lbs. per sq. in., dry	16,926·
" " " " wet	16,901·
" " " " " after freezing	15,112·
Transverse strength, lbs. per sq. in	1,589·
Shearing strength, lbs. per sq. in	1,341·
Loss on corrosion, grams per sq. in	·1495
Drilling factor, mm	17·2
Chiselling factor, grams (I)	·2
" " " (II)	3·0

The analysis shows that this stone is scarcely as pure as the very similar white stone from Marblehead: the insoluble matter, magnesia and sulphur are all slightly higher. The analysis by Leverin follows:—

	per cent
Insoluble matter	1·16
Soluble silica	·10
Lime[1]	53·55
Magnesia[2]	1·12
Ferrous oxide	·13
Ferric oxide	trace
Alumina	·04
Sulphur	·015
[1]Equivalent to calcium carbonate	95·62
[2]Equivalent to magnesium carbonate	2·35

No. 1425.—This grey (blue) stone is closely comparable with No. 1424a which has been described on page 164 as typical of the general average of the marbleized portions of the belt.

The stone is weaker, softer, and rather more porous than the white variety No. 1424, and like it, shows distinct etching and a few grains of tremolite under the corrosion test.

The physical properties are as follows:—

Specific gravity	2·72
Weight per cubic foot, lbs	169·10
Pore space, per cent	·411
Ratio of absorption, per cent, one hour	·111
" " " two hours	·137
" " " slow immersion	·138
" " " in vacuo	·142
" " " under pressure	·142
Coefficient of saturation, one hour	·78
" " " two hours	·96
" " " slow immersion	·97
" " " in vacuo	1·00
Crushing strength, lbs. per sq. in., dry	13,305·
" " " " wet	12,142·
" " " " " after freezing	12,022·
Transverse strength, lbs. per sq. in	1,262·
Shearing strength, lbs. per sq. in	1,390·
Loss on corrosion, grams per sq. in	·1408
Drilling factor, mm	22·4
Chiselling factor, grams (I)	·6
" " " (II)	5·3

The analysis shows that this stone, contrary to expectation, is a purer calcium carbonate than the white variety as it contains considerably less magnesia and insoluble matter. This same peculiarity was observed in the case of the white and blue Marblehead stones. It is probable, therefore, that in both cases the blue appearance is due to finely disseminated graphite and not to foreign silicates. The analysis by Leverin is as follows:—

	per cent
Insoluble matter	·20
Soluble silica	·10
Lime[1]	54·80
Magnesia[2]	·44
Ferrous oxide	·06
Ferric oxide	trace
Alumina	·04
Sulphur	·011
[1]Equivalent to calcium carbonate	97·86
[2]Equivalent to magnesium carbonate	·92

No. 1426.—This stone may be regarded as representing the average output of the quarry: it is essentially a white stone like No. 1424, but it

PLATE XXXIX.

Intermediate Nootka marble, Nootka Quarries, Limited.

is banded and clouded with grey and may be regarded as intermediate between the white and grey types, but with a closer resemblance to the white: it is shown in Plate XXXIX. The grain is very similar in all three stones. The present example is somewhat stronger and slightly harder than the white stone, which is rather unexpected in view of the fact that it is a mixture of the white variety with the softer and weaker grey stone. The explanation is found, however, in the fact that this stone is of lower porosity. The coefficients of saturation are much more satisfactory in this case but the corrosion test reveals even more tremolite than was observed in the two other cases.

The physical properties are as follows:—

Specific gravity	2·721
Weight per cubic foot, lbs.	169·39
Pore space, per cent	·277
Ratio of absorption, per cent, one hour	·060
" " " two hours	·066
" " " slow immersion	·073
" " " in vacuo	·079
" " " under pressure	·102
Coefficient of saturation, one hour	·58
" " " two hours	·65
" " " slow immersion	·71
" " " in vacuo	·78
Crushing strength, lbs. per sq. in., dry	18,992·
" " " " wet	18,000·
" " " " " after freezing	17,801·
Transverse strength, lbs. per sq. in.	2,349·
Shearing strength, lbs. per sq. in.	1,114·
Loss on corrosion, grams per sq. in.	·1348
Drilling factor, mm.	18·2
Chiselling factor, grams (I)	·2
" " " (II)	3·6

No. 1428.—This is a white crystalline stone of about the same grain as No. 1424; it is a less pure marble, however, as it is filled with crystals or crystalline aggregates of foreign matter about 5 mm. in maximum diameter. On fresh fracture these spots appear dark on account of their semi-transparent character, but the material is more soluble than the bulk of the stone and weathers out leaving a dead-white fibrous residue which appears in the bottom of pits. In microscopic section the foreign mineral, when fresh, has a fibrous and brown-flecked appearance with parallel extinction; when altered, it presents a wavy, fibrous section with undulatory extinction.

A substantial mill and good quarrying plant were installed by the Company (Plate XL). Most of the equipment is still on the property and may be briefly described as follows:—

Quarrying plant.

1 Sullivan swivel head steam channeller.
1 Patch borer with gasoline motor.
1 Sullivan drill ($2\frac{3}{4}$).
1 Canadian Rand drill.
1 tripod.
1 10-foot quarry bar.
1 12-foot quarry bar.
1 12-ton derrick (wood).
1 6-in. Fairbanks pump.

Mill.

The building is situated immediately north of the quarry and is provided with three tracks running north and south. At the south side is a cross transfer track. Blocks from the quarry may be loaded directly on gang cars which can be sent to any one of the three tracks within the mill. Gang saws are installed over the two outer tracks. Behind (north) of the saws are placed the rubbing bed and polishing machine, and the extreme north end of the building is used for finishing and storage. The essentials of the mill equipment are as follows:—

1 engine, 10 in. by 14 in. cylinder, Houston, Stanwood and Gamble, Cincinnati, Ohio.
1 36-h.p. boiler.
1 10-h.p. boiler.
1 pump.
1 feed-water heater.
2 Patch single-pitman gang saws.
1 12-ft. Patch overhead rubbing bed.
1 Patch polisher.
1 Patch lathe.
1 drill.
1 small crane.
A large amount of minor appliances and supplies.

Besides the mill there are several substantial buildings including a manager's residence (21 ft. by 20 ft.), a boarding house (49 ft. by 22 ft.), office, blacksmith shop, and other small buildings.

The mill contains a considerable amount of semi-finished stock, all of which attests the good quality of the stone, its freedom from iron-staining, and its capability of being successfully sawn, rubbed, turned, and polished.

Plant of Nootka Quarries, Limited, Nootka sound, B.C.

The Nootka quarries were opened in 1908 but have not been worked since July, 1909. The Report of the Minister of Mines of British Columbia for 1910 states that $3,000 worth of marble has been quarried on the property.

Gore and McGregor, Victoria.

Certain rights were acquired and some exploration was carried on by this firm on the marble belt to the westward of the head of the Tahsis arm. On the northeast side of the marble outcrops occurs a heavy mass of volcanic rock near which the prevailing limestone is more or less marmorized. An interesting series of specimens was obtained which illustrate the different stages in the conversion of the limestone into marble. The best stone is hard and of uneven grain (1420); it passes into varieties filled with amphibole (1419). The less altered limestone (1417) retains the diagonal fractures so characteristic of the stone along the east side of the arm.

A bore hole of 75 feet in depth was sunk on the property: the cores show white and bluish marble (1421) and volcanics (1422).

The location is very rough and covered with the heavy vegetation characteristic of the region. The small amount of work done does not justify definite statements: in a general way, however, I was not impressed by the quality of the stone or the formational features revealed.

The stone: No. 1417.—This rock is essentially the same as No. 1424 described on page 166; it differs in the greater retention of the diagonal fracturing of the unaltered limestone. The planes of fracture are marked by dark films and the stone easily breaks along these lines.

No. 1419.—This is a rather rough type of rock consisting of a general grey calcareous matrix with a grain intermediate between Nos. 1410 and 1417. It contains blotches of white calcite and large quantities of whitish, feathery actinolite or tremolite.

No. 1420.—A white crystalline dolomitic limestone of fine to medium grain. It shows a faintly variegated colour in rosy and bluish tints and is transversed by incipient planes of parting which are marked by yellow films. The stone is rather cleaner than No. 1427, but it is essentially the same rock. The economic possibilities as a marble are entirely unproved.

No. 1421.—Dark grey marble banded with white. Resembles No. 1417.

No. 1422.—A dark, greyish-green, fine-grained volcanic rock doubtless referable to the basalts.

Beaver Cove Area.

Sultan creek, Beaver cove, Vancouver Island.

Along the left hand side of this stream there is an extensive exposure of crystalline limestone running up to high cliffs. It may be briefly stated that much stone is available, that large blocks could be procured in places, and that the marble itself is a very desirable variety. On the other hand the formation is severely jointed for the most part and systematic quarrying could be carried on only at the expense of a very large amount of waste.

A quarry was operated on the belt at a point about one and three quarter miles from salt water. The product was floated down the creek at high water and was shipped from a little wharf on the south side of the cove. I am not aware that any was actually used for structural or decorative purposes but an example may be seen in the museum of the Provincial Mineralogist's department in Victoria.

The Report of the Minister of Mines of British Columbia for 1904 states that the bluff of marble is 200 feet high and that it extends up the creek for a half mile. The owner of the property at that time was Eustache Smith of Beaver Cove.

The stone: No. 1560.—This is a fine-grained, glistening, white crystalline limestone with faint cloudiness in light tints; it resembles the best white stone from the Marble Bay formation of northern Texada island (No. 1475, page 162).

No. 1561.—This is a white marble of the same fine grain as No. 1560, but very delicately lined and veined with blue. Both in grain and colour this is one of the most desirable marbles observed.

Prince Rupert Area.

Several of the islands off the mouth of the Skeena river contain bands of crystalline limestone. Claims have been staked in this vicinity and at numerous points along the coast. The chief locations are as follows:—

Khutzeymateen inlet, between Maas bay and Wark channel (1563).

Banks island, east side, lot 2224, J. F. Davies (1567).

Banks island, east side, lot 2225, E. M. Morgan (1564).

Elliott island, J. H. Mairs (1565).

Rivers inlet, near head.

Kum-ea-lon inlet, Grenville channel, Daniel Lyons (1562). (White, black, and variegated; said to occur in large quantities).

Porcher island, northeast coast, lot 534, James McCague.

Gurd island, off the south shore of Porcher island.

Smith island, lagoon on west coast, Wm. G. Radford.

Smith island, lagoon on west coast, John N. Horne.

Princess Royal island, lots 146, 147, Swanson Bay Forests, Woodpulp, and Lumber Mills Co.

Banks island, east side near south, lot 797, Albert Lund and Wm. Beaton.

Banks island, lot 619, George M. Davis.

Granby bay.

South end Digby island.
White Cliff island.

With the exception of the last two, all these locations have been taken up for lime-burning or other chemical purposes: they serve to illustrate the number of limestone bands in this region but they have not been suggested as sources of marble. The numbered stones will be briefly described before Digby and White Cliff islands are considered.

The stone: No. 1563.—This rock is a fine-grained marble of general greyish colour, composed of very evenly arranged narrow bands of white and grey. On an average, five bands of grey and five of white occur in a distance of 10 mm. The white bands are apparently of pure calcite, but the darker bands contain a considerable amount of tremolite in needle-like crystals. This rock would probably not be very durable as to colour, but it could probably be quarried easily in blocks of suitable size for ordinary building.

No. 1567.—A medium to coarse-grained, white crystalline limestone with occasional yellow spots.

No. 1562.—A very coarse-grained, bluish-white crystalline limestone lacking in purity of colour. It is stated that many varieties of variegated marbles occur at this locality.

No. 1564.—This rock is a medium-grained marble showing an intimate clouding of white and dark-coloured components. On polished surfaces the dark part is almost black and is itself of mottled appearance. The material is a handsome marble but nothing has been determined as to the possibility of obtaining quarry blocks on a commercial scale.

No. 1565.—A marble of general white colour but showing variations in grain from medium to very fine, and variations in tint from bluish to yellowish. It would probably polish to a handsome appearance.

South end, Digby island.

The southern extremity of Digby island, immediately opposite Spire island, exposes at low tide a long point bordered to the east by schists and to the west by crystalline limestone to a width of at least 200 yards. The formation is very little disturbed as it has a persistent strike of E. 40° S. and a dip of 35° to the northeast. Vertical joints cross nearly due north and south and therefore at an inconvenient angle to the strike of the formation. In places these joints are close, but in others they are not too nearly spaced to prevent the extraction of fair sized blocks. Irregular surface cracking is not at all conspicuous. The point is practically covered at high water and, therefore, is an impossible quarry site; but, as the formation doubtless extends farther into the island, it is probable that a more favourable location might be found under a moderate amount of stripping.

The rock is fairly solid and is evenly and distinctly banded. The prevailing stone is medium-grained and of a bluish colour with a slight tendency to part on the planes of stratification (1572). This general type is intimately banded with a darker variety which seems to be harder, as it weathers out in ridges on the exposed surfaces (1573). Towards the east of the outcrop, nearer to the schists, the darker type is more abundant (1574). In addition to the general mass made up of these two types, there are, in places, narrow bands of a fine-grained, white variety which, like the grey stone, stand above the average level of the eroded surface.

The stone: No. 1572.—A medium-grained, bluish-white marble of glistening aspect. A lack of purity in the bluish-white colour with a tendency to green and grey detracts somewhat from the value of the stone.

No. 1573.—A medium-grained, blue-grey and white, banded crystalline limestone of pronounced schistose structure and with glistening secondary mica on the planes of schistosity.

No. 1574.—Like No. 1573 but less intimately banded and with more of the dark-coloured component.

No. 1575.—A hard, fine-grained type, rendered very dark by the presence of a considerable amount of foreign matter of almost black colour. It has a strong tendency to weather red.

The persistent strike and dip, the even banding, and the fairly solid condition of the formation indicate that it is capable of yielding stone of fair dimensions. Quarrying on the point is of course impossible and one must look to the probable extension of the bed into the island for a more favourable site. It is to be remembered, however, that Digby island is of very slight altitude.

White Cliff Island, between Chatham Sound and Grenville Channel.

This small island is crossed in a northeasterly direction by a band of crystalline limestone which forms cliffs of 75 feet in height at the south end.

The limestone lies between white-weathering schists and the whole complex is much cut by dikes of igneous rock. The strike and dip are extremely variable and there is evidence of much local folding which, together with the injected dikes, gives the formation a seriously shattered and interrupted appearance. At the south end of the island the beds strike about S. 50° E. nearly vertically, but within a few feet the strike is north and south with a low dip to the west. Closely set, diagonal joints cross the formation in different directions.

The general run of the stone is white to greyish (1579) with a laminated structure due to incorporated bands of the schist. An increase in the amount of schist gives the type represented by No. 1581. In places the marble has a distinctly pinkish cast (1580); this variety is a rather handsome material which would have a distinct value if it could be procured in quantity.

The stone: No. 1579.—A medium to fine-grained marble of light colour indistinctly blotched with greyish and yellowish. It is somewhat schistose in structure with a considerable amount of light amber-coloured mica on the planes of schistosity.

No. 1580.—A fine-grained marble of light rose colour.

No. 1581.—White marble like No. 1579 interbanded with greenish mica schist. It is of no use as an ornamental stone.

The shattered nature of the deposit, the injection with volcanics, and the limited exposure are not encouraging. It is impossible to state that greater solidity would not be encountered at depth, but there is no present evidence of the capability of the formation to yield mill blocks, although the pink stone must be regarded as a desirable material.

It is said that an attempt was made to open a quarry in 1878. John Claverie at one time held a lease on 105 acres for quarrying purposes (Lot 1a, Bk. 1, Range 5).

Shames Area.

Prince Rupert Portland Cement Co., Hugh McLean, Vancouver, president; John Savage, c-o Wm. Savage, 408 Bank of Ottawa building, Vancouver, secretary; Philip Chesley, Box 546, Prince Rupert, local representative.

This company holds 1,480 acres of land on the northwest side of the Skeena river, extending along the line of the Grand Trunk Pacific railway from mile 79 to mile 82¾ east of Prince Rupert. Of this property, 463 acres are purchased lands (Van Hoof, E. Chesley, and Ritchie claims), and 1017 acres are leased lands with option of purchase (P. Chesley, Elson, and Kerr claims).

An extensive belt of crystalline limestone outcrops at intervals along the mountain-side for the full length of the property, a distance of 3½ miles. The belt is encountered one mile from the railway at the west end and 800 feet from the rail at the east end. Mr. W. E. Losee of Victoria, who made an extended examination for the company, states that at the east end the marble is found at an elevation of 100 feet in the dry bed of a creek along which it continues to its termination at an elevation of 950 feet. At the west end, the marble is seen at an elevation of 2,000 feet with a cliff of fully 1,000 feet above. Mr. Losee also states that opposite mile 81 the marble mass is a half mile wide and 1,000 feet high.

There can be no doubt that a very large mass of crystalline limestone is available on the property, but no work has been done, and no prospecting has been carried on, with a view to locating suitable sites for quarrying or of ascertaining the suitability of the stone for our present purposes. A brief examination of the western end of the outcrop shows greyish marbles mottled with white (1587) passing into the white variety (1586) and interbanded in places with green (1585). The beds strike N. 45° E. and dip 70° to the northwest. The stone appears to be rather thin-bedded and shows volcanic blebs and dikes in places. Pronounced and rather closely set joints strike east and west and dip 60° to the south. In other places a set is seen striking W. 35° N. and dipping 83° to the southwest. In the present entirely undeveloped condition of the outcrops it is impossible to determine the possibility of producing mill blocks. One can only say that the formational jointing is severe, that the stone seems to be thin-bedded, and that volcanic dikes interrupt its continuity in places. An examination of separated outcrops at the east end of the property leads to similar conclusions.

The available information leads to the following general conclusions:—A great belt of limestone extends for $3\frac{1}{2}$ miles in a northeast direction; it is about a half mile wide and vertical or highly inclined in position. The stone is greyish towards the southern border but passes into large masses of white varying somewhat in grain. Greenish bands are common and pinkish varieties occur in places. Weathered surfaces show thin bedding but the laminae may be coalesced at greater depth. Volcanic rocks are injected into the marble in places, but areas free from this trouble are easily found. Diagonal and closely set joints were observed at the few places examined. The property must be closely prospected for suitable quarry sites before any further expression of opinion is justified.

The stone: No. 1585.—A medium to fine-grained, greyish, impure crystalline limestone of little promise as a marble.

An analysis of this stone communicated by the company is as follows:—

Silica	9·00
Ferric oxide and alumina	2·00
Calcium carbonate	88·9
Magnesium oxide	·1
Sulphur trioxide	———

No. 1586.—A medium-grained, white crystalline limestone slightly tinged with greenish-grey.

No. 1587.—Similar to No. 1586 but slightly finer in grain and less uniform in colour; it shows yellow stains in places.

No. 1588.—This sample represents the extreme green type of No. 1585. It is fine in grain and of a general light yellow-grey-green colour. The stone is very impure, the colour being due to disseminated silicates in a decomposed condition.

An analysis of the average white stone furnished by the company is as follows:—

Silica	2·00
Ferric oxide and alumina	1·00
Calcium carbonate	97·00
Magnesium oxide	trace
Sulphur trioxide	——

This property is held primarily for the manufacture of Portland cement but no developing has been done. Level land at the foot of the mountain affords excellent sites for buildings and an adequate water power is available in Shames river to which the company has acquired rights. Good shipping facilities are afforded by the Grand Trunk Pacific railway and by the Skeena river.

Summary—Marbles of British Columbia.

Crystalline limestone more or less suitable for marble occurs in many of the rock formations of British Columbia from the Shuswap to Jurassic. The great ranges of the Rockies contain Cambrian marbles in quantity; the Shuswap marbles are quarried on Kootenay lake; Triassic and Jurassic marbles are known in Vancouver island and on the islands of the straits; and Carboniferous marbles have been quarried to a very limited extent at Sheep creek in the Nelson district and elsewhere.

Commercially the known marbles are of three general types as follows:—

White and blue-banded stones.

Reddish crinoidal marbles.

Pink and white, fine-grained dolomitic marbles.

Marbles of the first type are the most common and are remarkably alike irrespective of the formation from which they are obtained. Important quarries are situated on the Lardeau branch of the Canadian Pacific railway north of Kootenay lake, and extensive operations were attempted at Nootka sound on the west coast of Vancouver island. The Kootenay stone is described in detail on pages 130-133, and the Nootka stone on pages 166-169. The former is figured in Plates XXXI and XXXII and the latter in Plate XXXIX. The only commercial production has been from the Kootenay quarries.

The red crinoidal type of marble is found only in the southern part of Texada island: it is a very handsome stone and is shown in Plate XXXVII. Operations have been conducted on a small scale but the Malaspina Marble Company propose to further exploit the deposit.

The pink and white dolomitic marbles occur at Grant Brook on the line of the Grand Trunk Pacific railway. Operations have not passed the development stage. The pink variety is shown in Plate XXXVI.

Literature:—

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CHAPTER VII.

VOLCANIC ROCKS OF THE PROVINCE OF BRITISH COLUMBIA.

Rocks of volcanic origin are of common occurrence along the coast, in Vancouver island, and in the mining region of the southern part of the province. The only stone of this class actually quarried for building purposes is a light greyish andesite from Haddington island. A soft light-coloured volcanic tuff from Dease lake near Kamloops is a possible material, and a hard altered porphyrite from the north shore of Kamloops lake has been staked for the purpose of quarrying stone.

Volcanic rocks have been quarried for rip-rap and for the making of macadam at a number of places; these are incidentally referred to as well as certain volcanics encountered in the marble and lime quarries. The occurrences dealt with are arranged in the following manner:—

Kamloops area.
Burrard Inlet area.
Metchosin volcanics—Albert Head area.
Vancouver volcanics.
Andesite of Haddington island.

Kamloops Area.

D. P. Selby, Kamloops, B.C.

Mr. Selby has leased for quarrying purposes the property lying immediately east of Dease lake, described as the north half of legal subdivision 3 and the south half of legal subdivision 6 in section 21, township 19, range 15 west of the sixth meridian.

The stone is exposed at the extremity of a ridge which strikes about east and west and juts into the lake as a small point on its east side. The ridge continues eastward from the lake for about 200 yards where it is cut off by a cross ravine. The height is about 40 feet and the width 100 yards with a steep slope on the north side and a more gradual fall on the south. The actual exposure is only about 18 feet in height as the lower part of the point is covered with talus (Plate XLI).

The beds strike S. 5° E. and dip 75° to the west, and joints occur at E. 20° S. with a dip of 25° to the south. Neither of these sets of partings is too closely spaced to prevent the extraction of fair-sized stone when the zone of superficial weathering is passed. A third set of partings strikes E. 40° S. vertically, but the dividing planes are irregular and discontinuous. On the whole, the formation is rather too shattered to yield really large stone, but pieces of average size for ordinary building could doubtless be obtained.

The stone is fairly massive and uniform but in places there is a brownish lamination parallel to the bedding, and brownish concretions, sometimes a foot in diameter, occur at intervals. Naturally weathered surfaces are brownish, but the zone of oxidation is only skin deep. A rather thicker altered band occurs on the parting planes. The stone works with remarkable facility under the hammer and possesses a slight tendency to conchoidal fracture.

Most of the stone is of the general type of No. 1495, but some pieces were observed which have a bluish cast and a tendency to turn pink on weathering (1496).

This material has not yet been used for structural purposes, but it would be very interesting to see it tried in order to judge of its general appearance and weathering properties. Buildings would probably present a soft mottled effect in pink after moderate weathering.

The stone: No. 1495.—This is a soft very fine-grained, uniform, light-yellowish stone capable of being sawn with facility and of being chiselled into the most delicate form desired (No. 1, Plate XLVI).

The rock is composed of small angular fragments of volcanic glass ranging up to 5 mm. in diameter, imbedded in a semi-crystalline, very fine-grained, groundmass. Besides the fragments of volcanic glass are crystals of quartz, and other crystals which are probably orthoclase. Darker spots are seen but they are not determinable and probably represent feldspathic matter in a state of decay. The rock is evidently a volcanic tuff.

The behaviour of this stone under the freezing test was very peculiar: it did not disintegrate in the least, but at the twelfth freezing about a third of the cube parted by a clean fracture. Nothing further was observed until the thirty-fourth freezing when the whole cube began to break up into angular fragments without any apparent softening or disintegration of the stone substance.

In view of this result of the freezing test it is peculiar that the crushing strength of the wet sample is practically the same as that of the dry cube. Actually it was a little higher, but the difference is too slight to be significant. Considering its high porosity the stone is not remarkably bibulous. Under the corrosion test the general colour was changed very little, but fine reddish dots were developed throughout. The content of pyrite is very low as an analysis shows only ·004 per cent of sulphur which is equal to that of the stone from Kamloops lake, less than the content of the Haddington Island andesite, and with the exception of the blue granite from Okanagan lake, is the lowest figure obtained for the stones examined.

The physical properties are as follows:—

Specific gravity	2·654
Weight per cubic foot, lbs	135·90
Pore space, per cent	18·02

PLATE XLI

Point of volcanic tuff, east end of Dease lake, near Kamloops, B.C

Ratio of absorption, per cent, one hour	6·19
" " " two hours	6·37
" " " slow immersion	7·42
" " " in vacuo	8·14
" " " under pressure	8·26
Coefficient of saturation, one hour	·75
" " " two hours	·77
" " " slow immersion	·90
" " " in vacuo	·98
Crushing strength, lbs. per sq. in., dry	13,242·
" " " " wet	13,875·
" " " " wet after freezing	000·
Transverse strength, lbs. per sq. in	2,622·
Shearing strength, lbs. per sq. in	2,142·
Loss on corrosion, grams per sq. in	·01247
Drilling factor, mm	46·8
Chiselling factor, grams (I)	5·6
" " " (II)	....[1]

No. 1496.—This stone differs from No. 1495 in showing a slightly bluish cast and a tendency to assume a rosy hue on weathering. Under the microscope the structure is seen to be even finer than in No. 1495. The fragments of volcanic glass are smaller but more numerous; they average about ·2 mm. in diameter. Fine threads of reddish iron oxide are seen in places. The rock is merely a finer-grained phase of No. 1495.

W. H. Johnston; James A. Gill, Kamloops, B.C.

A spur of rock reaches the north shore of Kamloops lake and forms a point about 6 miles from its western end. Messrs. Johnston and Gill have leased the exposure as a quarry site, but no work has yet been done. Mr. Johnston holds legal subdivision 1, section 19, township 21, range 20, west of the 6th meridian, and Mr. Gill's property is the east half of legal subdivision 16 of the adjoining section 18.

The exposed face of the bluff rises about 150 feet above the lake and 100 feet above the line of the Canadian Northern railway along which a rock-cut exposes the stone for 825 feet in a general direction of N. 40° E. The actual trend of the belt of rock is hard to determine, but the neighbouring soft sedimentary and volcanic rocks strike about W. 20° N. with a dip of 45° to the northward. The rock under consideration is evidently of volcanic origin; it is intercalated in the soft country rock and the belt seems to have a strike in a slightly more northerly direction than that given above. The rock-cut shows a distinct, but discontinuous, arched sheeting

[1] The stone is too soft for this test. The slab broke to pieces.

with a steeper dip on the southwest side. About 25 sheets of varying thickness can be discerned. The jointing is excessive and so irregular that systematic description is impossible, particularly in view of the fact that the face is greatly fractured by the use of high explosives. Some fair sized stone could doubtless be obtained, but there is no present evidence of that degree of solidity without which systematic quarrying can not be commercially successful.

The stone is remarkably uniform throughout the exposure and has no discouraging formational features except the excessive fracturing. The weathering properties, however, are not good, as material exposed for 4 years is uniformly brown-spotted, not superficially only but deep into the blocks. Longer weathering results in a general rusty brown colour.

The stone: No. 1494.—This is a very tough, fine-grained, light greenish-grey to pinkish stone of igneous origin. The polished surface shows light green ill-defined spots in a light pinkish base which is fine-dotted with greenish-grey.

A microscopic examination reveals large, semi-decomposed plagioclase crystals, less orthoclase, and a considerable amount of corroded quartz. The ferro-magnesian constituents are of doubtful determination as they are very much altered. Many of the larger crystals are broken and re-cemented by a fine mosaic of quartz and feldspar. The rock is probably to be regarded as an altered porphyrite. The corrosion test produced a decided change: the greenish cast was lost and the surface assumed a minutely red-dotted appearance owing to the oxidation of iron. That this oxidation is not due to the presence of iron in the form of pyrite is shown by the fact that the stone contains only 0·004 per cent of sulphur.

The stone is among the strongest tested; its crushing strength is high and its transverse and shearing strengths are the highest obtained. In preparing the material for testing we found this stone the most difficult to work.

In a commercial sense this stone is more closely related to the granites than to the volcanic rocks; in consequence, it has been included with the granites and related rocks in the Tables of the Appendix.

The physical properties follow:—

Specific gravity	2·684
Weight per cubic foot, lbs	164·94
Pore space, per cent	1·559
Ratio of absorption, per cent, one hour	·240
" " " two hours	·295
" " " slow immersion	·471
" " " in vacuo	·495
" " " under pressure	·589

Coefficient of saturation, one hour		·41
" " " two hours		·50
" " " slow immersion		·80
" " " in vacuo		·84
Crushing strength, lbs. per sq. in. dry (a)	30,238·	
" " " " " (b)	32,255·	
" " " " " (average)	31,246·	
Transverse strength, lbs. per sq. in	3,253·	
Shearing strength, lbs. per sq. in	2,807·	
Loss on corrosion, grams per sq. in		·0028
Drilling factor, mm		4·7

Burrard Inlet Aea.

The proximity of Burrard inlet to Vancouver, its sheltered waters, and its steep shore make it an ideal site for the quarrying of stone. Granite and volcanic rocks are quarried on a large scale for filling and for the making of macadam, etc.

Nickson quarry, North arm, Burrard inlet.

This quarry, now abandoned, is situated on the west side of the arm opposite the power house; it was operated for the production of rough stone for making fills along the line of the Canadian Pacific railway. The excavation is about 100 feet by 50 feet with a face of 75 feet. The rock is a volcanic intrusion in the prevailing granite. The stone varies greatly in grain and colour and the formation is severely shattered. The outer rock is much decomposed and shows ferruginous stains on all joint planes. There is no possibility for the production of building stone.

The stone: No. 1459.—This is a hard, dark, tough volcanic rock. Under the microscope it shows a very fine-grained microlitic groundmass with scattered grains of magnetite, phenocrysts of plagioclase up to 2 mm. in length, and a less amount of faintly pleochroic hornblende in crystals of small size: it is a typical hornblende andesite.

Scott-Goldie Company; A. E. Plummer, 326 Homer St., Vancouver, liquidator.

This quarry was opened on a very small scale at a point on the west side of the north arm of Burrard inlet, a short distance south of the Nickson quarry. A small crusher plant was erected and a small amount of material was shipped. Later, an extensive plant was begun on which I am informed $165,000 was spent. Owing to financial difficulties this plant has not been finished. The stone is a volcanic rock essentially the same as that of the Nickson quarry described above.

Metchosin Volcanics—Albert Head Area.

Sir John Jackson Company, Limited, Victoria.

The Producers Rock and Gravel Company of Victoria hold a block of land at Albert head, measuring 16 chains on the water-front and extending 10 chains inland. From this property a large amount of rough rock has been quarried at different times. Extensive operations are now being carried on by the Sir John Jackson Company for the production of rough rock and crushed stone for the new breakwater at Victoria. A royalty of 3·5 cents per ton is paid to the owners of the property.

The quarry is 900 feet long and about 200 feet wide with an average face of 96 feet in a direction E. 15° S. The formation is so severely shattered that regular systems of jointing are scarcely to be determined; the only joints showing any evidence of regularity strike S. 40° E. almost vertical. Indistinct and variable sheeting is observable with the parting planes conforming roughly to the contour of the hill. The stripping is negligible. Quarrying is effected by the use of dynamite in deep holes.

The stone: All the product of the quarry is rough hard stone, not to be classed as a building stone unless that term be extended to include material used for the roughest structural purposes. The stone varies considerably, but the major output is of the type of No. 1402 described below. A somewhat similar stone but more resistant to breaking is No. 1403. About 10 per cent of the rock quarried conforms to the general type represented by No. 1404, and the vesicular variety, No. 1405, occurs in small amounts only.

The stone: Clapp describes the rocks of the series as follows:—

"The rocks of this series are all basic, principally basalt, but some augite andesites also occur, and there are many intrusive bodies of diabase. Texturally and structurally they vary widely, from coarsely porphyritic and ophitic basalts to amygdaloids, from fine to coarse-grained tuffs, and from injected dykes of diabase to pipes of agglomerate."

No. 1402.—A hard, tough, fine-grained, greenish-black rock, with numerous checks and fine veinlets of quartz. Disseminated grains of pyrite are of common occurrence. The stone is probably a basalt.

No. 1403.—A hard, tough, fine-grained rock of dark purplish colour. Throughout the groundmass are scattered crystals of light-coloured feldspar of about 3 mm. in diameter. Under the microscope it shows a microlitic groundmass with phenocrysts of plagioclase and a few crystals of augite; cavities with secondary quartz are of frequent occurrence—an augite andesite.

No. 1404.—A light, olive-green to grey rock of fine grain and with scattered cavities filled with calcite of secondary origin. It is tough and with a tendency to very irregular fracture, but it is less cut by diagonal flaws than Nos. 1402 and 1403. It is probably a basalt.

No. 1405.—This rock is a vesicular variety of No. 1404. In some places the cavities are so large and numerous that the stone is almost spongy in structure. It is of little value for any purpose.

A complete quarrying and crushing plant has been installed by the Company. An outline of the equipment follows:—

Quarrying plant:—

3 ten-ton derricks with steam hoists.

3 ten-ton travelling cranes by John H. Wilson, Liverpool.

1 five-ton electric loading derrick by Northwestern Iron Works, Seattle, Wash.

1 steam winch for hauling scows.

6 Ingersol-Rand drills.

1 steam shovel (Marion, model 76).

1 engine, 175 h.p., 16 in. × 22 in. cylinder, by Nagle Corliss Engine Works, Erie, Pa.

1 Allis-Chalmers generator (520 amperes, 240 volts).

2 Allis-Chalmers motors, 30 h.p., connected by belt to

2 Ingersol-Rand compressors, 10 in. × 10 in. cylinders, delivering air at 80 lbs. per sq. in.

1 boiler, return tubular, 6 feet by 8 feet, 74 four-inch tubes, by Andrew Gray Marine Iron Works, Victoria.

1 locomotive, Andrew Barclay, Kilmarnock, Scotland. Track, cars and accessories.

Crusher plant:—

The crusher is operated by a 85 h.p. General Electric motor and the elevators by a 35 h.p. Bullock motor.

At the time of my visit 117 men were engaged. Labourers are paid $3 and drill men $3.50 per day of 8 hours. As already stated, the whole of the present output is being used for the breakwater at Victoria.

Vancouver Volcanics.

A group of volcanic rocks, ascribed by Clapp to Lower Mesozoic age, is extensively developed in the southern part of Vancouver island.[1]

The series is of wide extent and consists chiefly of andesites, augite andesites, and dacite tuffs. The rocks are all rough and extensively fractured; in consequence they require little mention here.

[1] Geol. Sur. Can., Memoir 13, p. 51, 1912.

Esquimalt Harbour.

Incidentally a specimen was collected from Esquimalt harbour where easily accessible exposures give the stone a certain value as road material. (1401).

The stone: No. 1401.—A hard, fine-grained, greenish-black rock, filled with checks and flaws and traversed by fine veinlets of quartz. It is probably an andesite or basalt, and resembles No. 1402 from Albert head but is of somewhat coarser grain. It also resembles No. 1413 from the Associated Cement Company's quarry at Bembarton.

Associated Cement Company, Bembarton, B.C.

The quarry of this company shows numerous dikes of volcanic rock as described on page 158. The stone is of no use except for road metal or for mixing with concrete. A large amount already quarried is available (1413).

The stone: No. 1413.—A very fine-grained, greenish-black volcanic rock of the andesitic type. It is full of flaws, checks and veinlets and shows disseminated crystals of pyrite.

Vancouver Portland Cement Company, Brentwood, B.C.

The dikes of volcanic rock in this quarry are referred to on page 157.

The stone: No. 1409.—Essentially the same as No. 1413 described above, but of a lighter and more greyish colour.

Nootka Quarries, Nootka Sound, B.C.

The dikes in this quarry are referred to on page 165.

The stone: No. 1423.—This rock is hard, dark, greenish-grey, and of aphanitic texture. It is cut by diagonal planes of parting some of which are recemented by white films. The condition of the rock indicates much stress subsequent to its consolidation. Under the microscope it shows green hornblende, needle-like plagioclase, and numerous grains of magnetite: it is a hornblende basalt of fine grain.

Andesite of Haddington Island.

W. S. McDonald, office 703 Birks building, plant 1571 Main Street, Vancouver, B.C.

A unique and highly desirable building stone occurs on Haddington island, Broughton strait, off the northeast coast of Vancouver island. The rock has been opened in a large quarry by Mr. McDonald, and the stone has been used with success in some of the finest buildings in British Columbia.

The quarry (200 acres) is situated near the southeast angle of the island where the general trend of the shore is N. 15° E. The length in this

PLATE XLII.

Haddington Island andesite. Quarry of W. S. McDonald, Haddington island, B.C.

direction is 225 feet and the maximum width at right angles to this line is 165 feet. The present face is about 50 feet in height but it would increase with the extension of the quarry. Stone is available in both directions from the site of the quarry and an unlimited quantity must occur inland. (See Rep. Min. Mines, B.C., for 1904, p. 248).

The rock is disposed in highly inclined beds which seem to vary in both strike and dip in different parts of the quarry. At the northerly end the strike is W. 15° N. and the dip 77° to the northward; 10 feet south the strike is W. 20° N.; 10 feet more it is W. 30° N.; at the middle of the quarry it is W. 40° N. with a dip of 50° to the northward; on the south wall of the major opening it is W. 55° N. with a dip of 55° northward; at the extreme south wall the strike swings back to W. 40° N. with a dip of 80° northward. The thickness of these beds varies from a few inches to 10 feet.

Nearly vertical but irregular and widely spaced joints cut the formation at S. 30° W; it will be observed that these cut the bedding planes at a rather bad angle. A pronounced jointing occurs at N. 15° E., *i.e.*, parallel to the face, with a dip of 45° eastward; this set probably belongs to the same series as that first mentioned and indicates a slight variation in strike and a greater variation in dip for the series. Another series of joints crosses at N. 10° E. and dips 45° east; this set is scarcely to be seen in some parts of the quarry. Still another series occurs at W. 30 °S. with a dip of 50° to the southeast. The above rather detailed description of the jointing might lead to the conclusion that the formation is severely shattered, but such is not really the case as the joints are usually fairly widely spaced except in certain narrow headings. The non-rectangular character of the jointing occasions considerable waste and results in blocks of angular form. The best heavy stone—sometimes 20 feet long—comes out in strips with the long axis inclining 40° in a direction E.20°S. (Plate XLII).

The stone is of very uniform grain throughout the quarry, but there is some variation in colour; perfectly fresh stone has a slightly bluish cast (1555), while a yellow tone is presented by blocks which seem to have undergone a slow process of oxidation (1556). Long-weathered stone shows a reddish zonal oxidation to a depth of a foot, and all joint planes are strongly iron-stained. Blocks which have been lying in the quarry for 3 years show scarcely any change, but those which have been subjected to the action of salt water have turned white on the surface. The general effect of exposure for limited periods seems to be, first, the assumption of a lighter colour, and eventually, a darkening due to the imbibition of dirt.

The stone: No. 1414.—This example is taken as typical of the average stone of the quarry; it is intermediate in colour between the bluish type (No. 1555) and the yellow and more oxidized type (No. 1556). The sample was not obtained in the quarry but from the company's yard in Victoria.

The stone consists of a light, yellowish-grey, homogeneous and practically grainless groundmass dotted with darker specks up to 2 mm. in diameter. On fresh fracture these dots are not conspicuous, but they darken on exposure and become more apparent. Microscopic examination shows these dots to be twinned plagioclase feldspar with a zonal structure. They are imbedded in a fine-grained crystalline base in which the individual crystals do not exceed 0·1 mm. in diameter. The rock is andesite, a stone of volcanic origin. A polished surface is shown in Plate XLIII.

This stone dresses easily to fine sharp edges, but its hardness is rather in excess of the average sandstone of the coast. It is said to work better with machines and with pneumatic tools than under the hand chisel.

The freezing experiment produced no visible result beyond a slight darkening of colour which may be due to causes not inherent in the stone. The corrosion test accentuated the slight lamination of the stone and threw the small spots into stronger relief with a distinctly reddish-brown colour.

The following analysis is given in the Report of the Minister of Mines of British Columbia for 1904:—

	per cent.
Silica	70·5
Alumina and ferric oxide	18·7
Lime	2·7
Magnesia	trace
Alkalies	? ?
Loss on ignition	0·8

An examination for sulphur conducted in the laboratory of the Mines Branch showed only 0·006 per cent which is about equal to that of the better grades of Coast Range granite.

The physical properties follow:—

Specific gravity	2·67
Weight per cubic foot, lbs.	143·41
Pore space, per cent	13·96
Ratio of absorption, per cent, one hour	3·18
" " " two hours	3·29
" " " slow immersion	3·79
" " " in vacuo	6·00
" " " under pressure	6·07
Coefficient of saturation, one hour	·52
" " " two hours	·54
" " " slow immersion	·62
" " " in vacuo	·98
Crushing strength, lbs. per sq. in., dry	18,428·
" " " " wet	13,847·
" " " " wet after freezing	11,415·

PLATE XLIII.

Haddington Island andesite, quarry of W. S. McDonald.

Transverse strength, lbs. per sq. in.	1,160·
Shearing strength, lbs. per sq. in.	1,156·
Loss on corrosion, grams per sq. in.	·01058
Drilling factor, mm.	19·6
Chiselling factor, grams (I)	2·2
" " " (II)	5·4

I am informed by Mr. McDonald that the stone weighs 143 lbs. per cubic foot and that it has a crushing strength of 50,000 lbs. per square inch. The former statement is in accord with our determinations, but the extraordinary crushing strength could not have been determined in a reliable manner.

No. 1555.—Differs from No. 1414 in colour only. The stone has a distinctly faint blue instead of yellowish colour.

No. 1556.—Differs from No. 1414 in a greater depth of yellow in the colour and a pitted structure in the groundmass. The stone is probably more porous than No. 1414; it represents an extreme phase of oxidation and is to be regarded as the type to which No. 1414 would approximate on long exposure.

The quarry was not in commission at the time of my visit. The equipment includes the following:—

1 quarry derrick with boiler and steam hoist.
1 loading derrick with boiler and steam hoist.
2 tripod drills.
Track, cars, and minor appliances.

Loading into scows is easily effected as deep water occurs within command of the loading derrick. While no harbour is available, the narrow character of the surrounding waters renders unlikely any serious hindrance to operations on account of storms.

Mr. McDonald's plant at 1571 Main street, Vancouver, is briefly described below:—

Building, 300 feet by 80 feet, containing:—
1 crane, length of mill, 40-ft. span, 25 tons, electric.
1 gang saw, Patch, Rutland, Vt.
1 gang saw, New Albany.
1 planer, Patch.
1 planer, Anderson.
1 double diamond saw, Patch.
1 16-ft. rubbing bed.
1 16-ft. lathe, capable of 4-ft. material.
1 polisher, Patch.
1 surfacer, Livingstone.
1 surfacer, Kotten.

1 compressor, Compressed Air Machinery Co., San Francisco. 200 ft. free air per minute.

1 compressor, Bury, Erie, Penn. 400 ft. free air per minute.

1 blacksmith shop.

14 derricks not now in use.

All the machinery is electrically actuated by power from the British Columbia Electric Co.

Mr. McDonald also maintains a plant on Montreal street, Victoria, as follows:—

Building, 300 feet by 60 feet containing;—

1 20-ton crane.

1 5-ton crane.

1 gang saw, Patch.

1 gang saw, New Albany.

2 surfacers.

1 compressor, 500 feet free air per minute.

1 compressor, 100 feet free air per minute.

Several derricks and minor appliances.

In working the stone it is found that granite tools are most serviceable; for turning columns the device of rotating discs is used as with granite. Saws with 6 to 10 blades working with a mixture of crushed steel and shot have an efficiency of 8 inches per hour.

Owing to the war, operations have practically ceased; during the past few years an average of 60 stonecutters were at work. The following scale of wages was given to me by Mr. McDonald:—

Stonecutters—$5 per 8-hour day.

Engineers—$5 per 8-hour day.

Blacksmiths—$5 per 8-hour day.

Labourers—$2.80 per 8-hour day.

The production in 1915 was 18,000 cubic feet valued at $14,000.

The more important buildings of Haddington Island stone are as follows:—

Parliament buildings, Victoria, (Frontispiece, Plate XLIV, Plate XLV).

British American Trust Company's building, Victoria.

Empress hotel, Victoria.

Court house, Vancouver.

Cotton building, Vancouver.

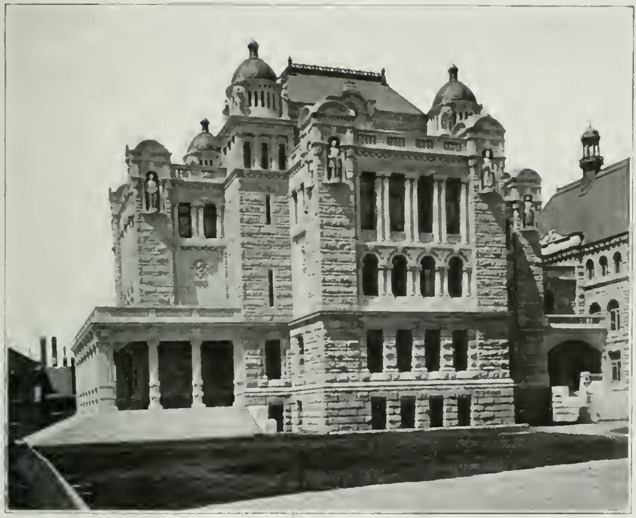
World building, Vancouver.

Bank of Ottawa, Vancouver.

Bank of Montreal, Main street, Vancouver.

Bank of Commerce, Kitsilano, Vancouver.

Merchants Bank, Hastings street, Vancouver.



Haddington Island andesite. New library, buildings of the Legislative Assembly of British Columbia, Victoria, B.C.

PLATE XLV

Haddington Island andesite. Main entrance, buildings of the Legislative Assembly of British Columbia, Victoria, B.C.

Merchants Bank, Granville street, Vancouver.
London building, Pender street, Vancouver.
Strathcona and other schools, Vancouver.
Bank of Commerce, Grand Forks.

An examination of all these structures shows a remarkable uniformity in appearance and a similarity in the effects of weathering. The magnificent buildings of the British Columbia Legislature at Victoria are undoubtedly the finest example of Haddington Island stone: the following remarks would apply with equal fidelity to any of the structures mentioned above.

Viewed from a short distance the buildings have a light yellowish-grey appearance very pleasing to the eye. Examined closely the stone shows minute, light brownish grains imbedded in a lighter-coloured matrix. The older parts of the buildings, constructed about 20 years ago, are somewhat darker, more grey, and less yellow, than the part recently built. Rock-face work is darker than work with smooth finish, owing to the imbibition of dirt. A variation in colour is to be observed, but it is not striking; some blocks are decidedly more brownish than others and in a few instances a pinkish cast is shown as in the case of weathered stone in the quarry. Where water has been allowed to run over the masonry, the stone is much darker, doubtless on account of the soaking in of dirt. The buildings show numerous pillars 6 to 8 feet long without any sign of flaws. The suitability of the stone to fine carving is attested by numerous statues and other highly ornamental work. The surface of the stone is hard without any sign of deterioration.

An interesting example of the use of Haddington Island stone is the pillars in front of the Holden building, Hastings street, Vancouver. These columns are 14 feet long, 18 inches in diameter at the bottom and 15 inches at the top: they were cut from single blocks of the andesite and were bored through longitudinally for the reception of iron columns.

Port McNeil, Vancouver island.

A stone very similar to the Haddington Island andesite but of finer grain is said to occur in large ridges about two and half miles south of the head of Port McNeil.

Summary—Volcanic Rocks.

The volcanic rocks of British Columbia are of common occurrence, but usually they are too hard and too severely fractured to be of any value as building stone. On the other hand they are largely quarried for road metal and concrete making. Extensive operations for these purposes have been carried on at Albert head near Victoria, on Burrard inlet, and at Fairview heights near Vancouver.

On Haddington island, Broughton strait, occurs a fine-grained, light yellowish-grey andesite which has proved to be one of the most valuable building stones in British Columbia, and has been used in the construction of some of the most important buildings in the province. A partial list is given on page 190, and a full description of the stone on pages 187-189. Plate XLIII shows a polished surface of the stone.

On Dease lake to the east of Kamloops is a soft, whitish-yellow volcanic tuff which is capable of fine carving and of being employed for structural purposes; it is described on pages 180-181, and is figured in Plate XLVI.

Literature:—

Rep. Min. Mines, B.C., for 1904. (Haddington island).
See also the list given under "Black Granite."

CHAPTER VIII.

SLATES OF THE PROVINCE OF BRITISH COLUMBIA.

Slate as a rock is of very common occurrence in the province but as a roofing material it has not yet proved commercially successful. The only attempts to work this stone were made at Glenogle on the Canadian Pacific railway, and at the head of Jervis inlet.

The occurrences which have received any attention from the economic point of view may be considered under the following areas:—

Ice River area.
Glenogle area.
Jervis Inlet area.
Queen Charlotte Island area.

Ice River Area.

Slates of the Chancellor formation (Upper Cambrian) occur to a thickness of 1,100 feet in the Ice River area. According to Allan, the lower part of the formation is of little promise but the upper 800 feet consist of thin-bedded, grey to black argillaceous slates.

"As a whole, these slates weather reddish, brownish to yellowish and buff where the outcropping edges of the beds have been exposed to the atmosphere for some time. The cleavage is developed parallel to the bedding and the beds vary in thickness from a fraction of an inch to several inches.

"In no place did the writer find crystals of pyrite disseminated through beds of slate. This would tend to uphold a secondary origin for the pyrite.

"Several tests were made on the amount of soluble material in the better varieties of this slate. In tests made with cold acid, the amount of soluble material was found to be between 35 per cent and 36 per cent of the whole. When the solution was boiled for a few minutes, more material was dissolved and the amount which disappeared was 39 per cent.

"The slates are best exposed in the Ice River valley on the east slope of Chancellor peak, and also in Zinc valley. In the former the beds outcrop almost down to the valley floor.

"If these rocks should prove of economic value, the material could be quarried and transported at low cost. There is now a disused wagon road from the railway to Ice river, and these exposures of slates are about 7 miles from the end of the road."[1]

[1] Geol. Sur. Can., Memoir No. 55, Pub. No. 1370, pp. 237-238, 1914.

Glenogle Area.

Glenogle, B.C.

A slate quarry was worked about 20 years ago directly across the Kicking Horse river from Glenogle on the main line of the Canadian Pacific railway, about 7 miles east of Golden. According to local report the quarry was abandoned on account of the hardness of the slate and the presence of pyrite.

The slates are exposed close to the river for a distance of several hundred yards and have been opened in a number of places. The formation strikes with the river, E. 10° S. and dips 60° north, or towards the water, but it curves around to E. 40° S. at the east end. The actual exposure is about 15 feet high and is covered with 4 or 5 feet of gravel; it would be accessible inland for a distance of 50 yards before passing under the heavy talus at the foot of the mountain.

Joints cross the formation at S. 10°-30° W. with a steep but variable dip to the southeast. There is also a pronounced cleavage at E. 20° S., which represents the grain of the slate; this is not coincident with the strike of the formation. It is always difficult and generally impossible to judge of the solidity of a slate formation from observation of the weathered surface. The present face looks to be severely fractured, but it is quite possible that better conditions prevail within the deposit. The cessation of operations was certainly not due to lack of material, and must have been caused by economic conditions or an unsatisfactory product.

The stone: No. 1541.—Severely weathered and water-soaked material from the face of a slate quarry is practically worthless for purposes of description: a short account of this stone is given for what it may be worth.

The slate is of dark blue-grey colour, irregular cleave, and dull "ring." The cleave is not deficient, but the planes are rough and irregular for the most part.

Jervis Inlet Area.

Jervis Inlet.

On the failure of the slate quarries at Glenogle the same company, or a reorganization of it, attempted to again work the old slate quarry at the head of Jervis inlet.

The deposit is thus described by Le Roy:—

"At Deserted bay work was resumed at the old slate quarry in September last. The quarry is at sea level and to the east the slate hills rise to heights of 3,000 feet or more. The slate is a black carbonaceous finely laminated rock free from objectionable impurities. Traces of bedding show horizontal or with low dips, the plane of the cleavage being at right angles. In places small veins of quartz and calcite occur and small dikes of granite cut the slate. Slate, formerly quarried, was graded as first-class, 18 by 10 inches, and third class, 14 by 9 inches.

"The former splits evenly and the latter not, giving a rough surface. The objection in the past was that too much waste had to be handled, but it is stated that half a mile inland better and more uniform beds have been found that will permit of more economic working."[1] Slate from this quarry was sent to California and was also used in a number of the barracks of the North West Mounted Police. It is said that financial difficulties and the failure of large sized sheets led to the final abandonment of the enterprise. The quarry was originally opened about 1890.

Howe Sound.

Unsuccessful attempts were made to work a deposit of slate similar to that of Jervis inlet.

Queen Charlotte Island Area.

It has long been known that the Indians employ a fine, black, carbonaceous shale from Queen Charlotte island for the making of pipes, miniature totem poles, etc. The material may have a distinct economic value on account of its very dark colour and its susceptibility of a fine polish.

James Richardson describes the occurrence as below:—

"On Slaty creek near the base of the band of coal-bearing black shale now under description, and close by the volcanic rock, there occurs a quarry which has been excavated by the Indians. It has a depth of 3 or 4 feet, a breadth of 4 or 5 yards, and a length of between 80 and 90 yards. The shale occurs in lenticular patches of 2 or 3 feet in the thickest part, and from 8 to 20 feet long, which are interstratified with a light grey not very hard sandstone.

"This rock shows no tendency to cleave into laminae until it is ignited, but breaks with a true conchoidal fracture. Its colour is greyish-black upon fractured surfaces, and black when polished. The rock has a hardness of about 2·5, a specific gravity of 2·88-2·89 and readily takes a fine polish. When fragments are heated in a crucible they decrepitate with considerable violence, and split up into numerous thin laminae.

The following analysis shows it to be a hydrated silicate of alumina and iron with several per cent of carbonaceous matter:—

	per cent
Silica	44·78
Alumina	36·94
Ferric oxide	8·46

[1] Geol. Sur. Can., Pub. No. 996, p. 54, 1908.

Lime	trace
Magnesia	trace
Water	7·15
Carbonaceous matter	3·18
	100·51

"The disseminated carbonaceous matter appears to be the cause of its being susceptible of taking a fine polish."[1] Dawson refers briefly to the deposit as occurring on Slate Chuck,[2] and W. Fleet Robertson states that investigating prospectors had made attempts to stake the quarry in the hope that the material would have a commercial value for the making of mantels or for other uses of civilization.[3]

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[1] Geol. Sur. Can., Rep. for 1872-73, pp. 61-62.

[2] Geol. Sur. Can., Rep. for 1878-79, p. 303.

[3] Ann. Rep., Min. of Mines of B.C. for 1909, p. 75.

CHAPTER IX.

MISCELLANEOUS STONES OF THE PROVINCE OF BRITISH COLUMBIA.

All the rocks at all worthy of the name "building stone" have been reviewed in the earlier chapters of this report. There remain however a few stones which have been used locally for foundations and other purposes of the roughest kind.

Some of the Palaeozoic limestones along the line of the Canadian Pacific railway have been sparingly employed. This type of stone has been fully dealt with in the fourth volume of the report and requires no further mention.

The hard dark-coloured Elk conglomerate of the Crowsnest coal-field and other rocks of the vicinity have also been used for the roughest purposes.

PRINCE RUPERT FORMATION.

The schists of the Prince Rupert formation have been used to a considerable extent in Prince Rupert for foundations, retaining walls, etc.

The stone: No. 1566.—This schist is of dark grey colour and strongly laminated structure. It is fine in grain for the most part and consists chiefly of quartz and biotite. Garnet is present in many samples, and in some is so numerous and of so great a size as to constitute a true garnet schist. Pyrite is usually present in small grains. The formation is extensively fractured, and there is a strong tendency for the stone to part on the planes of schistosity, nevertheless, blocks of sufficient size for ordinary rough building may be obtained. The weathering properties of the stone are very poor as the pyrite soon rusts, staining the stone a dirty, reddish-brown colour.

HAZELTON FORMATION.

The rocks of the Hazelton series exposed for a considerable distance along the line of the Grand Trunk Pacific railway have never been employed for building purposes as far as I am aware. Nevertheless, their nearness to the line of railway demands a mention at least in this report.

The stone: The great bulk of the formation is a hard indurated sandstone, variable in grain and colour, excessively shattered, cut by volcanics, and of little or no promise for structural purposes. Typical specimens from near New Hazelton are described below.

No. 1592.—A hard, light grey sandstone, almost a quartzite. Examined with the hand lens, it shows a minutely porous structure with yellowish stains.

No. 1593.—A darker type of stone, rather more uniform and less porous than No. 1592. It is too hard for chiselling, but it might be used for rough construction. The formational features are very unpromising.

Sodalite of Ice River.

A description of the beautiful blue mineral, sodalite, and an account of its occurrence in Ontario may be found in the first volume of this report. The pure mineral belongs to the class of semi-precious stones and the parent rock with spots and stringers of the sodalite is a decorative stone of unique character.

In the Ice River valley, south of the main line of the Canadian Pacific railway near Field, is a large mass of alkali syenite carrying sodalite. The outcrops have been examined in detail by J. A. Allan from whose report on the Field Map Area the following extracts are taken:—

"Sodalite occurs associated with the alkaline syenite intrusive mass of the Ice river. It has a beautiful blue colour which varies from the deep blue to light greyish blue and takes a high polish.

"The localities in which this mineral occurs can be most easily reached in Ice river or a little over a mile up the valley on the east side from the point where the main trail crosses the river. A mass of sodalite-bearing rocks has been exposed in the bed of the first large creek about ½ mile from where it enters the Ice river from the east. This prospect has furnished material for many tourists who visit it every summer. Neither the lateral nor vertical extent of this rock has yet been exposed.

"Another occurrence of the sodalite syenite is found towards the head of Sodalite valley, which is the second large depression entering Ice River valley from the east. On the west side of the valley another exposure of sodalite syenite occurs about 600 feet above the main valley on the south side of Shining Beauty creek, which is the first large creek entering Ice river from the west. Here the sodalite again occurs on the contact of the igneous mass with the overlying sediments. These three localities are all easily accessible and especially the first described occurrence, as it is only about 1½ miles from the end of the old wagon road and less than ½ mile from the Ice River trail.

"A small boulder of pure sodalite and cancrinite was found towards the head of Ice River valley, the occurrence of which suggests that in some locality about the head of the valley sodalite is not directly in contact with the igneous rock.

"There is at least one locality in which sodalite occurs on the west side of Moose Creek valley, towards its head, the extent of which is not yet known.

"The occurrence of the mineral, as has been previously stated, is found about the border of the igneous mass, usually on the contact between the igneous rock and the sediments. Where it occurs as a mineral constituent of the nephelite syenite, this rock becomes important as a decorative stone.

"The sodalite also forms veins of pure mineral in the sodalite syenite, varying from a fraction of an inch to an inch and a half in width. Minute veinlets of sodalite are found along seams in the sediments a few yards from the contact. It would appear as though this mineral has been brought in by pneumatolytic action at the close of the intrusion of nephelite syenite. In most cases the lateral extent of the veins is sharply defined. Although the veins are, as a rule, pure sodalite, yet there are sometimes grains of a brownish mineral which proves to be cancrinite. These grains are in some places scattered throughout, but in others are limited to the middle of the vein. Pyrite and other ferruginous material are also found sometimes sparsely scattered through the veins of sodalite and also through the sodalite syenite. These cause the rock on exposure to assume rusty coloured spots. A greenish coloured pyroxene is also associated with the sodalite, which microscopically is found to be aegirite-augite.

"The pure sodalite polishes excellently and assumes a handsome appearance when made into jewelry. In artificial light this mineral looks rather dark in lustre, but not more so than any other blue coloured mineral. Polished specimens of the sodalite retain their appearance much better in artificial light.

"An analysis of this mineral was made by Dr. Harrington. It is similar to sodalite found in the nephelite syenite of Mount Royal, where it occurs as a mineral constituent of nephelite syenite. The formula of the sodalite as derived from analysis is:

$$3\ Na_2O.Al_2O_3.2SiO_2 + NaCl.$$

"Before this mineral can be considered of economic importance it will be necessary to find out its extent, which can only be ascertained by development of the present exposures, because the rock immediately about these exposures is more or less covered up with rock debris.

"So far as at present known, the sodalite occurs in poorly defined small irregular masses associated with portions of syenite high in nephelite, and is developed on or near the upper contact of the laccolithic mass with the overlying sediments.

"It might be well to note that whereas the vein material is well defined, yet where the sodalite is a mineral constituent of syenite, the line between this mineral and the nephelite is not sharply defined, and the deep bluish coloured sodalite gradually becomes colourless towards the nephelite crystal.

"This occurrence is worthy of consideration because the material can be inexpensively worked, and it would seem possible to obtain large blocks of the sodalite syenite. The transportation problem would not be a difficult one as the first described deposit is about 14 miles from the railway and at present a disused wagon road extends to the Ice river and within 2 miles of the exposure. Mr. M. Dainard of Golden located some of the property, but up to the present, no important development has been done."[1]

[1] Geol Sur. Can., Memoir No. 55, Pub. 1370, pp. 239-242, 1914.

Plate XLVI.

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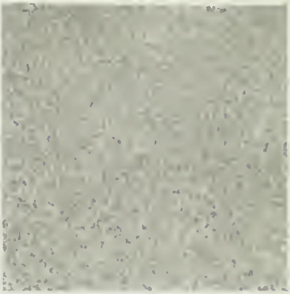

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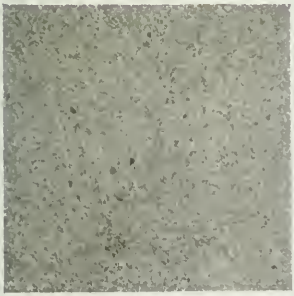

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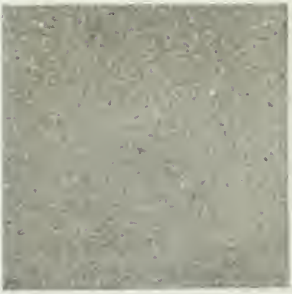

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PLATE XLVII.

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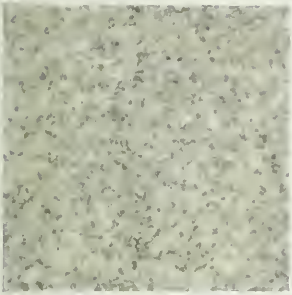

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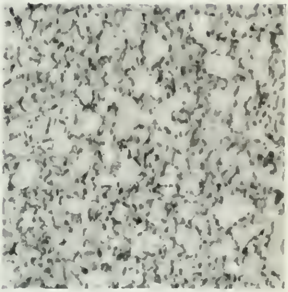

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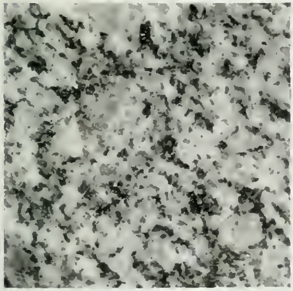

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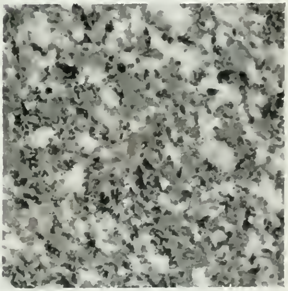

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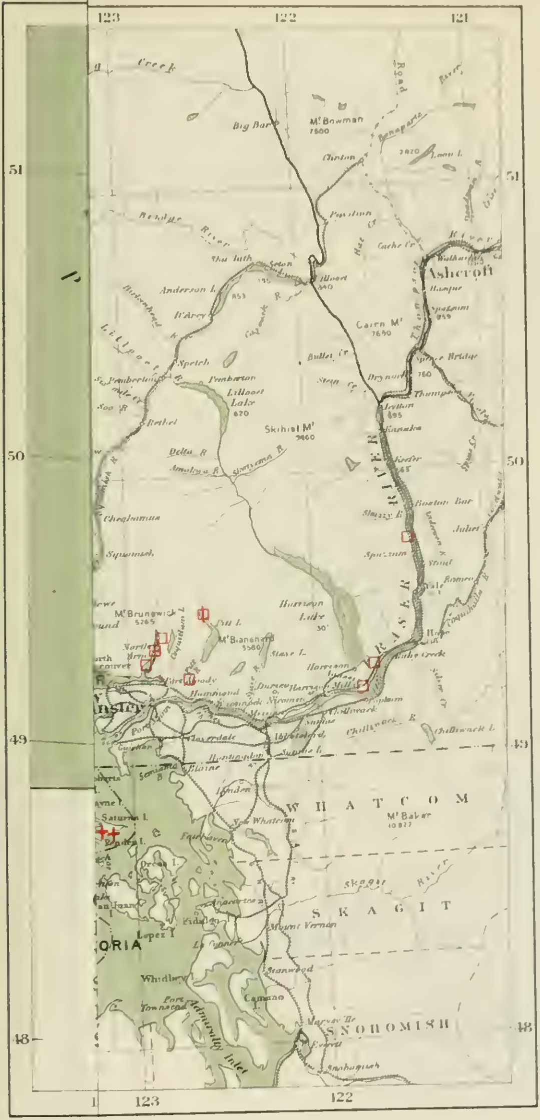

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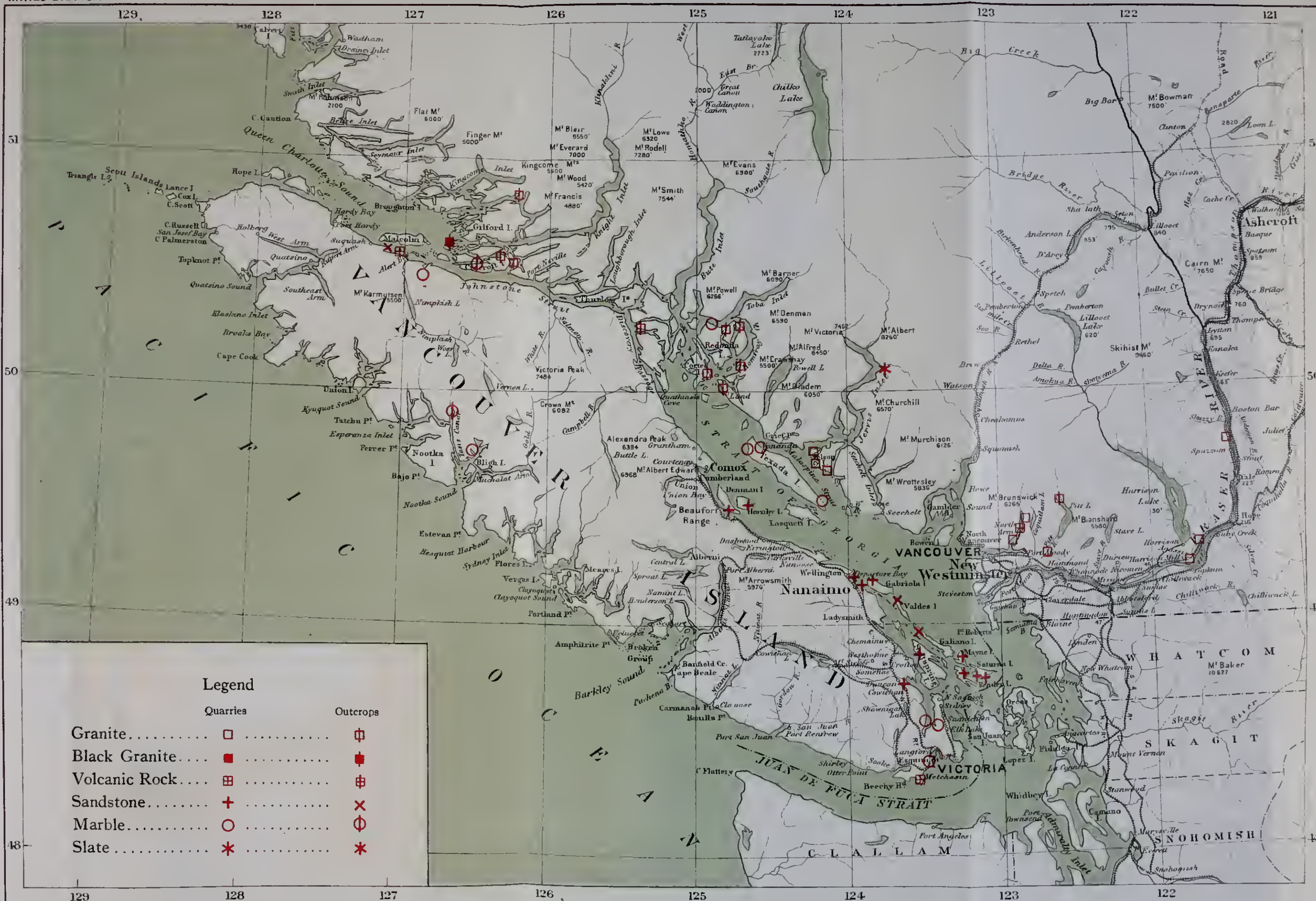
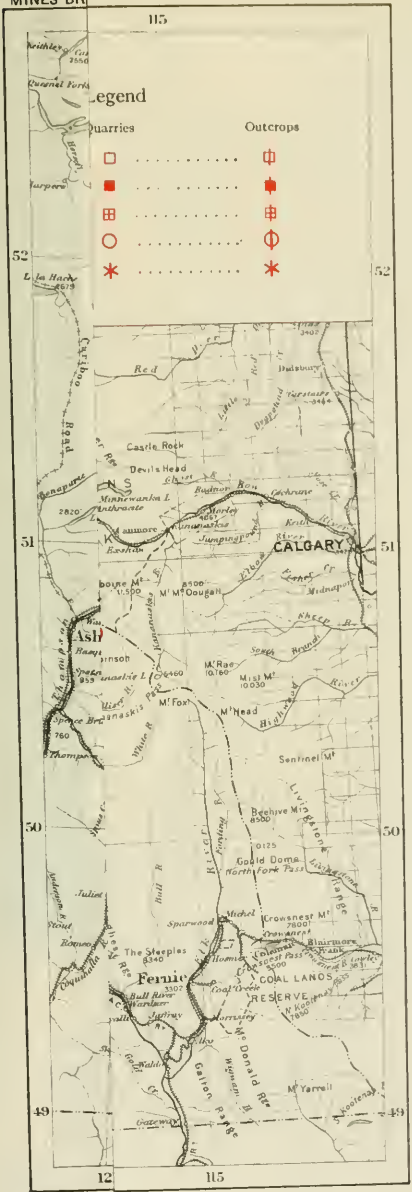


Base map, Dept. of Interior

Fig. 1. Map of Southwestern British Columbia, showing the location of the Chief Quarries and Rock Outcrops referred to in the report.

Scale: 35 miles to 1 inch

MINES BR



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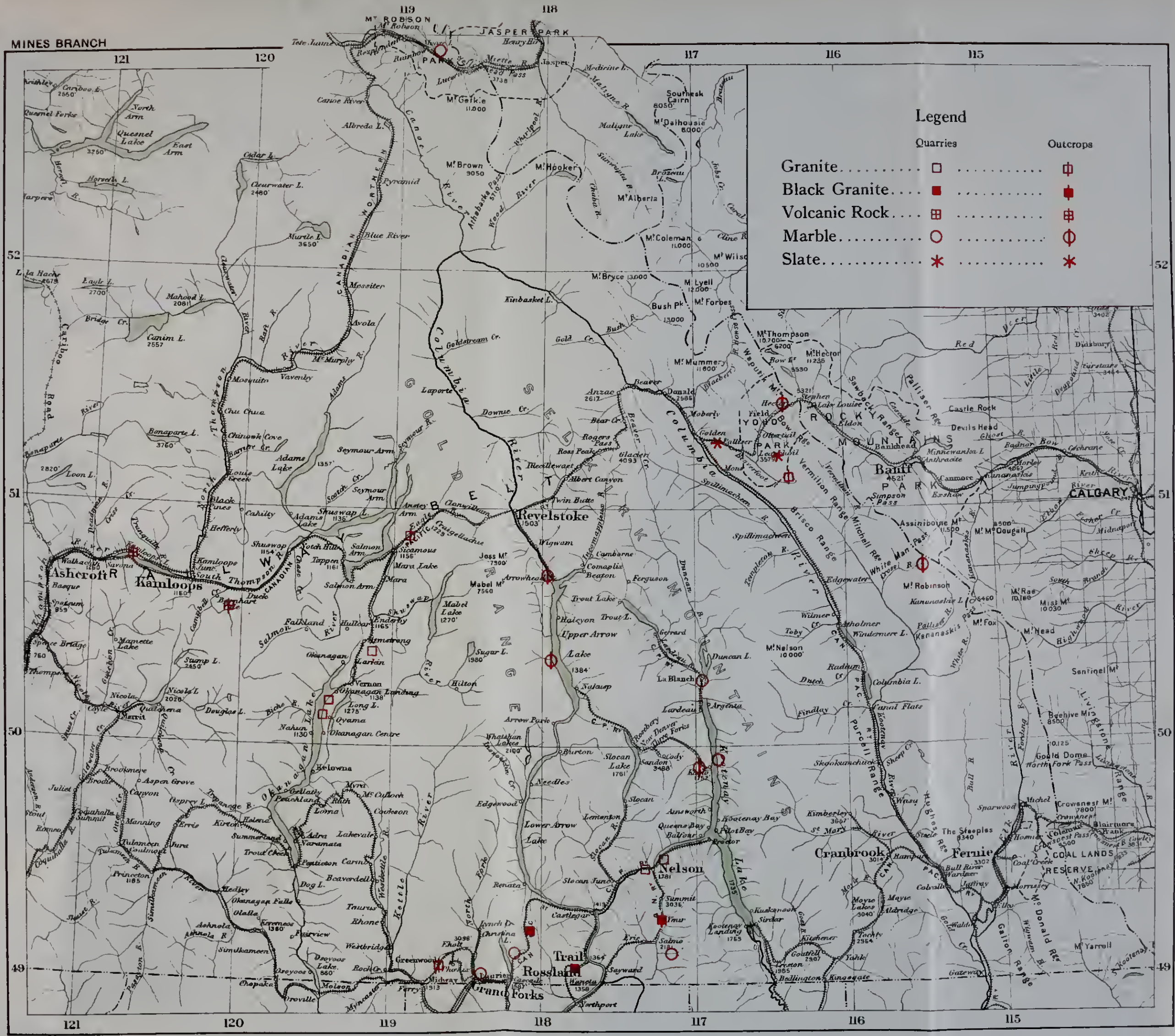

Base map, Dept. of Interior.

Fig. 2. Map of Eastern British Columbia, showing the location of the Chief Quarries and Rock Outcrops referred to in the report.

Scale: 35 miles to 1 inch

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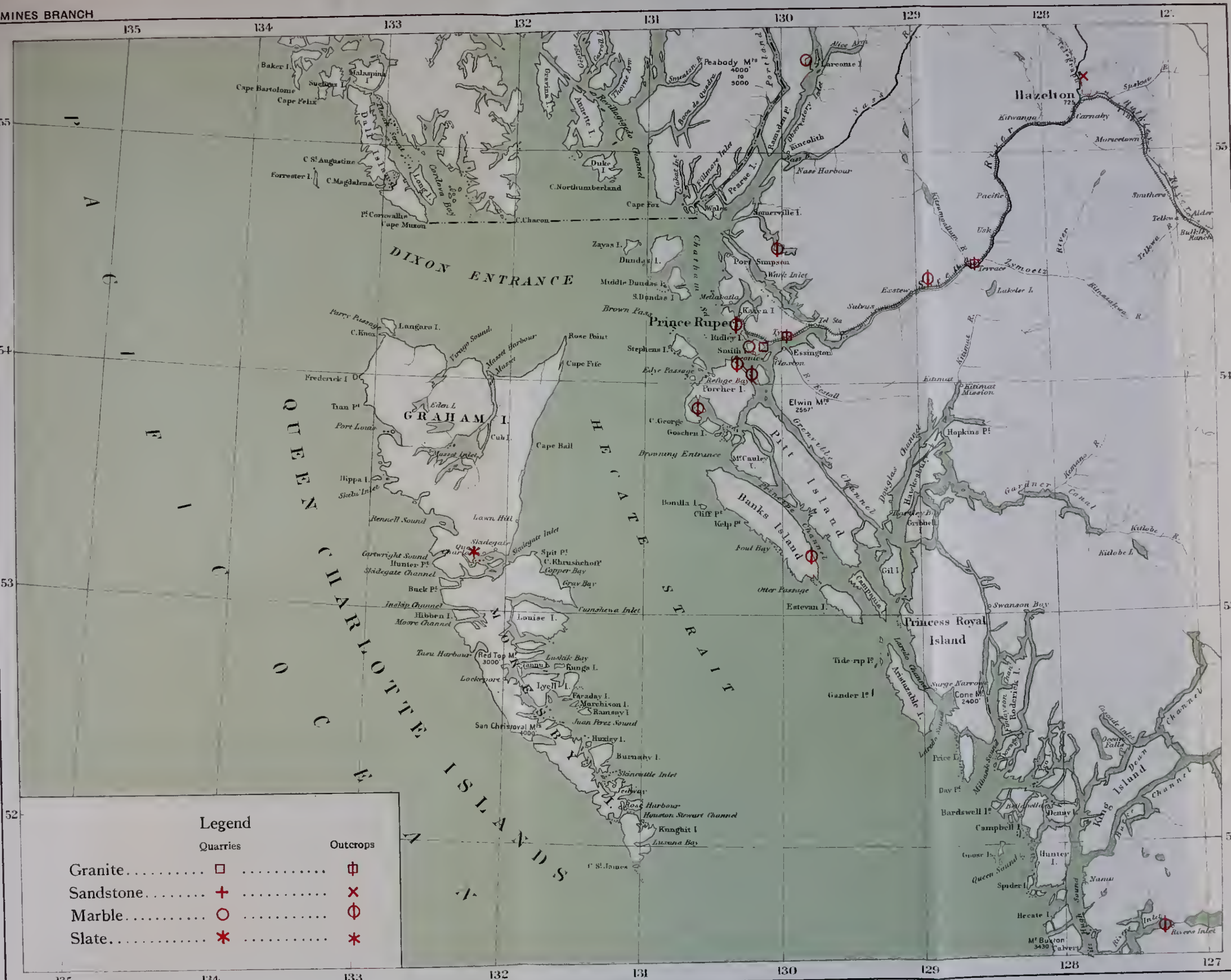

Base map, Dept. of Interior.

Fig. 3. Map of Prince Rupert district, showing the location of the Chief Quarries and Rock Outcrops referred to in the report.

Scale: 35 miles to 1 inch

APPENDIX I.

TABLE 1.

The Specific Gravity, Weight per Cubic Foot, Pore Space, Ratio of Absorption, and Coefficient of Saturation of British Columbia Building Stones.

GRANITES AND RELATED ROCKS.

No.	Owner	Area	Specific Gravity	Weight per cubic foot lbs.	Pore space, per cent	Ratio of Absorption, per cent.	Coefficient of Saturation
1453	West Coast Granite Co.	Jervis inlet	2·681	166·33	0·618	0·232	·77
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway	2·782	171·18	1·432	0·523	·69
1462	Sechelt Granite Quarries	Jervis inlet	2·703	167·56	0·695	0·259	·68
1467	Vancouver Granite Co.	Jervis inlet	2·66	164·93	0·679	0·257	·73
1487	Vancouver Granite Co.	Jervis inlet	2·657	164·82	0·691	0·262	·67
1493	Canadian Pacific Ry. Co.	Canadian Pacific Ry.	2·697	166·79	0·932	0·350	·85
1497	Benjamin Lefroy	Okanagan lake	2·643	162·57	1·47	0·563	·74
1498	Vernon Granite and Marble Works	Okanagan lake	2·67	164·30	1·427	0·543	·65
1512	Canadian Pacific Ry. Co.	Coryell	2·901	179·27	1·007	0·351	·70
1514	Kootenay Granite and Monumental Co.	Nelson	2·656	163·63	1·432	0·547	·74
1523	Canadian Pacific Ry. Co.	Nelson	2·705	167·13	1·03	0·385	·84
1524	Canadian Marble and Granite Works	Nelson	2·676	164·62	1·41	0·528	·72
1577	Prince Rupert Granite Co.	Prince Rupert	2·79	172·58	0·91	0·328	·70
1578	Alfred C. Gardé	Prince Rupert	2·777	171·95	0·812	0·294	·67
1515	Canadian Pacific Ry. Co.	Rossland	2·882	177·56	1·304	0·458	·80
1494	W. H. Johnston; James A. Gill	Kamloops	2·684	164·94	1·559	0·589	·80

SANDSTONES.

No.	Owner	Area	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1429	Western Fuel Co.	Nanaimo	2·656	152·38	8·15	3·38	·75
1434	Henry Lys	Nanaimo	2·689	153·36	8·64	3·51	·88
1441	E. G. Bittancourt	Southern Gulf islands	2·67	157·21	5·678	2·26	·93
1445	Mrs. David	Southern Gulf islands	2·661	149·02	10·29	4·31	·77
1449	George Taylor	Southern Gulf islands	2·667	148·31	10·92	4·6	·67
1450	George Taylor	Southern Gulf islands	2·674	148·41	11·10	4·67	·73
1481	Denman Island Stone Co.	Denman-Hornby islands	2·713	145·45	14·20	6·09	·87
1485	Murray, Martin and Murray	Denman-Hornby islands	2·673	145·09	13·05	5·62	·78
1486	Murray, Martin and Murray	Denman-Hornby islands	2·676	141·07	15·55	6·87	·71
1488	Vancouver Granite Co.	Nanaimo	2·695	152·34	9·45	3·87	·83

MARBLES.

No.	Owner	Area	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1424	Nootka Quarries, Limited	Nootka sound	2·72	169·27	0·312	0·115	·91
1425	Nootka Quarries, Limited	Nootka sound	2·72	169·10	0·411	0·142	·97
1426	Nootka Quarries, Limited	Nootka sound	2·721	169·39	0·277	0·102	·71
1468	Malaspina Marble Co.	Southern Texada island	2·712	169·00	0·177	0·065	·80
1530	Canadian Marble and Granite Works	Kootenay lake	2·718	168·70	0·572	0·212	·85
1531	Canadian Marble and Granite Works	Kootenay lake	2·719	169·05	0·438	0·162	·73
1532	E. W. Gillette	Kootenay lake	2·752	171·36	0·313	0·114	·87
1533	E. W. Gillette	Kootenay lake	2·759	171·81	0·304	0·110	·76
1249	Grant Brook	Grant Brook Mble. Co.	2·855	177·32	0·57	0·201	·78
1250	Grant Brook	Grant Brook Mble. Co.	2·868	177·79	0·699	0·247	·69

VOLCANIC ROCKS.

No.	Owner	Area	Specific Gravity	Weight per cubic foot, lbs.	Pore space, per cent.	Ratio of Absorption, per cent.	Coefficient of Saturation
1414	W. S. McDonald	Haddington island	2·67	143·41	13·96	6·07	·62
1495	D. P. Selby	Kamloops	2·654	135·90	18·02	8·26	·90

TABLE II.

The Ratio of Absorption and the Coefficient of Saturation under different Conditions—one hour soaking, two hours soaking, slow immersion and long soaking, in vacuo, and under pressure.

GRANITES AND RELATED ROCKS.

No.	Owner	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1453	West Coast Granite Co.	Jervis inlet	·121	·134	·178	·200	·232	·52	·57	·77	·86
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway	·307	·318	·362	·511	·523	·60	·61	·69	·97
1462	Sechelt Granite Quarries	Jervis inlet	·147	·161	·177	·232	·259	·56	·62	·68	·89
1467	Vancouver Granite Co.	Jervis inlet	·143	·143	·187	·216	·257	·55	·55	·73	·84
1487	Vancouver Granite Co.	Jervis inlet	·143	·152	·175	·226	·262	·54	·58	·67	·86
1493	Canadian Pacific Ry. Co.	Canadian Pacific Railway	·248	·248	·299	·341	·350	·71	·71	·85	·97
1497	Benjamin Lefroy	Okanagan lake.	·310	·325	·420	·498	·563	·55	·58	·74	·88
1498	Vernon Granite and Marble Works	Okanagan lake.	·254	·260	·354	·465	·543	·47	·48	·65	·85
1512	Canadian Pacific Ry. Co.	Coryell	·208	·211	·246	·330	·351	·59	·60	·70	·94
1514	Kootenay Granite and Monumental Co.	Nelson	·329	·339	·407	·530	·547	·60	·62	·74	·97
1523	Canadian Pacific Ry. Co.	Nelson	·264	·277	·324	·368	·385	·69	·72	·84	·95
1524	Canadian Marble and Granite Works		·323	·335	·380	·520	·528	·61	·63	·72	·99
1577	Prince Rupert Granite Co.	Prince Rupert	·201	·208	·232	·300	·328	·61	·63	·70	·91
1578	Alfred C. Gardé	Prince Rupert	·161	·164	·197	·285	·294	·55	·56	·67	·97
1515	Canadian Pacific Ry. Co.	Rossland	·303	·322	·368	·427	·458	·67	·70	·80	·93
1494	W. H. Johnston; James A. Gill	Kamloops	·240	·295	·471	·497	·589	·41	·50	·80	·84

SANDSTONES.

No.	Owner	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1429	Western Fuel Co.	Nanaimo	1·09	1·34	2·53	3·15	3·38	·32	·39	·75	·93
1434	Henry Lys	Nanaimo	1·92	2·27	3·09	3·43	3·51	·54	·64	·88	·97
1441	E. G. Bittancourt	Southern Gulf islands	1·40	1·67	2·11	2·11	2·26	·62	·73	·93	·93
1445	Mrs. David	Southern Gulf islands	2·73	2·98	3·33	3·71	4·31	·63	·69	·77	·86
1449	George Taylor	Southern Gulf islands	2·42	2·68	3·09	3·63	4·60	·52	·58	·67	·78
1450	George Taylor	Southern Gulf islands	2·40	2·65	3·42	3·72	4·67	·51	·56	·73	·79
1481	Denman Island Stone Co.	Denman-Hornby islands	1·73	2·06	5·28	5·96	6·09	·28	·34	·87	·98
1485	Murray, Martin and Murray	Denman-Hornby islands	3·57	3·82	4·37	4·82	5·62	·63	·68	·78	·86
1486	Murray, Martin and Murray	Denman-Hornby islands	4·47	4·48	4·89	6·82	6·87	·65	·65	·71	·99
1488	Vancouver Granite Co.	Nanaimo	2·38	2·69	3·21	3·56	3·87	·61	·69	·83	·92

MARBLES.

No.	Owner	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1424	Nootka Quarries, Limited......	Nootka sound	·072	·074	·105	·114	·115	·63	·64	·91	·99
1425	Nootka Quarries, Limited......	Nootka sound	·111	·137	·138	·142	·142	·78	·96	·97	1·00
1426	Nootka Quarries, Limited......	Nootka sound	·060	·066	·073	·079	·102	·58	·65	·71	·78
1468	Malaspina Marble Co..........	Southern Texada island	·034	·036	·052	·051	·065	·51	·55	·80	·93
1530	Canadian Marble and Granite Works	Kootenay lake.	·136	·144	·179	·198	·212	·64	·68	·85	·93
1531	Canadian Marble and Granite Works	Kootenay lake.	·093	·108	·119	·135	·162	·57	·66	·73	·83
1532	E. W. Gillette..................	Kootenay lake.	·072	·079	·099	·101	·114	·63	·69	·87	·88
1533	E. W. Gillette..................	Kootenay lake.	·063	·076	·084	·095	·110	·57	·69	·76	·86
1249	Grant Brook Marble Co.......	Grant Brook...	·150	·153	·157	·185	·201	·74	·76	·78	·92
1250	Grant Brook Marble Co.......	Grant Brook..	·161	·161	·172	·231	·247	·65	·65	·69	·93

VOLCANIC ROCKS.

No.	Owner	Area	Ratio of Absorption, per cent.					Coefficient of Saturation			
			One hour	Two hours	Slow immersion	In vacuo	Under pressure	One hour	Two hours	Slow immersion	In vacuo
1414	W. S. McDonald..............	Haddington island	3·18	3·29	3·79	6·00	6·07	·52	·54	·62	·98
1495	D. P. Selby..................	Kamloops	6·19	6·37	7·42	8·14	8·26	·75	·77	·90	·98

TABLE III.

The Crushing Strength of British Columbia Building Stones.

GRANITES AND RELATED ROCKS.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.					Probable error, lbs. per sq. in.		Remarks
			a maximum	b	c	d minimum	Average	Of average	Of single test	
1453	West Coast Granite Co.....	Jervis inlet....	37,500	34,093	......	33,841	35,144	795	1,377	Flat lower pyramids.
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway	32,166	......	......	31,673	31,919	166	180	Powder.
1462	Sechelt Granite Quarries....	Jervis inlet....	33,710	30,666	30,165	28,323	32,288	964	1,925	Cubes all yielded before ultimate load.
1467	Vancouver Granite Co......	Jervis inlet....	39,082	36,083	......	32,737	35,967	1,235	2,440	Cubes all began to yield from corners.
1487	Vancouver Granite Co......	Jervis inlet....	37,060	35,391	......	32,019	34,823	1,000	1,731	" "
1493	Can. Pac. Ry. Co..........	Canadian Pacific Railway	32,533	......	......	31,368	31,950	393	556	" "
1497	Benjamin Lefroy..........	Okanagan lake	31,288	30,598	......	29,481	30,455	402	697	Good failure; powder.
1498	Vernon Granite and Marble Works	Okanagan lake	25,254	24,800	......	24,319	24,791	162	279	Sharp chipping before collapse.
1512	Can. Pac. Ry. Co.........	Coryell.......	23,600	23,305	......	22,969	23,291	123	212	Yielded from corners before collapse.
1514	Kootenay Granite and Monumental Co.	Nelson.......	31,798	......	......	27,014	29,406	1,613	2,281	Cracks before ultimate load.
1523	Canadian Pacific Ry. Co....	Nelson......	35,788	......	......	35,230	35,512	186	263	Flat upper pyramids.
1524	Canadian Marble and Granite Works	Nelson......	37,827	......	......	25,390	36,608	821	1,316	Cracked at corners before collapse.
1577	Prince Rupert Granite Co...	Prince Rupert .	26,870	25,730	......	23,593	25,374	659	1,144	Failure began from one side.
1578	Alfred C. Gardé..........	Prince Rupert..	26,106	......	......	......	26,106	......	......	Failure began from one side.
1515	Canadian Pacific Ry. Co ..	Rossland....	29,343	27,662	......	27,498	28,167	377	654	Initial failure before collapse.
1494	W. H. Johnston; James A. Gill	Kamloops.....	32,255	......	......	30,238	31,246	770	961	All cubes began to fail at corners.

SANDSTONES.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.	Remarks
1429	Western Fuel Co	Nanaimo	14,849	Slight initial cracking; small lower pyramid.
1434	Henry Lys	Nanaimo	11,276	Slight initial cracking; irregular wedges.
1441	E. G. Bittancourt	Southern Gulf islands	27,229	Sharp sudden collapse; powder only.
1445	Mrs. David	Southern Gulf islands	16,505	Flat lower pyramid.
1449	George Taylor	Southern Gulf islands	14,800	Slight crack before collapse; upper and lower wedges.
1450	George Taylor	Southern Gulf islands	13,450	Initial crack at corner; large lower wedge.
1481	Denman Island Stone Co	Denman-Hornby islands	8,551	Yielded without snap; large lower pyramid.
1485	Murray, Martin and Murray	Denman-Hornby islands	10,226	Sudden collapse; irregular lower pyramid.
1486	Murray, Martin and Murray	Denman-Hornby islands	8,256	Sudden collapse; narrow wedges.
1488	Vancouver Granite Co	Nanaimo	10,589	Sharp snap; large lower wedge.

MARBLES.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.	Remarks
1424	Nootka Quarries, Ltd	Nootka sound	16,926	Preliminary cracks; irregular wedges.
1425	Nootka Quarries, Ltd	Nootka sound	13,305	Sudden collapse; powder and flat lower pyramid.
1426	Nootka Quarries, Ltd	Nootka sound	18,992	Sharp preliminary cracks; mostly powder.
1468	Malaspina Marble Co	Southern Texada islands	18,518	Large diagonal lower wedge.
1530	Canadian Marble and Granite Works	Kootenay lake	{12,486 13,101}	Sudden collapse; thin irregular wedges.
1531	Canadian Marble and Granite Works	Kootenay lake	{11,471 11,172 13,188}	Rather soft yield; sloping wedges.
1532	E. W. Gillette	Kootenay lake	13,987	Preliminary crack; powder and lower pyramid.
1533	E. W. Gillette	Kootenay lake	13,267	Undoubtedly too low as the failure occurred from one side.
1249	Grant Brook Marble Co	Grant Brook	{25,114 23,700}	Sharp chipping before collapse; powder.
1250	Grant Brook Marble Co	Grant Brook	34,670	Early crack but held without further yielding; powder.

VOLCANIC ROCKS.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.	Remarks
1414	W. S. McDonald	Haddington island	18,428	Sudden collapse; powder and small wedges.
1495	D. P. Selby	Kamloops	13,242	Sudden collapse; lower pyramid.

TABLE IV.

The Comparative Crushing Strength of British Columbia Building Stones, dry, wet, and wet after being frozen forty times.

SANDSTONES.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.			Remarks
			Dry	Wet	Wet after freezing	
1429	Western Fuel Co. (Newcastle island)....	Nanaimo.............	14,849	11,874	9,670	Frozen cube crushed from one side; perhaps low.
1434	Henry Lys (Jack point).............	Nanaimo.............	11,276	7,116	5,265	Good tests; small upper pyramids with wet stones.
1441	E. G. Bittancourt (Saltspring island)....	Southern Gulf islands...	27,229	17,800	17,797	Wet cube gave wedges; frozen cube gave large lower pyramid.
1445	Mrs. David (Mayne island)..........	Southern Gulf islands...	16,505	10,869	8,893	Large pyramids; wet upper, frozen lower.
1449	George Taylor (Saturna island)........	Southern Gulf islands ..	14,800	11,837	11,601	Sharp snap; irregular slanting pyramids.
1450	George Taylor (Saturna island)........	Southern Gulf islands ..	13,450	11,617	8,976	Upper pyramids.
1481	Denman Island Stone Co. (Denman island)	Denman-Hornby islands	8,551	3,963	2.052	Soft yield; wet upper wedges, frozen upper pyramid.
1485	Murray, Martin and Murray (Hornby island)	Denman-Hornby islands	10,226	8,080	2,741	Soft yield with shearing; small upper pyramids.
1486	Murray, Martin and Murray (Hornby island)	Denman-Hornby islands	8,256	6,990	3,577	Upper pyramids.
1488	Vancouver Granite Co. (Gabriola island)	Nanaimo.............	10,589	10,068	7,564	Wet, irregular wedges; frozen, large lower pyramid.

MARBLES.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.			Remarks
			Dry	Wet	Wet after freezing	
1424	Nootka Quarries, Ltd. (White marble)	Nootka sound	16,926	16,901	15,112	Powder and small lower wedges.
1425	Nootka Quarries, Ltd. (Grey marble)	Nootka sound	13,305	12,142	12,022	Good lower pyramids.
1426	Nootka Quarries, Ltd. (Intermediate type)	Nootka sound	18,992	18,000(?)	17,801	Preliminary cracks; small lower pyramids.
1468	Malaspina Marble Co.	Southern Texada island.	18,518	13,586(?)	17,213	Small lower pyramids. The wet test must be wrong; no apparent reason.
1530	Canadian Marble and Granite Works (White type)	Kootenay lake	12,486 13,103	11,978	9,362	Sharp failures; wedges.
1531	Canadian Marble and Granite Works (Dark type)	Kootenay lake	13,188 11,471 11,172	10,691	11,069	Tests all good. Wet must be a little low.
1532	E. W. Gillette (White type)	Kootenay lake	13,987	10,184	11,560	Upper flat pyramids. Wet is a little low.
1533	E. W. Gillette (Dark type)	Kootenay lake	13,267	16,530	13,250	Dry test is too low; cube failed from one side.

VOLCANIC ROCKS.

No.	Owner or locality	Area	Crushing strength, lbs. per sq. in.			Remarks
			Dry	Wet	Wet after freezing	
1414	W. S. McDonald	Haddington island	18,428	13,847	11,415	Fine lines before collapse; flat lower pyramid.
1495	D. P. Selby	Kamloops	13,242	13,875	....	The frozen cube disintegrated. Other tests of dry cubes gave still lower results. The stone is really stronger when wet.

TABLE V.

The Transverse Strength of British Columbia Building Stones.

GRANITES AND RELATED ROCKS.

No.	Owner	Area	Modulus of rupture, lbs. per sq. n.	Remarks
1453	West Coast Granite Co...	Jervis inlet	3,521	Sharp snap. Irregular fracture on line on one side and ·5 in. off on the other.
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway	2,457	Sharp snap. Fracture even but wavy, diagonal across line.
1462	Sechelt Granite Quarries.	Jervis inlet......	1,453	Gentle snap. Fracture uneven, on line above but to one side below.
1467	Vancouver Granite Co...	Jervis inlet......	3,139	Fair snap. Fracture slightly irregular, ·15 in. off line on one side and ·5 in. off on the other.
1487	Vancouver Granite Co...	Jervis inlet......	2,871	Gentle snap. Fracture uneven, ·15 in. off line above and ·5 in. off line below.
1493	Canadian Pacific Railway Co.	Canadian Pacific Railway	2,340	Fair snap. Fracture rather uneven, on line on one side and ·2 in. off on the other.
1497	Benjamin Lefroy........	Okanagan lake ...	2,032	Fracture slightly uneven but practically on line.
1498	Vernon Granite and Marble Works	Okanagan lake	1,968	Fracture very uneven, convex towards line and ·25 in. off at nearest point.
1512	Canadian Pacific Railway Co.	Coryell.....	2,278	Fair snap. Fracture slightly uneven, almost on line above but a little off below.
1514	Kootenay Granite and Monumental Co.	Nelson..........	1,708	Fair snap. Fracture slightly uneven, and diagonal to line above, to one side below.
1523	Canadian Pacific Railway Co.	Nelson..........	2,543	Gentle snap. Fracture slightly uneven, on line at one side and ·4 in. off on the other.
1524	Canadian Marble and Granite Works	Nelson..........	2,158	Gentle snap. Fracture fairly even, straight, and almost on line.
1577	Prince Rupert Granite Co.	Prince Rupert....	1,476	Fair snap. Fracture slightly irregular, on line at one side and ·75 in. off on the other.
1578	Alfred C. Gardé........	Prince Rupert....	1,646	Gentle snap. Fracture fairly even but slightly diagonal to median line.
1515	Canadian Pacific Railway Co.	Rossland........	1.692	Gentle snap. Fracture irregular and hackly, on line at one side and ·25 in. off on the other.

GRANITES AND RELATED ROCKS—*Continued*

No.	Owner	Area	Modulus of rupture, lbs. per sq. in.	Remarks
1494	W. H. Johnston; James A. Gill	Kamloops.	3,253	Fair snap. Fracture hackly on line above, to one side and more irregular below.

SANDSTONES.

No.	Owner	Area	Modulus of rupture, lbs. per sq. in.	Remarks
1429	Western Fue Co.	Nanaimo.	1,170	Gentle snap. Fracture even on line above, slightly to one side below.
1434	Henry Lys.	Nanaimo	841	Gentle snap. Fracture hackly and slightly diagonal to line.
1441	E. G. Bittancourt	Southern Gulf islands	2,296	Gentle snap. Fracture even, nearly on line above, rougher and slightly off below.
1445	Mrs. David	Southern Gulf islands	892	Gentle snap. Fracture wavy but almost on line.
1449	George Taylor	Southern Gulf islands	1,212	Fair snap. Fracture very even, and exactly on line.
1450	George Taylor	Southern Gulf islands	967	Gentle snap. Fracture even but slightly diagonal to line, rougher below.
1481	Denman Island Stone Co.	Denman-Hornby islands	1,128	No snap. Fracture straight and even on line.
1485	Murray, Martin and Murray	Denman-Hornby islands	778	No snap. Fracture straight above, irregular below, on line on one side, ·2 in. off on the other.
1486	Murray, Martin and Murray	Denman-Hornby islands	704	Gentle snap. Fracture even, on line at one side, ·2 in. off on the other.
1488	Vancouver Granite Co.	Nanaimo	849	Gentle snap. Fracture even and parallel to line but ·2 in. to one side.

MARBLES.

No.	Owner	Area	Modulus of rupture, lbs. per sq. in.	Remarks
1424	Nootka Quarries, Ltd.	Nootka sound	1,589	Gentle snap. Fracture slightly irregular and slightly diagonal to line.
1425	Nootka Quarries, Ltd.	Nootka sound	1,262	Gentle snap. Fracture even, slightly diagonal above and to one side below.
1426	Nootka Quarries, Ltd.	Nootka sound	2,349	Sharp snap. Fracture even, but hackly, on line at one side and ·2 in. off on the other.
1468	Malaspina Marble Co.	Southern Texada island	2,466	Gentle snap. Fracture hackly but fairly straight, ·15 in. off line on one side and ·25 in. on other.
1530	Canadian Marble and Granite Co.	Kootenay lake.	2,127	Fair snap. Fracture even, on line at one side and ·2 in. off on the other.

MARBLES—*Continued*

No.	Owner	Area	Modulus of rupture, lbs. per sq. in.	Remarks
1531	Canadian Marble and Granite Co.	Kootenay lake....	1,577	Fair snap. Fracture slightly uneven, on line at one side and ·2 in. off on the other, diagonal across line below.
1532	E. W. Gillette..........	Kootenay lake....	1,254	Fair snap. Fracture uneven and hackly, on line at one side and ·2 in. off on the other, irregular below.
1533	E. W. Gillette..........	Kootenay lake....	1,581	Fair snap. Fracture straight on line at one side and ·1 in. off on the other.

VOLCANIC ROCKS.

1414	W. S. McDonald.......	Haddington island	1,160	Gentle snap. Fracture straight but slightly diagonal to line and more pronounced below.
1495	D. P. Selby............	Kamloops........	2,622	Sharp snap. Fracture very smooth and even, slightly diagonal to line.

TABLE VI.

The Shearing Strength of British Columbia Building Stones.

GRANITES AND RELATED ROCKS.

No.	Owner	Locality	Area	Shearing strength, lbs. per sq. in.
1453	West Coast Granite Co..	Granite island......	Jervis inlet	2,756
1454	Patterson, Chandler and Stephen	Agassiz...........	Canadian Pacific Railway	1,842
1462	Sechelt Granite Quarries. .	Hardy island........	Jervis inlet	1,393
1467	Vancouver Granite Co...	Nelson island......	Jervis inlet	2,343
1487	Vancouver Granite Co....	Nelson island......	Jervis inlet	2,300
1493	Canadian Pacific Railway Co.	Cathmar.......	Canadian Pacific Railway	2,120
1497	Benjamin Lefroy.........	Okanagan lake....	Okanagan lake.......	2,205
1498	Vernon Granite and Marble Works	Okanagan lake.....	Okanagan lake.......	1,821
1512	Canadian Pacific Railway Co.	Coryell..........	Coryell.............	2,752
1514	Kootenay Granite and Monumental Co.	Three-mile point, Kootenay lake	Nelson.............	1,790
1523	Canadian Pacific Railway Co.	Granite..........	Nelson.............	1,418
1524	Canadian Marble and Granite Works	Nelson..........	Nelson.............	2,610
1577	Prince Rupert Gr. Co.....	Smith island......	Prince Rupert......	1,425
1578	Alfred C. Gardé.........	Tyee...............	Prince Rupert	1,535
1515	Canadian Pacific Railway Co.	Rossland............	Rossland............	1,053
1494	W. H. Johnston; James A. Gill	Kamloops lake.......	Kamloops...........	2,807

SANDSTONES.

No.	Owner	Locality	Area	Shearing strength, lbs. per sq. in.
1429	Western Fuel Co.	Newcastle island	Nanaimo............	1,406
1434	Henry Lys..............	Jack point..........	Nanaimo............	1,053
1441	E. G. Bittancourt	Saltspring island....	Southern Gulf islands.	1,926
1445	Mrs. David............	Mayne island........	Southern Gulf islands.	1,227
1449	George Taylor.......	Saturna island........	Southern Gulf islands	1,404
1450	George Taylor.......	Saturna island	Southern Gulf islands.	1,297
1481	Denman Island Stone Co..	Denman island.....	Denman-Hornby islands	846
1485	Murray, Martin and Murray	Hornby island......	Denman-Hornby islands	1,058
1486	Murray, Martin and Murray	Hornby island......	Denman-Hornby islands	628
1488	Vancouver Granite Co....	Gabriola island.......	Nanaimo...........	1,054

MARBLES.

No.	Owner	Locality	Area	Shearing strength, lbs. per sq. in.
1424	Nootka Quarries, Ltd....	Nootka sound........	Nootka sound........	1,341
1425	Nootka Quarries, Ltd....	Nootka sound........	Nootka sound........	1,390
1426	Nootka Quarries, Ltd ...	Nootka sound........	Nootka sound........	1,114
1468	Malaspina Marble Co ...	Anderson bay, Texada island	Southern Texada island	1,782
1530	Canadian Marble and Granite Co.	Marblehead..........	Kootenay lake........	1,156
1531	Canadian Marble and Granite Co.	Marblehead..........	Kootenay lake........	1,248
1532	E. W. Gillette...........	Kaslo..............	Kootenay lake........	1,688
1533	E. W. Gillette..........	Kaslo..............	Kootenay lake........	1,097

VOLCANIC ROCKS.

No.	Owner	Locality	Area	Shearing strength, lbs. per sq. in.
1414	W S. McDonald........	Haddington island....	Haddington island....	1,156
1495	D. P. Selby............	Dea e lake...........	Kamloops............	2,142

TABLE VII.

The Drilling and the Chiselling Factors of British Columbia Building Stones.[1]

GRANITES AND RELATED ROCKS.

No.	Owner	Area	Drilling factor, millimetres per 30 seconds
1453	West Coast Granite Co.	Jervis inlet	6·3
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway	6·8
1462	Sechelt Granite Quarries	Jervis inlet	7·4
1467	Vancouver Granite Co.	Jervis inlet	5·6
1487	Vancouver Granite Co.	Jervis inlet	7·0
1493	Canadian Pacific Railway Co.	Canadian Pacific Railway	5·5
1497	Benjamin Lefroy	Okanagan lake	7·9
1498	Vernon Granite and Marble Works	Okanagan lake	8·5
1512	Canadian Pacific Railway Co.	Coryell	9·2
1514	Kootenay Granite and Monumental Co.	Nelson	6·5
1523	Canadian Pacific Railway Co.	Nelson	4·6
1524	Canadian Marble and Granite Works	Nelson	3·5
1577	Prince Rupert Granite Co.	Prince Rupert	6·4
1578	Alfred C. Gardé	Prince Rupert	6·2
1515	Canadian Pacific Railway Co.	Rossland	6·7
1494	W. H. Johnston; James A. Gill	Kamloops	4·7

SANDSTONES.

No.	Owner	Area	Drilling factor, mm. per 30 sec.	Chiselling factor, grams per 3 in. per 10 sec.		
				Factor		Remarks
				I	II	
1429	Western Fuel Co.	Nanaimo	15·1	·3	3·1	Even track, no side chips, II slightly jumpy.
1434	Henry Lys	Nanaimo	25·4	1·0	3·9	Even track, no side chips, II slightly jumpy.

[1] This table should not be used without due consideration of the remarks on page 14 *et seq.*

SANDSTONES—*Continued.*

No.	Owner	Area	Drilling factor, mm. per 30 sec.	Chiselling factor, grams per 3 in. per 10 sec. Factor I	Factor II	Remarks
1441	E. G. Bittancourt	Southern Gulf islands	12·4	·15	1·1	Track smooth. Tool was rapidly dulled.
1445	Mrs. David	Southern Gulf islands	19·6	·6	4·7	Even track, no chips, II slightly jumpy.
1449	George Taylor	Southern Gulf islands	25·4	2·3	5·9	Good track, small side chips, II slightly jumpy.
1450	George Taylor	Southern Gulf islands	27·0	1·2	4·2	Good track, small side chips, II slightly jumpy.
1481	Denman Island Stone Co	Denman-Hornby islands	27·8	2·8	10·0	II very jumpy with some side chips.
1485	Murray, Martin and Murray	Denman-Hornby islands	37·4	2·6	7·2	Good tracks, II jumpy but with very small chips.
1486	Murray, Martin and Murray	Denman-Hornby islands	38·0	3·6	11·3	II with considerable side chipping, jumpy.
1488	Vancouver Granite Co	Nanaimo	23·2	1·1	5·2	Good tracks, slightly jumpy, no side chips.

MARBLES.

No.	Owner	Area	Drilling factor, mm. per 30 sec.	Chiselling factor, grams per 3 in. per 10 sec. Factor I	Factor II	Remarks
1424	Nootka Quarries, Limited	Nootka sound	17·2	·2	3·0	Even tracks, but results a little low possibly.
1425	Nootka Quarries, Limited	Nootka sound	22·4	·6	5·3	II jumpy, stone liable to break, results low?
1426	Nootka Quarries, Limited	Nootka sound	18·2	·2	3·6	Even track, no side chips, II may be a little low.

MARBLES—*Continued.*

No.	Owner	Area	Drilling factor, mm. per 30 sec.	Chiselling factor, grams per 3 in. per 10 sec.		
				Factor		Remarks
				I	II	
1468	Malaspina Marble Co.	Southern Texada island	16·0	·4	5·6	II, rough and uneven with side chips; I, good track.
1530	Canadian Marble and Granite Works	Kootenay lake	22·2	·9	4·3	Both tracks smooth and even, no chips, no jumps.
1531	Canadian Marble and Granite Works	Kootenay lake	17·2	2·0	8·2	Both tracks smooth and even, no chips, no jumps.
1532	E. W. Gillette	Kootenay lake	15·4	·4	6·3	II, rough and jumpy; stone is too coarse for test.
1533	E. W. Gillette	Kootenay lake	27·4	·4	7·6	II is jumpy with small side chips.

VOLCANIC ROCKS.

No.	Owner	Area	Drilling factor, mm. per 30 sec.	Chiselling factor, grams per 3 in. per 10 sec.		
				Factor		Remarks
				I	II	
1414	W. S. McDonald	Haddington island	19·6	2·2	5·4	Fair tracks, both jumpy, II with small chips.
1495	D. P. Selby	Kamloops	46·8	5·6	High	I is very jumpy. II impossible as chisel digs straight into slab and stops motor.

TABLE VIII.

The Loss in Weight per Square Inch of Surface Exposed, and the Colour Changes produced by soaking specimens of British Columbia Stones in Water saturated with Oxygen and Carbonic Acid for four weeks.

GRANITES AND RELATED ROCKS.

No.	Owner	Area	Loss in weight, grams per sq. in.	Colour changes
1453	West Coast Granite Co.	Jervis inlet..........	·000197	The feldspars become whiter and more opaque.
1454	Patterson, Chandler and Stephen	Canadian Pacific Railway..........	·000536	No apparent effect.
1462	Sechelt Granite Quarries	Jervis inlet..........	·000702	The feldspars become whiter and the minerals are more sharply defined.
1467	Vancouver Granite Co..	Jervis inlet..	·001264	The feldspars become more opaque and the contrast is increased.
1487	Vancouver Granite Co.	Jervis inlet..........	·000851	Very little change.
1493	Canadian Pacific Railway Co.	Canadian Pacific Railway	·0008	No visible change.
1497	Benjamin Lefroy.......	Okanagan lake........	·001963	The definition of components is increased.
1498	Vernon Granite and Marble Works	Okanagan lake........	·00153	No visible effect.
1512	Canadian Pacific Railway Co.	Coryell..............	·001635	No visible effect.
1514	Kootenay Granite and Monumental Co.	Nelson..............	·00138	The feldspars become less translucent.
1523	Canadian Pacific Railway Co.	Nelson..............	·00217	No visible change.
1524	Canadian Marble and Granite Works	Nelson..............	·000663	No visible change.
1577	Prince Rupert Granite Co.	Prince Rupert........	·000486	Very slight change.
1578	Alfred Gardé..........	Prince Rupert........	·000373	The yellow epidote is more sharply defined.
1515	Canadian Pacific Railway Co.	Rossland.............	·00474	The contrast between components is increased.
1494	W. H. Johnston; James A. Gill	Kamloops............	·0028	Decidedly changed. The green cast disappears and the surface is covered with bright red dots.

SANDSTONES.

1429	Western Fuel Co...	Nanaimo.	·00997	Rougher and with more contrast.
1434	Henry Lys.........	Nanaimo............	·0122	Blue tone gone; distinctly buff with white and dark spots.

SANDSTONES *Continued*

No.	Owner	Area	Loss in weight, grams per sq. in.	Colour changes
1441	E. G. Bittancourt	Southern Gulf islands	·00533	Slightly lighter and less blue with a tendency to buff. More contrast between grains.
1445	Mrs. David...........	Southern Gulf islands	·0109	Practically no change.
1449	George Taylor	Southern Gulf islands	·0113	Slightly more yellow.
1450	George Taylor	Southern Gulf islands	·01066	Blue tone gone; distinctly lighter and more yellow.
1481	Dennam Island Stone Co.	Denman-Hornby islands	·01775	Blue tone gone; buff with the grains more sharply defined.
1485	Murray, Martin and Murray	Denman-Hornby islands	·0838	Slightly more yellow.
1486	Murray, Martin and Murray	Denman-Hornby islands	·01036	No visible change.
1488	Vancouver Granite Co..	Nanaimo............	·00861	Blue tone gone; distinctly buff with light and dark grains more defined.

MARBLES.

1424	Nootka Quarries, Ltd..	Nootka sound......	·1495	Whiter, distinctly etched, sharper contrast between clear and opaque crystals; small crystals of tremolite in relief.
1425	Nootka Quarries, Ltd..	Nootka sound.....	·1408	Etched; strong contrast between light and dark crystals; a few tremolite crystals.
1426	Nootka Quarries, Ltd ..	Nootka sound.......	·1348	Like No. 1424 but with much more tremolite.
1468	Malaspina Marble Co..	Southern Texada island	·1236	Red part is pitted and shows whitish veins. When wet the red is darker and the contrast is increased.
1530	Canadian Marble and Granite Works	Kootenay lake......	·1346	Etched, small pyrite crystals revealed but not attacked. No tremolite.
1531	Canadian Marble and Granite Works	Kootenay lake......	·1116	Etched and with greater contrast. No tremolite or pyrite.
1532	E. W. Gillette.........	Kootenay lake......	·103	Whitened and etched. Large crystals of tremolite show in relief and are slightly yellowed.
1533	E. W. Gillette.........	Kootenay lake........	·0934	Whitened, etched, and with greater contrast. Tremolite shows in relief.

MARBLES—*Continued*

No.	Owner	Area	Loss in weight, grams per sq. in.	Colour changes
1249	Grant Brook Mble. Co.	Grant Brook.........	·00586	Very little etched and colour scarcely affected.
1250	Grant Brook Mble. Co.	Grant Brook.........	·00599	Very little etched. The fine mottling is slightly enhanced.

VOLCANIC ROCKS.

1414	W. S. McDonald.......	Haddington island....	·01058	Very little change. A slight lamination is revealed and the scattered dots are darker.
1495	D. P. Selby...........	Kamloops..	·01247	General colour little affected but fine bright red dots are developed throughout.

APPENDIX II.

Production of Stone in British Columbia in 1913, 1914, and 1915.

Year	Building stone	Ornamental & monumental	Rubble	Crushed stone	Paving and curb	Furnace flux	Total
1913..	$112,763	$ 834	$238,893	$182,495	$7,064	$38,830	$ 580,879
1914..	151,391	300	736,247	79,310	6,000	51,435	1,024,683
1915..	271,693	1,500	388,395	59,194	———	76,094	796,876

APPENDIX III.

Production of Stone by Classes in British Columbia in 1913, 1914, and 1915.

Year	Limestone	Granite	Marble	Sandstone	Total
1913..	$38,830	$469,666	$ 600	$71,783	$ 580,879
1914.	51,435	918,131	3,343	51,744	1,024,683
1915..	79,583	701,593	1,700	14,000	796,876

APPENDIX IV.

Production of Stone in Canada by Provinces in 1915.

Province	Granite	Limestone	Marble	Sandstone	Total	Per cent	Labour	
							Men employed	Wages
Nova Scotia	$ 79,636	$ 255,024	....	$ 33,264	$ 367,924	8·7	659	$ 233,396
New Brunswick	8,335	....	....	145,177	153,512	3·6	192	74,845
Quebec	594,744	1,189,633	$145,400	36,417	1,966,194	46·3	2,638	1,045,280
Ontario	140,894	634,728	10,927	19,588	806,137	19·0	1,009	371,218
Manitoba	351	153,113	....	....	153,464	3·6	148	94,785
Alberta	....	....	....	890	890	....	8	700
British Columbia	701,593	79,583	1,700	14,000	796,876	18·8	490	368,078
Total	$1,525,553	$2,312,081	$158,027	$249,336	$4,244,997			$2,188,302
Per cent	35 9	54·5	3·7	5·9	....	100·0		

APPENDIX V.

Reference List by Number to the Stones described in this Report.

Number	Class of Stone	Locality	Page
1249	Marble	Grant Brook	144
1250	"	"	145
1400	Granite	Esquimalt	107
1401	Volcanic	"	186
1402	"	Albert head	184
1403	"	"	184
1404	"	"	184
1405	"	"	185
1406	Marble	Rosebank	159
1407	"	"	159
1408	"	"	159
1409	Volcanic	Brentwood	186
1410	Limestone	"	157
1411	"	Bembarton	158
1412	Dolomite	"	158
1413	Volcanic	"	186
1414	Andesite	Haddington island	187
1417	Limestone	Tahsis arm, Nootka sound	171
1418	"	" "	163
1419	"	" "	171
1420	Marble	" "	171
1421	"	" "	171
1423	Volcanic	Deserted creek, Nootka sound	186
1424	Marble	" "	166
1425	"	" "	165
1426	"	" "	168
1427	Dolomite	" "	164
1428	Marble	" "	169
1429	Sandstone	Newcastle island	46
1430	"	Gabriola island	51
1432	"	Protection island	48
1433	"	" "	48
1434	"	Jack point, Nanaimo	42
1435	"	Nanaimo	44
1436	"	"	44
1437	"	Valdes island	52
1438	"	"	52
1439	"	Galiano island	52
1440	"	Saltspring island	54
1441	"	" "	53
1442	"	Pender island	57
1443	"	" "	57
1444	"	Mayne island	55
1445	"	" "	55
1446	"	Saturna island	58
1449	"	" "	59
1450	"	" "	61
1451	"	Koksilah	63
1452	"	"	64
1453	Granite	Granite island	89
1454	"	Agassiz	73
1455	"	Burrard inlet	79
1456	"	" "	79
1457	"	" "	79
1458	"	" "	80

Number	Class of Stone	Locality	Page
1459	Volcanic	Burrard inlet	183
1460	Granite	" "	81
1461	"	Nelson island	87
1462	"	" Hardy island	93
1463	"	Fox island	91
1464	"	Granite island	90
1465	"	" "	90
1467	"	Nelson island	86
1468	Marble	Texada island	151
1469	"	" "	153
1470	"	" "	153
1471	"	" "	153
1472	"	" "	181
1473	"	" "	153
1474	"	" "	161
1475	"	" "	162
1476	"	" "	162
1477	Granite	Walsh cove, Redonda island	162
1478	"	Pitt Meadows	77
1479	"	Pitt lake	78
1480	Sandstone	Hornby island	40
1481	"	Denman island	34
1482	"	Hornby island	40
1483	"	" "	40
1485	"	" "	38
1486	"	" "	39
1487	Granite	Nelson island	85
1488	Sandstone	Gabriola island	49
1489	Granite	Agassiz	73
1490	"	Waleach	75
1493	"	Cathmar	76
1494	Porphyrite	Kamloops lake	182
1495	Volcanic tuff	Dease lake, Kamloops	180
1496	"	" "	181
1497	Granite	Okanagan lake	67
1498	"	" "	69
1499	"	Armstrong	70
1500	"	Greenwood	114
1503	Marble	Grand Forks	141
1512	Monzonite	Coryell	120
1513	Marble	Fife	149
1514	Granite	Nelson	112
1515	Monzonite	Rossland	118
1516	Marble	Sheep creek	148
1517	"	"	148
1518	"	"	148
1521	Monzonite	Ymir	122
1523	Granite	Nelson	109
1524	"	"	110
1525	Limestone	Marblehead	133
1526	Marble		133
1527	"	"	133
1528	"	"	133
1529	"	"	133
1530	"	"	130
1531	"	"	131
1532	"	Kootenay lake	135
1533	"	" "	137
1534	Gneiss	" "	137
1535	Marble	" "	139

Number	Class of Stone	Locality	Page
1536	Marble	Kaslo creek	139
1537	"	"	139
1538	"	"	139
1539	"	"	139
1540	"	"	139
1540a	"	Arrowhead	140
1541	Slate	Golden	194
1542	Granite	Nelson island	88
1543	"	Deep bay	104
1544	"	Melanie cove	103
1545	"	Pendrell sound	102
1546	"	Walsh cove, Redonda I	100
1547	"	Dean point, Redonda I.	101
1548	Marble	Redonda island	162
1549	"	" "	162
1550	Granite	Squirrel cove, Cortes I	101
1551	"	Blind cove, Cortes I	105
1552	"	Lund	104
1553	"	"	104
1554	"	"	105
1555	Andesite	Haddington island	189
1556	"	" "	189
1557	Sandstone	Port McNeill	41
1557	Gabbro	Midsummer island	123
1558	Orbicular gabbro	" "	124
1559	Marble	Harbledown island	156
1560	"	Beaver cove	172
1561	"	"	172
1562	"	Kum-ea-lon	173
1563	"	Khutzeymateen inlet	173
1564	"	Banks island	173
1565	"	Elliott island	173
1566	Schist	Prince Rupert	197
1567	Marble	Banks island	173
1568	Granite	Dundas island	95
1569	"	Falls river	95
1572	Marble	Digby island	174
1573	"	"	174
1574	"	"	174
1575	"	"	174
1577	Granite	Smith island	96
1578	"	Tyee	98
1579	Marble	White Cliff island	175
1580	"	" "	175
1581	Schist	" "	175
1585	Marble	Shames	176
1586	"	"	176
1587	"	"	176
1588	"	"	176
1589	Granite	Little canyon	115
1590	"	"	115
1592	Sandstone	Hazelton	197
1593	"	"	198

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