GEOLOGY
AND
ECONOMIC MINERALS
OF
CANADA

GEOLOGICAL SURVEY,
DEPARTMENT OF MINES
OTTAWA,
1909.

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH.

A DESCRIPTIVE SKETCH

OF THE

GEOLOGY, AND ECONOMIC MINERALS

OF

CANADA.

BY

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INTRODUCTION

BY

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PART I.

INTRODUCTION

BY

R. W. Brock.

The present booklet is intended to give a brief account of the general geological conditions in Canada, and of the minerals which, under recent development, have assumed the greatest economic importance.

Excellent sketches covering the subject have been written by Dr. George M. Dawson, late Director of the Geological Survey of Canada; but these are now out of print, and the increasing demand for this general information has rendered necessary a new publication such as this. The present review is largely based on these preceding ones.

In a brief and general statement concerning so wide a subject, and covering so vast a territory, much that is interesting and important must of necessity be passed without notice; and the broad generalizations cannot be expected to present with absolute fidelity the actual facts. What has been attempted is, to give merely a general idea of the conditions obtaining in the various geological provinces into which the Dominion of Canada is naturally subdivided, together with the more important minerals which are characteristic of, or which have been exploited in each.

GEOLOGICAL INVESTIGATIONS.

The geological investigation of Canada may be said to have commenced in 1843, with the organization of the Geological

Survey of Canada, under Sir William Logan. The classical work of Logan, and his little coterie of assistants, Murray, Hunt, Billings, &c., was summarized in the Geology of Canada published in 1863, which deals with the southern portions of the Provinces of Ontario and Quebec. Since this was written the work of the Geological Survey has gradually widened, until, as at present, it embraces the northern half of the continent of North America. Much of this work has been exploratory. The great field to be covered with a small force has prevented concentration of effort, and in no single district can it be claimed that the geological problems are completely solved. The natural difficulties of travel in the northland have rendered the progress of even reconnaissance work tedious, and a large part of Canada is still practically unexplored. Nevertheless, sufficient has been done to make known its main geological features; to roughly indicate the territories that will be found to be mineral bearing; to presage the character of its mineral resources in the different geological provinces, and to demonstrate that Canada is destined to become one of the great mining countries of the world.

The reader is referred to the geological map, and to the mineral map for indications of the distribution of the main rock formations of the country, and important occurrences of minerals.

It will be noted on the mineral map, that the greater part of Canada is as yet unprospected. Even the portions of the country represented as being within the prospected territory must not be considered as more than partially explored for minerals. To illustrate the condition with respect to this: six years ago the line representing prospected territory would probably have been placed considerably north of Lake Timiskaming, yet only a few miles west of a silver lead deposit on Lake Timiskaming—that had been known for a century and a half—lay the undiscovered silver veins of Cobalt, recently revealed by constructing a railway through them.

It will, therefore, be readily seen that, the amount of mineral bearing territory still awaiting the prospector is prodigious, the greatest, in fact, that now remains anywhere on the globe.

The mining industries of the country may be said to have only just begun. The reason for this tardiness in developing the mineral resources is probably to be found in Canada's wealth in farming lands. The first settlers, in order to provide food, were forced to become agriculturalists. As population increased, and fertile lands were to be had in plenty, fresh acres were brought under the plough. Naturally, Canada became an agricultural country, and it was the farming lands that were sought after, and that were developed by lines of transportation. The lack of transportation facilities in the mineral bearing areas, and the extent of country in proportion to its population were contributory factors.

In 1886 the mineral production of Canada did not reach $10,250,000 in value, and was only $2.23 per capita. In 1908 the production was over $87,000,000, or $12.57 per capita. Although mining is only in its infancy, it has become one of the leading industries of the country. The output of the mine is now greater than the combined output of forest and sea, and ranks next to agriculture.

The total production of minerals for the last twenty-three years amounts to $926,516,579: of which gold represents $267,700,000.

Though just entering the field, Canada already ranks well among the mineral producing countries. According to the review of the world's production in 1907, Canada ranked first in asbestos and nickel; third in chromite; fourth in silver; seventh in copper; eighth in gold, and tenth in coal. The nature of the product, and the relative importance of the various minerals, is shown in the statement of the annual production for 1908, prepared by Mr. J. McLeish of the Mines Branch, Department of Mines.

ANNUAL PRODUCTION OF MINERALS IN CANADA, 1908.

Product.		Quantity.	Value.
Metallic.			
Copper	Lbs.	64,361,636	$ 8,500,885
Gold			9,559,274
Pig iron from Canadian ore	Tons	99,420	1,664,302
Lead	Lbs.	45,725,886	1,920,487
Nickel	"	19,143,111	8,231,538
Cobalt	"	1,853,286	112,253
Silver	Ozs.	22,070,212	11,667,197
Total value, metallic			41,655,936
Non-Metallic.			
Arsenic	Tons	699	38,054
Asbestos	"	65,534	2,547,507
Asbestos and asbestos sand	"	25,239	25,829
Calcium carbide	"	6,864	417,150
Coal	"	10,904,466	25,567,235
Chromite	"	7,225	82,008
Corundum	"	1,039	100,389
Feldspar	"	7,877	21,099
Graphite	"	251	5,565
Grindstone	"	3,843	45,128
Gypsum	"	340,964	575,701
Limestone for flux in iron furnace	"	418,661	289,705
Magnesite	"	120	840
Mica	"		191,602
Mineral Pigments:—			
Barytes	"	4,091	18,265
Ochres	"	4,746	30,440
Mineral waters			109,391
Natural gas (h)			1,012,060
Petroleum (i)	Bls.	527,987	747,102
Phosphate (apatite)	Tons	1,596	14,794
Pyrites	"	47,336	224,824
Quartz	"	27,134	32,277
Salt	"	79,975	378,798
Talc	"	1,076	3,048
Tripolite	"	36	195
Total value, non-metallic			$32,479,006

STRUCTURAL MATERIAL AND CLAY PRODUCTS.

Product.		Quantity.	Value.
Cement, natural	Bls.	1,044	$ 815
Cement, Portland	"	2,665,289	3,709,063
Flagstones	No.	4,000	3,600
Sand and gravel (exports)	Tons	298,954	161,387
Sewer pipe			514,042
Clay products, stone, lime, etc. Estimated			8,500,000
Total structural material prodacts and clay products			$12,888,907
All other non-metallic			32,479,006
Total value non-metallic			45,367,913
Total value metallic			41,655,936
Estimated value of mineral not reported			300,000
Total value 1908			$87,323,849

The geographical distribution is shown by the prod action of the provinces.

MINERAL PRODUCTION OF BRITISH COLUMBIA, 1907.

Material.		Quantity.	Value.
Gold, placer	Ozs.	41,450	$ 828,000
Gold, lobe	"	196,179	4,055,020
Silver	"	2,745,448	1,703,825
Lead	Lbs.	47,738,703	2,291,458
Copper	"	40,832,720	8,166,544
Coal	Tons, 2,240 lbs.	1,800,067	6,300,235
Coke	" "	222,913	1,337,478
Other materials			1,200,000
			$25,882,560

MINERAL PRODUCTION OF ALBERTA, 1907.

Material.	Quantity.
Lignite coal	639,355 tons
Bituminous coal	939,295 "
Anthracite coal	256,115 "
Coal used in coke production	112,887 "
Coke produced	73,782 "
Briquettes produced	49,585 "

MINERAL PRODUCTION OF ONTARIO, 1907.

Material.		Quantity.	Value.
Gold	Ozs.	3,810	$ 66,399
Silver	"	10,028,259	6,157,871
Cobalt	Tons.	739	92,751
Nickel	"	10,972	2,271,616
Copper	"	7,303	1,045,511
Iron ore		205,295	482,532
Pig iron		286,216	4,716,857
			$14,833,537
Less value Ontario iron ore (120,177 tons) smelted into pig iron			282,702
Net metallic production			$14,550,835

Non-Metallic.		Quantity.	Value.
Arsenic	Tons.	2,958	$ 40,104
Brick, common	No.	273,882,000	2,109,978
Tile drain	"	15,578,000	250,122
Brick, pressed	"	69,763,423	648,683
" paving	"	3,732,220	73,270
Building and crushed stone			675,000
Calcium carbide	Tons.	2,667	173,763
Cement, Portland	Bl.	1,853,692	2,777,478
" natural rock	"	7,239	5,097
Corundum	Tons.	2,683	242,608
Feldspar		12,328	30,375
Graphite	Tons.	2,000	20,000
Gypsum		10,186	19,652
Iron pyrites		15,755	51,842
Lime	Bu.	2,650,000	418,700
Mica	Tons.	456	82,929
Natural gas			746,499
Peat fuel	Tons.	200	1,040
Petroleum	Imp. gal.	27,621,851	1,049,631
Pottery			54,585
Quartz	Tons.	56,585	124,148
Salt	"	62,806	432,936
Sewer pipe			435,088
Talc	Tons.	1,870	5,010
Non-metallic production			$10,468,538
Add net metallic			14,550,835
Totals			$25,019,373

MINERAL PRODUCTION OF QUEBEC, 1907.

Product.		Quantity.	Value.
Bog iron ore	Tons of 2,000 lbs.	22,681	$ 80,231
Calcined ochre		2,300	29,430
Raw ochre		2,700	5,400
Chrome iron ore		6,407	63,130
Copper ore		29,574	160,455
Asbestos		61,985	2,455,919
Asbestic		29,193	27,293
Mica, trimmed		550,247	199,848
Mica, crude		150	24,030
Phosphate of lime		408	3,410
Prepared graphite		120	5,000
Magnesite		35	....
Slates	Squares	4,336	20,056
Flag stones	Sq. yds.	3,000	2,550
Cement	Bls.	....	640,000
Granite	Cub. yds.	51,873	560,236
Lime	Bu.	556,000	96,000
Bricks		94,000,000	525,000
Tiles and pottery		....	270,000
Limestones	Cub. yds.	97,710	223,580
			$5,391,568

MINERAL PRODUCTION OF NOVA SCOTIA.

(YEAR ENDING SEPT. 30, 1907.)

Material.		Quantity.
Coal	Gross tons.	5,730,660
Pig iron	Gross tons.	293,436
Coke made	Net tons.	493,102
Iron ore	Gross tons.	562,746[1]
Limestone	Net tons.	458,601
Gypsum	Gross tons.	332,345
Gold	Ozs.	15,006
Bricks		25,000,000
Building stones	Net tons.	63,861
Cement	Bls.	58,762
Antimony ore	Net tons.	1,403
Manganese ore	Gross tons.	495[2]
Copper ore	Net tons.	2,471
Drain pipe	Feet.	300,000
Grindstones	Net tons.	350
Copper	Lbs.	12,320
Moulding sand	Net tons.	190

[1] Including imported ore. N.S. ore 48,337 tons.

[2] Imported.

DISTRIBUTION OF THE CHIEF MINERALS.

Coal is abundant and is extensively worked in the eastern and western provinces. The more important mines are situated in Nova Scotia, British Columbia, and Alberta. New Brunswick produces small quantities of coal for local use, and lignites are mined to some extent in Saskatchewan. There is no available coal in Ontario and Quebec, but the abundant waterpowers that may be utilized for electrical energy, together with petroleum and natural gas in Ontario, to a considerable extent compensate for this deficiency.

Iron is found in most parts of Canada; but only in Nova Scotia, Ontario, and Quebec is it as yet of industrial importance, and here, only developed on a limited scale. Substantial progress is, however, being made, and notable expansion is to be expected.

Gold is worked in British Columbia, Yukon Territory, Ontario, Nova Scotia, and Quebec, and certain rivers in Alberta. In British Columbia the lode mines now furnish the principal production; but placers are still of importance. Ontario and Nova Scotia have only lode mining. Elsewhere, placer mining furnishes the gold.

Silver is to be credited to the rich silver ores of northern Ontario, and the silver-lead mines of British Columbia. The phenomenal development of the silver district of Cobalt and Montreal river has placed this region in the premier position among the silver camps of the world. An important addition to the output of silver is contributed by the gold-copper ores of British Columbia. A certain amount is also produced in the copper sulphur ores of Quebec.

Copper is furnished by British Columbia, Ontario, and Quebec—in the order named. The copper production of the former is rapidly expanding.

Lead is almost entirely derived from the mines of British Columbia, but it also occurs in the other provinces.

Zinc is widely distributed, but the production is as yet light, and mostly from the lead mines of British Columbia.

Nickel is one of the most important metallic products of Canada, but is largely confined to the mines of the Sudbury district in Ontario. A certain amount is produced in the Cobalt district, and prospects still farther north—resembling the Sudbury occurrences—are undergoing development.

Manganese, in the form of its oxides, is produced intermittently in Nova Scotia and New Brunswick.

Mercury has been furnished in small quantity by British Columbia.

Platinum occurs in some gold placer deposits in British Columbia, and also in the nickel-copper ores of Sudbury.

Tin and wolfram have recently been found in the gold veins of Nova Scotia. Wolfram also occurs in certain gold veins in British Columbia. Tin-bearing minerals have been found in certain pegmatites of eastern Ontario and Quebec.

Arsenic is obtained in connexion with gold ores in eastern Ontario, and in the silver ores of Cobalt.

Antimony is produced, to some extent, in Nova Scotia. It is being developed in New Brunswick, and at a few points in British Columbia.

Chromite is mined in Quebec.

Asbestos is the chief mining product of Quebec, and the deposits of this mineral in that Province are the most important in the world.

Graphite occurs in important deposits in eastern Ontario and Quebec; but the industry is not fully developed.

Gypsum is extensively mined in Nova Scotia, and New Brunswick. It is also mined in Ontario. It occurs in other provinces as well, and is beginning to attract attention in British Columbia.

Mica is an important product of Ontario and Quebec, where it occurs in shoots in veins. Some of the deposits are very large.

Phosphate of lime, or apatite, is still produced, generally as a by-product of the mica mines.

Corundum is extensively produced in eastern Ontario, from deposits which, as regards purity and magnitude, are unique.

Feldspar occurs in wonderful purity in eastern Ontario and Quebec, and is of considerable industrial importance.

Pyrites is now mined extensively in Ontario, and to some extent in Quebec.

Petroleum and natural gas are obtained in Ontario; Alberta is also producing a large quantity of gas, and will probably develop petroleum fields.

Salt of excellent quality is obtained in Ontario, and in quantities regulated only by the requirements of the market. New Brunswick and Manitoba also furnish a certain amount.

Magnesite occurs in Quebec, and hydromagnesite in British Columbia. Little has yet been done in the way of their development, but the indications are that in the near future they will be utilized.

Structural materials and clay products are found throughout the country and the production is rapidly growing.

In addition to the mineral products just enumerated, a great many others that are useful or valuable have been found, and these will become economically important as the mineral resources become more extensively developed.

LATENT POSSIBILITIES OF THE MINERAL INDUSTRY.

More interesting, however, than past production or present development are the latent possibilities of the mineral industry.

Although, as has been said, the greater part of Canada is unprospected, and much of it even unexplored, what is known of its geological structure enables forecasts as to its mineral wealth to be made. As will be seen from the following pages the country falls naturally into a number of geological provinces, characterized by certain peculiarities in the way of rocks, rock structure, and minerals. The general outlines of these provinces are known. Their southern portions, at least, both in Canada and in the United States, have been more or less developed, demonstrating their mineral possibilities, and it is fair to assume that in the northward unprospected extensions of these provinces, the mineral deposits will also, in some measure, be repeated. Any hesitation one might feel about applying this principle is removed when one compares the results already obtained in the frontier camps, with the corresponding stage in the development of the older mining districts of Canada and the United States, in the same geological province, and when one remembers the discoveries that have followed the opening up of each new section, and considers that geological explorers report the occurrences of the same minerals and the same geological conditions in the north that characterize that geological province in the south.

A brief summary of the characteristics of the main natural divisions of the country will at least suggest the possibilities of great expansion in the mineral development of the country.

APPALACHIAN REGION

The southeastern portion of Quebec, together with the Maritime provinces, form the northeastern extension of the Appalachian Mountain system. The Appalachian region is characterized by rock formations, ranging from pre-Cambrian to Carboniferous, that are typically disturbed and thrown into a succession of folds. In Canada, the Appalachian extension is found to possess many of the minerals which have placed some of the eastern states in the foremost rank of mineral and industrial districts of the world. Important deposits of coal, iron, and gold are mined in Nova Scotia. Of lesser importance, but still considerable, are the gypsum, stone and building material industries; manganese, antimony, tripolite and barite are also mined, and some attention has been paid to copper.

Pennsylvania, which is probably the best developed Appalachian state, now has an annual production of domestic minerals approximately equal to $9,340 per square mile of territory, or to $67 per capita.

Nova Scotia has an annual production of about $1,000 per square mile, or $46 per capita. Taking into consideration the more intensive production which follows increase of population and development, a geological comparison would appear to be fair, and Nova Scotia would seem to possess proportionately equal mineral resources with the most favoured Appalachian states. Its coal reserves have been estimated by Hon. R. Drummond to be 6,000,000,000 tons.

The mineral development of New Brunswick is backward. This is partly due to the covering of soil, and the forested areas which make discoveries difficult; so that very little of it has been prospected. The principal products at present are gypsum, lime, coal, building material, grindstones, clays, and mineral water. Iron, manganese, and albertite have been important; and iron promises to again become prominent. Antimony is being mined; copper, lead, silver, nickel, gold and other minerals have been found. Shales rich in oils and ammonium salts occur in large quantity, and seem likely to give rise to an important industry.

The southeastern portion of Quebec—also belonging to this area—may be said to be a high producer of economic minerals.

The main asbestos mines of the world are situated in this area; and important industries are carried on in chrome iron ore, copper, and pyrites. Iron ores, and gold, also occur.

LOWLANDS OF THE ST. LAWRENCE VALLEY.

The southern portion of Ontario and the valley of the St. Lawrence are very similar, geologically, to the State of New York: consisting mainly of flat-lying Palæozoic rocks; and the mineral products are the same: clay, cement and other building materials, petroleum, natural gas, salt, gypsum and other non-metallic products—extremely valuable, if less showy than the metallic minerals.

THE LAURENTIAN PLATEAU.

North of the valley of the St. Lawrence, from Newfoundland to beyond Lake of the Woods, and enclosing Hudson bay like a huge V, is an area of pre-Cambrian rocks, estimated to cover 2,000,000 square miles, or over one-half of Canada. Over the greater portion reconnaissance surveys only have been made, and the southern fringe of it alone may be said to be known, and of this fringe only a portion prospected. These rocks of the pre-Cambrian are remarkable for the variety of useful and valuable minerals they contain. Iron, copper, nickel, cobalt, silver, gold, platinum, lead, zinc, arsenic, pyrite, mica, apatite, graphite, feldspar, quartz, corundum, talc, actinolite, the rare earths, ornamental stones and gems, building materials, etc., are all found, and are, or have been, profitably mined. Most of the other materials, both common and rare, that are used in the arts, have been found. Diamonds have not been located; but from their discovery in glacial drift from this area, it is altogether probable that they occur.

A tongue of these pre-Cambrian rocks extends into New York State, which supports some large and varied mineral industries. Another extension crosses over from Canada into Michigan, Wisconsin, and Minnesota. In it are located the Michigan Copper mines, and the great Lake Superior iron ranges. Along the southern edge of the pre-Cambrian in Canada, there are known the gold ranges of the Lake of the Woods; the silver of Thunder bay; a succession of iron ranges extending from Minnesota for hundreds of miles to Quebec; copper rocks of Michipicoten and Bruce mines;

the Sudbury copper nickel deposits; the Montreal River and Cobalt silver areas; the corundum deposits of eastern Ontario; the magnetites of eastern Ontario and Quebec, and their large apatite-mica deposits, etc. It is quite true that few good merchantable iron deposits have been found in our extensive iron range formations; but in the Mesabi range—the richest in the world—only about two per cent is iron ore, so that immediate discovery in the little prospected areas in Canada is scarcely to be expected. To realize the unprospected nature of the country, it is only necessary to remember that the greatest asbestos deposits of the world were brought to notice by blasting the Quebec Central railway through them; that the greatest corundum deposits extending in a belt a hundred miles long, were found in a settled district by an officer of the Survey only twelve years ago; that the Sudbury nickel deposits were discovered by putting a railway through them; that Cobalt, now the premier silver camp, although only a few miles from one of the earliest routes of travel in the country, and only a few miles from a silver-lead deposit known a hundred and fifty years ago, was discovered less than six years ago, and then only by means of a railway cutting through a rich vein.

In trying to form an idea of the mineral possibilities of this great stretch of 2,000,000 square miles, we have a few facts on which to base an opinion. It is known from the explorations of the Geological Survey, that scattered over this area are patches of all the various formations that go to make up the pre-Cambrian; that almost all the minerals known to occur in the developed southern edge have been noted by explorers in the north; that in the known or partially known southern border, are found the greatest iron mines in the world: mines that have produced over 400,000,000 tons of iron ore, and are calculated to furnish at least 1,500,000,000 tons more; what may still be called the greatest copper camp: having produced about 4,500,000,000 pounds of copper and yet steadily increasing its production; also the greatest nickel mines in existance; and what promises to prove one of the greatest silver districts. In fact, in the known districts of Canada the pre-Cambrian appears to be as important from the mineral standpoint as in the highly developed districts in the United States. It seems to be safe, therefore, to assume that in the great northern areas, as yet unattacked by the pick of the prospector, are vast stores of minerals which will become available as the country is opened up.

THE INTERIOR PLAIN.

The greater portions of Manitoba and Saskatchewan, which lie outside of the pre-Cambrian, and the Province of Alberta, are pre-eminently agricultural, but in addition to furnishing an important market for the product of the mines, they will have a large output of non-metallic minerals. The Interior plain is underlain for the most part by sedimentary rocks, chiefly of Cretaceous age, and containing coal, building stones, clays, and cement materials. Natural gas over wide areas and under great pressure has been tapped, and there is every indication of a large oil field in the northern portion, at least, of Alberta, and some oil has been encountered in the southwest. The lower sandstones of the Cretaceous along the Athabaska river, when they come to the surface, are for miles saturated with bitumen. These tar sands will probably average 12 per cent in maltha or asphaltum. Mr. R. G. McConnell estimates that the tar sands seen by him occupy 1,000 square miles, which, with the thickness of 150 feet, would give 28·40 cubic miles of tar sands in sight; or about 6·5 cubic miles of bitumen; or, by weight, 4,700,000,000 tons of bitumen. The lignites of the eastern plains, useful for local purposes, become more highly bituminized as the mountains are approached. Mr. D. B. Dowling has estimated the available coal in the known fields of the northwest provinces as follows:—

Province.	Area of Coal Land	Anthracite.	Bituminous.	Lignite.
	In Square miles.	In Million Tons.	In Million Tons.	In Million Tons.
Manitoba	48	....	....	330
Saskatchewan	7,500	....	....	20,000
Alberta	19,582	400	44,530	60,002
Mackenzie district	200	....	....	500

Gold is found in a number of the rivers coming from the mountains. Clay ironstone occurs in many parts of the northwest, and will in time be utilized. Salt and gypsum also occur.

THE CORDILLERAN BELT.

The Cordilleran belt, in South America, in Mexico, and in the western states, is recognized as one of the greatest mining regions of the world: noted principally for its wealth in gold, silver, copper, and lead. The Cordilleras stand unparalleled in the world for the continuity, extent, and variety of their mineral resources. In Canada, and in Alaska, this belt maintains its reputation; although in both for the greater part unprospected.

In Canada this belt has a length of 1,300 and a width of 400 miles. It is pre-eminently a great mining region. Its rocks range from the oldest formations to the youngest; vulcanism and mountain building processes have repeatedly been active.

Although developed along the International Boundary Line on the south, and while some of the main streams have been prospected to some extent for placer gold, the greater part of the belt is as yet untouched. Probably not one-fifth may be said to have been prospected at all; not one-twentieth prospected in detail; and not one area, however small, completely tested.

Lode mining may be said to have commenced in British Columbia about fifteen years ago, the production previous to this date being largely in placer gold and coal. In 1893 the annual production of minerals in British Columbia had a value of about $3,500,000; it now runs about $25,000,000. The total production of British Columbia to the end of 1907 was approximately $300,000,000. The Yukon, which up to the present has produced practically only placer gold, is credited with over $125,000,000.

The Cordilleran belt in Canada is not only rich in gold, silver, copper, lead, and zinc, but has enormous resources of coal of excellent quality, varying from lignites to anthracite, which is conveniently distributed. Only the coal areas in the southern portion of the Province, and a few small areas on the Telkwa and Nass rivers, and on the Yukon, are at present known; but the estimated coal in the known fields is enormous, as shown in the following table prepared by Mr. D. B. Dowling:—

	Coal Areas. In Square miles.	Anthracite. In Million Tons.	Bituminous. In Million Tons.	Lignite. In Million Tons.
British Columbia.	1,123	20	38,642	314
Yukon.	400	32	32	850

Great unprospected areas are known to contain, in places, coal formations, and will, no doubt, when explored, add greatly to the above reserves. The coal production is not large as compared with the supply; but a large increase in production may be expected in the near future, as these are the best steaming and coking coals in the west, and railway facilities will be provided to supply the transcontinental railways, and the great smelters in the northern states.

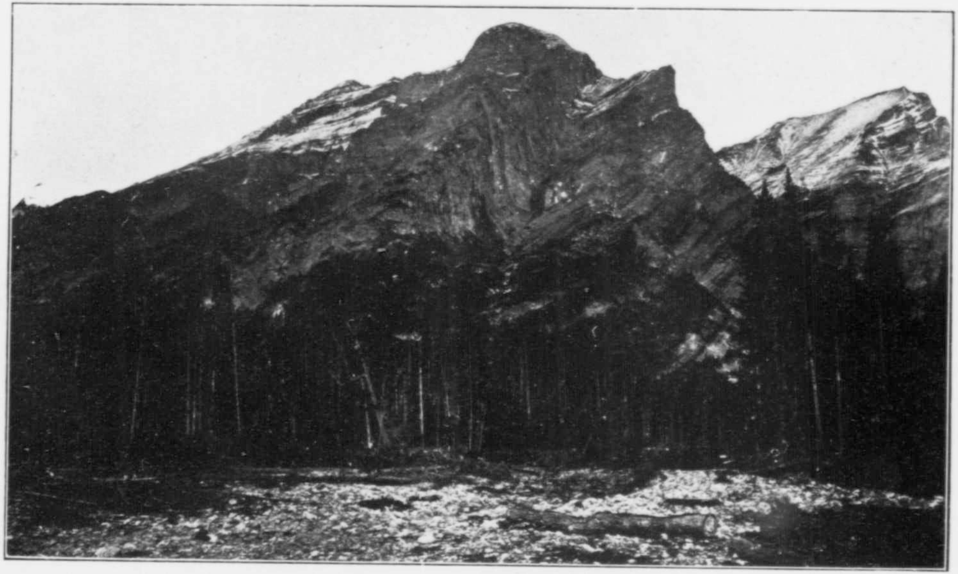
The whole belt of the Cordilleras, from Mexico to Alaska, may be considered as forming one general geological province. The nature and mode of occurrence of the minerals are in general similar throughout. The great mineral wealth of Mexico and the western states has been amply demonstrated by mining. Only about one-fifth of Alaska has been explored, and lack of transportation facilities, and rigorous climatic conditions still handicap rapid development; but already it has a large production, showing that the Cordillera maintains throughout, its highly mineralized character.

Probably nowhere along the Cordilleran belt has the maximum production been reached. The value of the production of the non-metallic minerals, such as coal, oil, etc., is rapidly growing, as is also that of the baser metals, copper and iron; and most of the minerals used in commerce and the arts are being produced.

The prospective resources of the Cordilleran belt in Canada may, therefore, be considered enormous. Though mostly unprospected, it has already been proved to possess the greatest coal fields; one of the greatest copper mines; one of the greatest silver-lead mines; and two of the greatest placer camps in western America—a region noted for its extraordinary mineral wealth.

Upon the knowledge already gleaned concerning the economic deposits of the Dominion, by geological exploration, by prospecting, and by actual mining, it is safe to predict that the mineral industry will become a very great and valuable one. Its development will render essential a close study of the geology of the country. The geological field in Canada is as rich and inviting as the mining. Perhaps half the rock history of the world is written in the pre-Cambrian, and it is of this portion that most remains to be deciphered. Since the greatest spread of these old rocks occurs in Canada, much of this work will fall to Canadian geologists, and the careful solution of the problems presented will be as valuable to science as to the mining industry.

NOTE.—For detailed descriptions of the geology and mineral resources, etc., the reader should consult the publications of the Geological Survey, and the Mines Branch, Department of Mines, also the reports of the Bureau of Mines of the several provinces.



Folds in mountain, Mount Kidd, Selkirks, B.C.

PART II.

A DESCRIPTIVE SKETCH

OF THE

GEOLOGY, AND ECONOMIC MINERALS

OF

CANADA

BY

G. A. Young.

CHAPTER I.

Introductory.

The description of the geology of Canada set forth in the following pages is only a generalized view of the subject. No attempt has been made to enter into details; since such a mode of procedure would greatly increase the bulk of the volume, and probably result in the production of a work of interest to only a very limited number of readers. Unfortunately, the broadly descriptive method adopted frequently renders it necessary to condense into a few words the description of the complicated geology of many and wide regions. There is, perhaps, a tendency to make it appear as though the geological history of the greater part of Canada was now definitely known, when in truth, there is scarcely a district in which important geological problems do not still remain unsolved.

Palæontological subjects have been scarcely touched upon, since, under the plan adopted, little better could have been offered than comparatively uninteresting lists of fossils. In dealing with the occurrences of the various economic minerals in different districts, no endeavour has been made to mention or describe all of the deposits that are at present of economic importance, nor all such as may yet become of value. Instead, as far as possible, the aim has been to indicate the nature and mode of occurrence of the more characteristic mineral deposits of each region. It will be apparent that, in following this plan, more space has been devoted to certain classes of deposits or individual occurrences than their relative economic importance would otherwise demand. The inclusion, under the title of mineral deposits, of descriptions of peat bogs, etc., cannot, of course, be strictly justified.

In dealing with the geology, the plan followed has been largely that adopted by the late Dr. G. M. Dawson in his admirable outline of the physical geography and geology of Canada, prepared for the Handbook of Canada at the time of the Toronto meeting, in 1897, of the British Association for the Advancement of Science. The author also wishes to record his indebtedness to Mr. R. W. Brock, Director of the Geological Survey, and to Messrs. W. McInnes and R. A. A. Johnston for aid received and revisions suggested during the preparation of the work. In the case of the description of the ore deposits, many sentences have been transcribed almost word for word from articles by numerous writers. Since in the present work it has seemed best not to give references to the host of authorities consulted, the author may only here acknowledge in general terms his indebtedness to the various geologists and professional men who have contributed to the written record of Canadian geology.

Canada embraces the northern half of the continent of North America, with its adjacent islands, including those of the Arctic ocean between the 141st meridian and Greenland, but exclusive of Alaska in the extreme northwest, the island of Newfoundland, which still remains a separate British colony and holds jurisdiction over the Labrador coast, and the small islands of St. Pierre and Miquelon, retained by France. The total area of Canada is estimated at about 3,729,665 square miles. This area is somewhat larger than the United States (including Alaska) and not much less than all Europe.

The form of the North American continent may be described as that of an isosceles triangle, of which the narrower part, pointing south, constitutes Mexico; a wide central belt—the United States; while the broader base is the Dominion of Canada. The northern margin of the continental land lies approximately on the seventieth parallel of north latitude, but in the east the land area is continued far northward by the great islands of the Arctic archipelago, while south of these the continent is broken into by the large but shallow sea named Hudson bay, 800 miles from north to south, and some 600 miles in width.

Surrounding Hudson bay lies the Laurentian plateau, or Canadian Shield, a tract of land underlain by ancient, largely crystalline rocks, and, though relatively elevated, scarcely ever rising over 2,000 feet above the sea, except in the extreme northeast. Spreading widely in the Ungava peninsula, this upland runs with narrower dimensions round the southern extremity of Hudson bay, and thence continues northwestward to the Arctic ocean. Along the southern margin of the Laurentian plateau lies the great waterway, the river St. Lawrence, reaching to the very centre of the continent, and expanding there into the group of inland fresh-water seas generally spoken of as the Great lakes, while the Winnipeg system of lakes, with Athabaska, Great Slave, and Great Bear lakes, occupies a very similar position on the outer rim of the western extension of the plateau.

Following respectively the trend of the southeast and southwest sides of the Laurentian plateau, the two great mountain systems of the North American continent—the Appalachian in the east, and the Cordilleran in the west—converge to the south, embracing between them, to the south of the Great lakes, the central plain of the continent that, west of the Laurentian plateau, extends northward through Canada to the Arctic ocean. But in the east, in Canada, the Appalachians closely follow the border of the Canadian Shield, separated from it only by the valley of the St. Lawrence river. While the two mountain systems of the continent are, with respect to one another, symmetrically disposed, they are opposed in extent and character. The Cordilleran system of the west embraces a mountainous tract, of which large areas are elevated more than 5,000 feet above the sea, with peaks rising to heights of 10,000 feet and more. On the other hand, the mountains or hills of the Appalachian system, in Canada, seldom rise more than 2,000 feet above the sea, and over the greater part of the eastern provinces—New Brunswick, Nova Scotia, and Prince Edward Island—the land lies below the 1,000 ft. datum line.

A large portion of Canada is essentially a region of lakes and rivers, and no feature of the country is more important, whether historically or geographically, than the great length and volume of its principal watercourses, and the manner in which these interlocking streams penetrate almost every part of the area. In eastern Canada—in the Maritime provinces—the waterways, though of local importance, and including the St. John river, nearly 400 miles long, are relatively unnoteworthy; but elsewhere are river and lake systems almost unequalled in size and extent. The St. Lawrence river, with its numerous tributaries, amongst which may be mentioned the Ottawa, nearly 700 miles long, drains a basin lying largely in Canada, and having an estimated area of 530,000 square miles. The easterly flowing St. Lawrence, with the great system of lakes at its head, offers, above Montreal, by aid of the canals on the Ste. Marie, Niagara, and St. Lawrence rivers, a navigable route nearly 3,000 miles long, leading to the heart of the continent; while, eastward of Montreal to the Strait of Belle Isle, for almost 1,000 miles the estuary of the river and the Gulf of St. Lawrence form a route for the largest sea-going vessels.

Emptying into Hudson bay and strait are numerous rivers, draining an estimated area of 1,486,000 square miles. The height of land bounding the Hudson Bay basin runs southwesterly through the Ungava peninsula, and westerly through Quebec and Ontario to near the head of Lake Superior, whence, diverging southward into the United States and again entering Canada, it follows a general westerly course to the Rocky mountains, leaving in southern Saskatchewan and Alberta a narrow strip of territory whose waters find their way to the Gulf of Mexico. Continuing northward for some distance along the crest of the Rocky mountains, the divide then assumes a general northeasterly course, and, passing just north of Edmonton, runs to a point north of Hudson bay. Within this basin, in the west, is the Saskatchewan river, rising in the Rockies and flowing easterly to the Winnipeg system of lakes, beyond which it is continued by the Nelson, emptying into the southwest corner of Hudson bay, thus forming a river system 1,660 miles long. North of the Saskatchewan lies the Churchill river, that, with its tributaries, has a total length of about 1,300 miles. Besides these, many other rivers, often of no inconsiderable size, drain countless lakes, large and small, and flow from all sides into Hudson bay.

In western Canada, northwest of the Hudson Bay basin, and between it and the continental divide, lies a great region of about 1,290,000 square miles, draining northward to the Arctic ocean.

The greater part of this territory is drained by the Mackenzie and its tributaries, affording a river system with a maximum length of about 2,500 miles. West of the continental divide, within the Cordilleran region, lies the Pacific basin, with an area of about 387,300 square miles, drained by numerous rivers breaking transversely through the northerly trending mountain ranges. In the south, the Fraser, 695 miles long, and the Columbia—only partly in Canada—are the chief rivers. In the north, the Yukon—about 1,760 miles long—drains an area in Canada of about 145,000 square miles, and finds its way through Alaska to Bering sea.

Thus, with the exception of a relatively insignificant area of about 13,000 square miles, the whole of Canada lies on the northern slope of the continent, draining into the northern Atlantic, the Arctic, or Pacific oceans.

Canada is notable not only for the size and volume of its great river systems, but also for its almost countless and often large lakes, that occur more particularly within or along the borders of the Laurentian plateau. Lying along the boundary between Canada and the United States are the large bodies of fresh water known as the Great lakes, having a total area of over 95,000 square miles, of which Lake Superior, the largest, occupies about 31,800 square miles, and Lake Ontario, the smallest, 7,260 square miles. Westward, in Manitoba, Lakes Winnipeg and Winnipegosis have areas respectively of 9,460 square miles and 2,086 square miles. Farther to the northwest lies Lake Athabaska, with an area of 2,842 square miles; Great Slave lake, 10,719 square miles, and Great Bear lake, 11,820 square miles. Besides these there are many other lakes whose size would place them in the first class.

In this connexion it may be useful to state the height of a few of the larger lakes, each of which marks the lowest level of large tracts of adjacent land. The Great lakes, though they stand at four levels, in reality occupy only two distinct stages, separated by Niagara Falls. Below this cataract is Lake Ontario, 246 feet above the sea; above it, Lake Erie, 572 feet; Lake Huron and Lake Michigan, 581 feet; and Lake Superior, 602 feet. Farther to the west are: Lake of the Woods, 1,057 feet; Lake Winnipeg, 710 feet; Lakes Manitoba and Winnipegosis, 810 feet and 840 feet respectively; Athabaska lake, 620 feet; Great Slave lake, about 520 feet; and Great Bear lake, about 390 feet.

The great, central, U-shaped Laurentian plateau, with an area of over 2,000,000 square miles, is, both physiographically and geologically, a dominant feature of Canada. Composed mainly of very ancient rocks, largely of the nature of granites, and formed during the first geological era, it represents a portion of the pre-Cambrian land, that at one time doubtless extended far to the north, west, and south, possibly forming a continental mass resembling the present one in extent. During succeeding ages, seas alternately advanced over and retreated from the area of this continental land, and in them were deposited the sandstones, shales, limestones, etc., now almost entirely surrounding the Laurentian upland, and in places lying within it.

East and west, towards the borders of the continent, periods of mountain building, of volcanic activity, and of invasions of deep-seated igneous bodies alternated with the processes of sedimentation. But during all these times the central Canadian Shield, as well as its westward extension now hidden by the younger strata of the western plains, remained comparatively stable, unaffected by mountain building processes or by the invasion of igneous masses. Probably a very large portion of the Laurentian highlands was never covered by the successively invading seas, in which, on all sides, were laid down great volumes of sediments, in part, at least, derived from the erosion of the central uplands.

Except locally, or for comparatively short periods of time, eastern Canada, from the close of the second great geological era (the Palæozoic), appears to have remained elevated above the sea, undergoing erosion and unaffected by mountain building processes. But west of the Canadian Shield, during Mesozoic and later times, sedimentation, mountain building, and igneous activity continued until a recent date. Thus Canada might be divided into two portions—an eastern one of relatively low relief and fundamentally underlain only by Palæozoic or older strata, and a western division, in which sedimentation continued through Mesozoic and Cenozoic times, accompanied by, in the west, igneous activity and the operations of mountain building forces. For the further description of the geology and physical features of the country it is, however, more convenient to employ a sixfold division, as follows:—

(1.) *The Appalachian Region*, including the portion of Canada east of a line running from Lake Champlain to the neighbourhood of the city of Quebec and thence down the channel of the St. Lawrence.

(2.) *The St. Lawrence Lowlands*, including the plains bordering the St. Lawrence river above the city of Quebec and extending through southern Ontario to Lake Huron.

(3.) *The Laurentian Plateau Region*, including the great U-shaped upland surrounding Hudson bay.

(4.) *The Arctic Archipelago*, including the islands of the Arctic ocean north of Hudson bay.

(5.) *The Interior Continental Plain*, including the central belt of plains lying between the western margin of the Laurentian plateau and the Rocky mountains.

(6.) *The Cordilleran Region*, including the mountainous region of the western portion of the continent.

CHAPTER II.

THE APPALACHIAN REGION.

GEOLOGY.

The *Appalachian region* of Canada may be defined as including the territory lying east of a line running northeast from the foot of Lake Champlain on the Vermont border, to the city of Quebec and thence down the St. Lawrence valley, that is, it contains most of the Province of Quebec lying east of the St. Lawrence, together with the Maritime provinces of New Brunswick, Prince Edward Island, and Nova Scotia. The country is part of a mountainous belt, the Appalachian Mountain system, that, commencing not far from the Gulf of Mexico, continues northeastward through the eastern portion of the continent to the Gulf of St. Lawrence, beyond which it reappears in the island of Newfoundland. Throughout this belt the strata are frequently highly folded and faulted, and evidence of igneous activity is not wanting; while within it, in Canada as elsewhere, are many valuable mineral deposits, including the asbestos deposits of southeastern Quebec, the most noted in the world, the coal and gold fields of Nova Scotia, as well as bodies of iron, copper, and various other ores.

The Appalachian Mountain system, throughout its entire course of 1,700 miles within the limits of the continental land, preserves a general southwest and northeast trend. South of New York state it is represented by two parallel ridges, upon the eastern one of which many peaks rise above 6,000 feet. In northern New York, the New England States, and eastern Canada, the mountain system is less regular in structure. In Vermont occur the Green mountains, whose highest peak rises to 4,430 feet. Farther east, towards the southeastern angle of the Province of Quebec, lie the White mountains, with Mount Washington 6,291 feet high. Northern Maine, bordering the Province of Quebec on the east, is also mountainous, with one peak rising above 5,000 feet. In eastern Canada, the Appalachian system, regarded

Hunter River, Prince Edward Island: typical island village.

Farming scene, Prince Edward Island.

as a mountainous belt, is, strictly speaking, represented only by the elevated tracts of eastern Quebec and northern New Brunswick. Elsewhere, over the greater part of the Maritime provinces, the Appalachian character is mainly represented by the general trend of the major hills and of the large indentations of the sea, and by the general geological structure of the country as a whole.

In the Eastern townships of southeastern Quebec, the Green mountains of Vermont are continued northeastward by the Notre Dame mountains, that approach the St. Lawrence below Quebec, and from there, bordering the estuary of the river, continue with increasing altitudes into and through the Gaspé peninsula, where they are known as the Shickshocks. In the Eastern townships the Notre Dame mountains are represented by three rudely parallel ridges, that, passing eastward, have progressively higher average elevations, and finally, over considerable areas, rise above 2,000 feet, with Sutton mountain, in the westernmost range, attaining a height of nearly 3,000 feet.

Proceeding northeastward to a point opposite the city of Quebec, the Notre Dame mountains sink to lower and lower elevations, but beyond this they again increase in height, so that in the Gaspé peninsula they form an uplifted area with a general elevation of from 1,000 feet to 2,000 feet, with many peaks rising above 3,500 feet. Throughout the elevated tract of eastern Quebec the country is largely drained by tributaries of the St. Lawrence, flowing northwestward through defiles which they have trenched across the northeasterly trending ridges.

In the Maritime provinces the Appalachian system is represented by the broken, hilly district of the northwestern part of New Brunswick, where the general elevation over considerable tracts of country is above 1,000 feet, while a number of hills rise over 2,500 feet above the sea. A second relatively high tract in this Province borders the Bay of Fundy, and, though much broken in its westward portion, forms a considerable area of plateau-like country, with a general elevation of about 1,200 feet. Lying between the two hilly portions, a very large part of New Brunswick has a mean elevation of only a few hundred feet, and the same is true of Prince Edward Island. The higher land of the peninsula of Nova Scotia forms a central ridge seldom reaching 1,200 feet, though, in what may be regarded as its continuation, in the island of Cape Breton, some higher points attain an altitude of 1,500 feet.

Though the general course of the hills of the Maritime provinces parallels that of the Appalachians, the propriety of including the territory in the Appalachian region is better shown by the geological features such as the Appalachian folding, and by the pronounced northeasterly trend of the whole Province of Nova Scotia, the parallel, long indentation of the Bay of Fundy in the southeast, and that of Chaleur bay, with the valley at its head, in the northwest.

The Appalachian region, though essentially a broken, often rugged, hilly country, contains many fertile, cultivated districts. Amongst these may be mentioned the valleys of the Eastern townships of Quebec, the St. John River valley of New Brunswick, and in Nova Scotia the Annapolis-Cornwallis valley that parallels the Bay of Fundy, from which it is separated by the long ridge of North mountain. Much of the Appalachian region in Canada is, however, a forested country, traversed by swiftly flowing streams, and, in parts of Nova Scotia and New Brunswick, dotted with small lakes. Some of these are very picturesque, and in Cape Breton the salt, nearly land-locked, Bras d'Or lakes, with their often bold shores, are justly noted for their beauty.

Geologically the Appalachian region of Canada is characterized by a very complicated structure. The strata, chiefly of Palæozoic age, at various times and over large tracts, have been greatly disturbed, traversed by many faults, and now lie in highly inclined positions. During earlier Palæozoic times, embayments of the sea spread over the region in question, alternately expanding and contracting, while frequently these bodies of water seem to have taken the form of long, wide sounds, extending in a general southwesterly direction, sometimes to join the great interior seas that flooded the central portions of the continent. In these embayments were deposited great volumes of sediments, which, during intervals of emergence, were eroded, and folded and faulted during successive periods of activity of mountain building forces. Over considerable districts intrusive areas of igneous rocks occur, and the geological history is further complicated by the local presence of volcanic material.

As a result of the successive action of similar mountain building processes in the Appalachian region, there is now a pronounced general tendency for the different formations to occur in elongated bands, striking approximately northeast and southwest. In the

Brook in Pictou County, N.S.

Eastern townships and Gaspé peninsula, along the central axes of folding and uplift, crystalline rocks of pre-Cambrian age are now exposed. Rocks of this ancient era occupy considerable areas within the two hilly regions of New Brunswick, and also in the northern and eastern portions of Cape Breton island.

Cambrian and Ordovician strata occupy much of southeastern Quebec, and continue northeastward into Gaspé, where they are accompanied by large volumes of Devonian and Silurian sediments. Silurian measures are widely displayed over northwestern New Brunswick, and appear, associated with Devonian, Ordovician and older strata, in the southern part of the Province. In Nova Scotia, Devonian and older beds occupy the main portion of the Province.

In the Canadian Appalachian region strata of Carboniferous and Permian age are confined almost entirely to the Maritime provinces, where they occupy all of Prince Edward Island, and, on the mainland, border the shores of the Gulf of St. Lawrence; while in southern New Brunswick they extend westerly almost completely across the Province. Triassic measures occur both in Nova Scotia and New Brunswick along the shores of the Bay of Fundy, but, with the exception of these beds, the Mesozoic system, as well as the Tertiary, is unrepresented in the Canadian Appalachian region.

The pre-Cambrian rocks of the Appalachian region are largely of igneous origin, often deformed and now schistose or gneissic. In the Eastern townships of Quebec, the rocks of the pre-Cambrian areas appear to be almost entirely volcanic rocks, chiefly basic varieties; no true sediments are definitely known to be included with them, though, by the action of later earth movements, they are now, in places, intricately associated with more or less altered Palæozoic strata. In the Gaspé peninsula the corresponding rocks include other forms, of the nature of granites, as well as acid volcanics and possibly sediments. The same is true of the regions in northern New Brunswick, while in southern New Brunswick and Cape Breton, besides large volumes of granitic and gneissic rocks, variously altered acid and basic volcanics are common, and there also occur masses of crystalline limestone, as well as schistose rocks of possibly sedimentary origin.

The comparatively limited, but widely separated areas of pre-Cambrian rocks, are the visible portions of the ancient pre-

Palæozoic continent upon which the later rocks, during periods of depression, were deposited. Though usually largely composed of igneous matter, the general character of the different assemblages varies rather widely from place to place, indicating the likelihood that the buried portions are also heterogeneous, perhaps in places including large amounts of sedimentary rocks. Possibly the great series of sediments known as the gold-bearing (or Meguma) series, which occupy a very large portion of the Nova Scotia peninsula, may represent such an ancient sedimentary series, though they have been generally regarded as of early Palæozoic age.

The gold-bearing series of Nova Scotia, together with great intrusive masses of later granites, occupies the whole Atlantic coast of the peninsula, extending in the southwest almost completely across it, and underlying, in all, an area of some six or seven thousand square miles. This series, consisting of a lower division comprised largely of quartzites, and of an upper one mainly of dark slates, has yielded a section of over 25,000 feet of sediments, thrown into a series of folds whose axes follow a general northeasterly course. Cutting the sediments are large, batholitic bodies of granite of a later age, possibly late Devonian. Along the axes of folding, within the lower quartzite division, is a widespread system of veins of quartz, often gold-bearing. The gold-bearing series has generally been regarded as of early Cambrian age, though, so far, without fossil evidence, and the entire dissimilarity of the measures as a whole to the undoubted Cambrian beds found elsewhere in the Maritime provinces, lends support to the alternate view that the formation of this great volume of sediments antedated the Palæozoic era.

Fossiliferous strata of Cambrian age are well developed at two points in the Maritime provinces—in Cape Breton and in the neighbourhood of St. John city. In these, often highly disturbed measures, which consist largely of shales, slates and sandstones, yielding total sections of over 3,000 feet, the whole Cambrian system is represented. In Quebec an almost continuous zone of Cambrian sediments extends from the extremity of Gaspé peninsula to the Vermont border. Within this belt, following a course nearly 600 miles long, the strata are usually intricately folded and faulted, and the volume of the beds, largely sandstones and slates, is very great, probably reaching a total thickness of above 5,000

PLATE VI.

Cape St. Mary, looking toward Yarmouth, Digby County, N.S.

Valley of the St. Mary River looking up from the post-road at foot of Cochranes belt and head of Stillwater, with the Crows Nest mine in the distance on the right, Guysborough County, N.S.

feet, representing various divisions of the Cambrian from the lowest to the highest.

The Cambrian beds of the Maritime provinces have yielded a rich and varied fauna, presenting close analogies to the types recovered from beds of similar age in northern Europe. On the other hand, the Cambrian measures of eastern Quebec hold a fauna unlike, in some respects, that of New Brunswick and Nova Scotia. Largely on the evidence thus afforded, considered in connexion with the distribution of the sediments, the Cambrian strata of Quebec are believed to have been deposited in a long sound extending from beyond Gaspé, through eastern Quebec, to the southern United States. This sound, it is believed, was separated from the eastern Cambrian sea, that reached at least from Massachusetts in the south, through New Brunswick and Nova Scotia, to Newfoundland in the north.

Both of the Cambrian seas appear to have continued to exist through very early Ordovician times, but during this period, as has often been the case throughout geological time, differential movements of the earth's surface progressively shifted the position of the coast lines. In the northeastern portion of the peninsula of Nova Scotia are considerable districts occupied by greatly disturbed formations, probably of Ordovician age, consisting of sediments accompanied by large volumes of igneous rocks, some of which may represent the products of contemporaneous volcanoes. In New Brunswick, Ordovician beds partly occupy the broken, hilly country stretching northeasterly through the Province to Chaleur bay. In this region, the beds of this system consist of shales and sandstones or their altered equivalents, often penetrated by large bodies of granite and other igneous rocks.

In northeastern Quebec, various divisions of the Ordovician, sometimes largely of calcareous measures, sometimes chiefly slates and sandstones, occur along the shores of the St. Lawrence and Chaleur bay, but the Ordovician system is best exemplified in the districts lying southward towards the Vermont border. There it is represented by considerable volumes of sediments of various kinds, all highly disturbed, but indicating by their relations constantly occurring changes in the extent of the land and sea areas.

Towards the close of the Ordovician period, the whole Appalachian region of eastern America was involved in a series of mountain building movements. During this interval much, if not most of the eastern portion of the continent was elevated above the sea, and the strata folded and eroded before subsiding beneath the Silurian seas that appear to have swept over much of the Maritime provinces and the peninsula of Gaspé, and that probably extended southwestward into southeastern Quebec. During Silurian times there also appears to have been at least one general, though temporary, retreat of the seas.

Throughout western and northwestern New Brunswick, and the Gaspé peninsula generally, large tracts are floored by great volumes of shales (often calcareous), sandstones, and limestones of Silurian age, now usually highly folded and faulted. With these beds occur many varieties of igneous rocks, some of which represent the products of contemporaneous volcanoes. In Nova Scotia, the Silurian strata are largely confined to the northeastern portion of the Province, and at one locality, on the shores of Northumberland strait, there is a nearly complete section of the whole system represented by about 3,000 feet of sediments. In other portions of the Province, igneous rocks, possibly in part of contemporaneous volcanic origin, are associated with the sedimentary beds.

Devonian strata are widely distributed over the Canadian Appalachian region; the earlier ones are often largely calcareous, and their fossils indicate true marine conditions of deposition; but large portions of the system consist mainly of shales and sandstones, often rich in the remains of land plants, and apparently, were laid down in lakes—fresh, brackish, or salt; or in estuaries, tidal flats, etc. True marine, calcareous beds occur locally at a few points in southeastern Quebec, indicating the former presence of once extensive seas, whose deposits have since been largely removed by erosion. Early Devonian beds of a similar nature also occur in Nova Scotia, while at the extremity of Gaspé peninsula these earlier marine beds are represented by about 2,000 feet of shales and calcareous strata. These are overlain by 7,000 feet or more of conglomerates, sandstones, and shales, abounding in plant remains, and even occasionally containing thin coal seams. Towards the head of Chaleur bay is a disturbed basin of such measures, famous for their contained fish remains. In southwestern New Brunswick great volumes of argillaceous and arenaceous strata occur, sometimes with an estimated thickness of about 7,500 feet; these have also been assigned to the Devonian.

The same conditions are duplicated in Nova Scotia, where at one place occur strata containing tuff-like beds indicative of contemporaneous volcanoes.

In late Devonian, and, perhaps, during a portion of early Carboniferous times, the Canadian Appalachian region was again subjected to widespread earth movements, by which much of the region was once more elevated, the strata folded and faulted, and the mountains further uplifted. At the same time deep-seated intrusions of granites and allied rocks took place over considerable areas throughout the region. These granitic bodies, intruding and altering the older strata, as well as the Devonian, are found in the Eastern townships, over large areas in New Brunswick, and throughout the Province of Nova Scotia, forming there the large bodies of granite penetrating the gold-bearing rocks of the Province. Perhaps the granitic and related igneous rocks forming the Cobequid hills, along the north side of Minas bay, were intruded during this interval. From this time onwards, until a comparatively recent geological date, nearly the whole of Quebec remained above the sea, but large portions of the Maritime provinces were, during the succeeding period, gradually depressed, and floored with immense volumes of sediments. The boundaries of the Carboniferous sediments, with the older formations in many places, still indicate the old, sinuous shore lines that followed along the base of the ancient uplands of Carboniferous time. This condition is strikingly shown in the western portions of Cape Breton, where the Carboniferous strata occur along the sea coast as a mere fringe, skirting hills of crystalline pre-Cambrian rocks, or penetrating them along the courses of old pre-Carboniferous bays and valleys.

The Carboniferous strata of the Maritime provinces, within which occur the prolific coal seams of Nova Scotia, are of immense volume. Near the Sydney coal fields, Cape Breton, there is a combined section of above 13,000 feet, and along the Nova Scotia shores of the Bay of Fundy, the famous Joggins section, including younger Permo-Carboniferous, or Permian strata, has a thickness of above 14,500 feet, in which over seventy coal seams are exposed. Throughout the region bordering the Strait of Northumberland the Carboniferous measures are succeeded by a great volume of Permian rocks that extend throughout Prince Edward Island.

The Carboniferous sediments in New Brunswick occupy about 10,000 square miles, forming an area, triangular in shape, bordering the eastern coast, and contracting inland between the two elevated districts of the Province. The Carboniferous and overlying measures extend eastward into Nova Scotia, occupying much of the country north of the Bay of Minas, and reaching into Cape Breton. These areas, as indicated by the presence of Carboniferous strata on the Magdalen islands, lying far north in the Gulf of St. Lawrence, appear to be but the outer margin of a larger area now submerged beneath the waters of the gulf. Over nearly the whole of New Brunswick, Prince Edward Island, and much of Nova Scotia, the measures still lie nearly flat, or with gentle undulations, though in certain districts the beds are tilted and traversed by dislocations of considerable magnitude.

Within the Carboniferous and the succeeding system, are horizons of unconformity, marking intervals of uplift, of the contraction of the basins, or of periods of expansion. The strata consist very largely of shales, sandstones, grits, and conglomerates, but at one widespread horizon occur beds of limestone, often accompanied by thick beds of gypsum. Younger than the true Carboniferous measures are huge volumes of sandy and shaly beds of Permian age, extensively developed along the shores of Northumberland strait, and throughout Prince Edward Island. Sometimes these Permian beds succeed the Carboniferous, with no very evident unconformity, but at times their basal portion is marked by hundreds of feet of conglomerate, in places overlapping older formations.

With the close of the Palæozoic era, almost the whole of the area of the Maritime provinces seems to have been permanently withdrawn from the sea. In early Mesozoic times, however, Triassic strata, largely red shales and sandstones, were locally deposited, and in Nova Scotia now occupy a narrow strip along the Bay of Fundy; they also appear on the New Brunswick side of the same body of water. These beds indicate only local submergence, and may be of the nature of estuarine or tidal-flat deposits. With them occur thick sheets of diabase (trap), which in Nova Scotia form a sheet overlying the Triassic sediments that extend almost continuously along the Bay of Fundy shore for nearly 250 miles.

Willows in Park at Sydney, N.S.

The Triassic marks the close of the subaqueous history of the Canadian Appalachian region; the deposition of strata then ceased, and the cycle of erosion, inaugurated over a large part of the country in Carboniferous or earlier times, has continued to the present day. There are reasons for believing that this process of degradation was already far advanced in Cretaceous times, when portions of the Maritime provinces, in common with much of the coastal region of the United States, were probably reduced to the condition of a sloping plain. But the geological record of the Appalachian regions is largely a blank from the close of Palæozoic times onwards to the glacial period, the leading features of which will be discussed later in connexion with the glacial history of Canada as a whole.

ECONOMIC MINERALS.

The most important economic minerals of the Appalachian region in Canada are the asbestos of the Eastern townships of Quebec, and the coal of Nova Scotia. Approximately two-thirds of the total coal production of Canada is at present furnished by Nova Scotia, while the asbestos deposits of Quebec are particularly notable, since they are the largest bodies of this mineral now being worked in any country. Gold, copper, chromite, iron, barite, and gypsum are also mined, whilst deposits of various other minerals of economic value have been worked from time to time, or are now engaging attention.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE APPALACHIAN REGION.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold......	Free gold with pyrite, etc., in a gangue of quartz, with some calcite forming veins in the gold-bearing series of Cambrian or pre-Cambrian age.	Nova Scotia gold fields.
	Free gold with pyrite, etc., in a gangue of quartz forming veins in pre-Cambrian schists, etc.....	Cape Breton.
	Alluvial gold in pre-glacial sands and gravels in ancient, largely buried river valleys..........	Gilbert River field, Que.
	See also under copper, antimony..............	Eastern townships, Que.
Copper-Gold-Sulphur...	Chalcopyrite with small amounts of chalcocite and bornite, in pyrite, replacing country rock and forming lenses in pre-Cambrian schistose porphyries and andesites..........................	Eustis, Capelton and Suffield mines, Eastern townships, Que.
Copper....	Chalcopyrite, bornite and chalcocite forming irregular bodies in Ordovician sediments and near intrusive, basic dikes........................	Acton, Quebec.
	Chalcopyrite with a little pyrite in pyrrhotite, forming irregular bodies lying along the contact of Ordovician strata and intrusive diabase.....	Southeastern Quebec.
	Chalcopyrite, etc., in mineralized zones in pre-Cambrian felsites, etc........................	Coxheath, Cape Breton.
	Native copper in veins and along jointing planes in Triassic trap............................	Minas basin, N.S.
Lead......	Galena in small veins and pockets in Carboniferous limestone..................................	Colchester co., N.S.
	Galena and sphalerite in veins cutting Silurian strata......................................	Gloucester co., N.B.

CHIEF MINERAL DEPOSITS—Continued.

Element or Mineral Sought	Character and Mode of Occurrence of Deposit.	Example.
Tin	Cassiterite in small quantities associated with various minerals containing lithium, boron, etc., in pegmatite cutting Devonian granite	Lunenburg co., N.S.
Chromium	Chromite forming irregular pockets in serpentine of Ordovician or pre-Cambrian age	Eastern townships, Que.
Manganese	Chiefly pyrolusite forming veins, pockets and large bodies in Carboniferous limestone	Hants co., N.S., near Sussex, N.B.
Tungsten	Scheelite with mispickel in quartz veins cutting the gold-bearing series	Halifax co., N.S.
	Hübnerite in quartz veins cutting pre-Cambrian gneiss	Inverness co., N.S.
Iron	Hematite in fossil-bearing beds in Devonian and Silurian strata	Torbrook, N.S.
	Hematite, high in manganese, forming beds in Silurian slates	Woodstock, N.B.
	Siderite, limonite, etc., occurring within a zone of veins of ankerite, siderite, etc., cutting Devonian sediments near intrusive acid igneous bodies	Londonderry, N.S.
	Magnetite in elongated bodies with local developments of pyrite, etc., lying in early Palæozoic or older altered sediments and volcanics	Gloucester co., N.B.
Sulphur	*See* under copper-gold-sulphur	Eastern townships, Que.
Antimony	Auriferous stibnite with pyrite, mispickel and galena, in a gangue of calcite, forming veins cutting the gold-bearing series	West Gore, N.S.
	Native antimony and stibnite in quartz veins cutting early Palæozoic sediments in the neighbourhood of intrusive bodies of granite and diabase	Prince William, N.B.
Barium	Barite forming pockets and irregular bodies in Palæozoic strata	Cumberland co., N.S.
	Barite in a gangue of calcite with some quartz and fluorite, forming veins cutting pre-Cambrian schists, etc.	Cape Breton.
Asbestos	Complicated systems of narrow, gash veins of asbestos in small bodies of Ordovician and pre-Cambrian serpentine with which is associated granite, etc.	Thetford, Black Lake, Que.
Coal	Bituminous coal in Carboniferous strata	Sydney, and Inverness, Pictou and Cumberland cos., N.S.
Oil and sulphate of ammonia	In beds of highly impregnated shales of early Carboniferous age	Albert co., N.B; Hants, Pictou and Antigonish cos., N.S.
Gypsum	In thick beds with anhydrite and associated with Carboniferous limestones	Hillsborough, N.B.; Windsor, etc., N.S.

GOLD.

The more prominent gold-bearing districts of the Canadian Appalachian region are two in number—the alluvial gold deposits of the Chaudiere river and its tributaries in southeastern Quebec, and the area occupied by the gold-bearing series of Nova Scotia. Gold has also been found in other portions of eastern Canada. Quartz veins carrying gold have been discovered, from time to time, in southeastern Quebec, while recently the mineral has been found in dikes of granite porphyry near Lake Megantic. Alluvial gold has been recovered from the tributaries of the Tobique river, in northwestern New Brunswick. Near Woodstock, in the same Province, a gold-bearing quartz vein has been opened. In Nova Scotia gold also occurs with the antimony deposits of West Gore, Hants county. At Gays river the lower Carboniferous conglomerate overlying the gold-bearing series contains gold, and has been worked on a small scale. In Cape Breton gold-bearing quartz veins have been discovered, and in some cases considerable development work has been carried out.

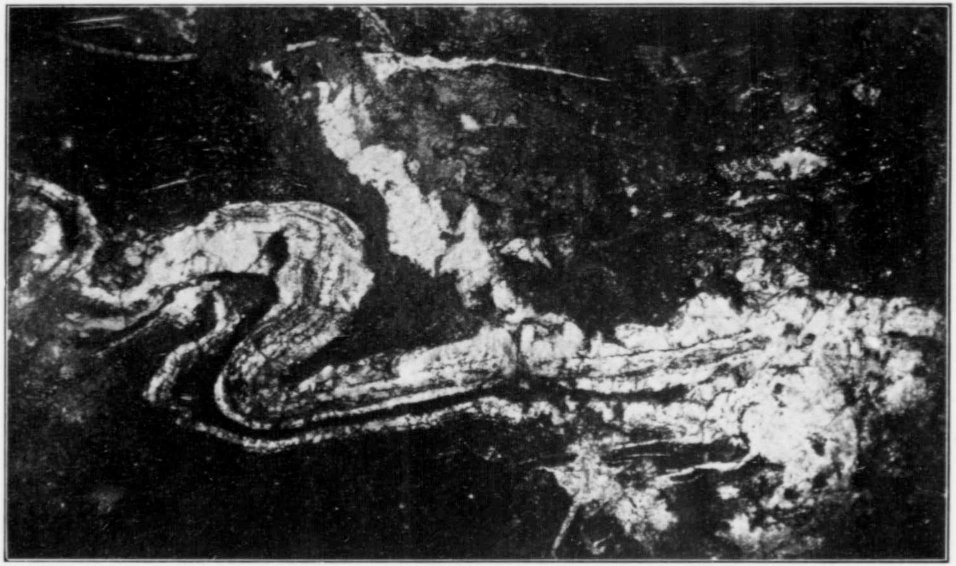
The gold-bearing districts within the gold-bearing series of Nova Scotia are of special interest because of their wide distribution, the regularity of their mode of occurrence, and the many points of similarity between them and the gold field of Bendigo, Australia. Gold was discovered in Nova Scotia in 1860, and mining operations then commenced. Two years after the discovery gold, valued at nearly $142,000, was recovered from the quartz veins, and since that time the annual production has, with the exception of one year, fluctuated between $200,000 and $628,000, nearly attaining the latter figure in 1902. In 1908, the production was probably not over $225,000.

The gold occurs in connexion with veins chiefly of quartz, but with some calcite. The veins commonly follow planes of stratification between beds or bands of slate lying within the thick group of quartzites that form the lower portion of the highly-folded gold-bearing series. The vein quartz is usually dark, ribboned, and dense. Pyrite and arsenopyrite occur in both the country rock and the veins, the pyrite being especially abundant in the slates and often lying along the planes of bedding. The distribution in the veins of these sulphides, with which the gold is doubtless associated in origin, is somewhat erratic; but,

Waverley Gold district looking west from Laidlaw Hill, N.S.

Isaac Harbour, N.S.

PLATE XI.



Vein at Goldenville, N.S.

Valley of the Chaudière River, Beauce County, Que.

in general, pyrite is common and, when abundant, usually occurs along or near the borders of the veins. Pyrrhotite, chalcopyrite, and galena also occur, though but sparingly.

Gold occurs in the veins, in the slates, and, to a much less extent, in the quartzites. In the veins a large proportion of the gold within the zone of oxidation is free, occurring in the form of filaments, leaves and nuggets, or so fine as not to be visible. The precious metal is sometimes uniformly distributed through the veins, but usually is, to a varying extent, locally concentrated, and, commonly, the richer ground is situated towards the middle of the zones of quartz veins. The larger particles of gold are usually found at points of local enrichment at or near the junction of the main veins with branches.

The average yield of gold in some districts has been as high as 1½ ounces per ton, while in other districts, 100 ton lots or over have carried as high as 3½ ounces to the ton. More attention has of late been paid to the lower grades of ore that contain sulphides of iron and arsenic with gold. The total production from 1862 to 1906 averaged $8.97 per ton, while the ore mined in 1907 averaged about $4 per ton.

The gold-bearing series of Nova Scotia is a sedimentary group of rocks thrown into a system of nearly parallel folds following a general southwest and northeast direction. The beds are cut by numerous dikes, bosses, and batholites of granite, intruded after the folding of the sediments and later than the formation of the gold-bearing quartz veins. The sediments and the igneous rocks stretch along the whole length of the southeastern seaboard of the Province, occupying an area roughly estimated at 8,500 square miles, of which about two-fifths is underlain by the sedimentary beds.

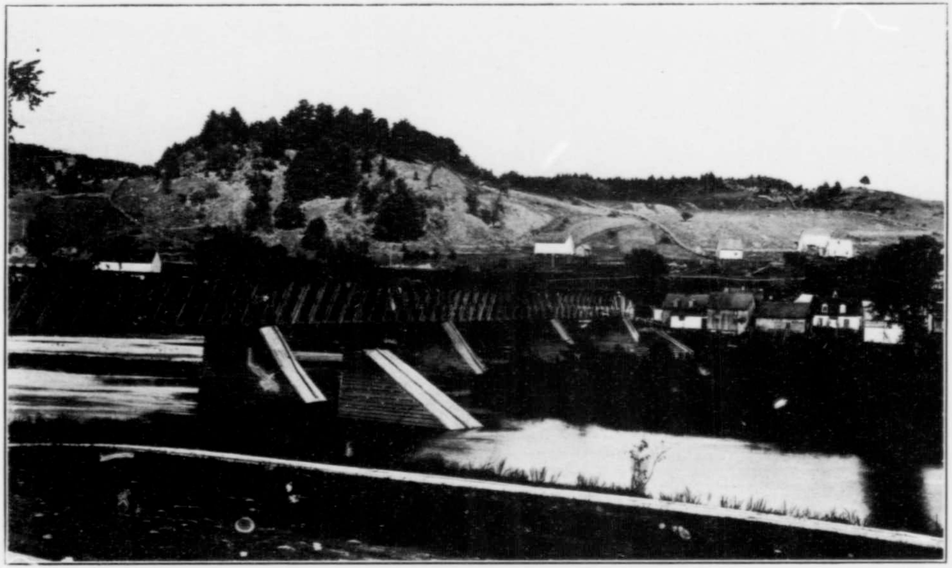
The gold-bearing series has generally been classed with the lower Cambrian, but may belong to the pre-Cambrian system. The series consists of two portions, of which the lower is formed very largely of quartzites, but with many interstratified beds and bands of slate; while the upper portion is almost entirely composed of dark slates. It has been estimated that the visible portion of the series is at least 25,000 feet thick, while its total thickness must be considerably greater, since neither the top nor the bottom of the series is exposed.

The auriferous quartz veins are almost entirely confined to the lower quartzite group. Most, if not all of the gold-bearing centres are situated at points of doming along the anticlinal axes of folding, and are scattered throughout the whole length of the area underlain by the gold-bearing series. Though mining operations have been conducted over only a small proportion of the known domes, yet nearly every dome is known, directly or indirectly, to be a point of occurrence of quartz veins, often gold-bearing. The number of these domes must be very large, for over considerable districts the average distance apart of the axes of the anticlinal folds is less than five miles, while the average distance between one dome and the next, along the same anticlinal axis, varies from ten to twenty-five miles. Though it is believed that most of the domes are centres of systems of quartz veins, it is not to be inferred that every point of doming will eventually prove to be a profitable gold-mining centre.

The auriferous quartz-veins are dominantly bedded veins formed along the planes of stratification of the slates, within, or more commonly, along the borders of bands of slate interbedded with the quartzites. Accompanying these are the so-called angulars—branches of the main, bedded veins, cutting irregularly across all structures and dying out at various distances from the parent mass.

Where the strata are closely folded and the opposing limbs of the anticlines make with one another angles of 45° or less, the veins are largely localized along the crowns of the arches, giving rise to a series of superimposed saddle reefs individually attaining thicknesses of fifteen to twenty feet or more, but rapidly thinning out along the legs of the folds. Where the folds are broader, the veins, as a rule, do not occur along the courses of the anticlinal axes, but at a variable distance to one side of them, and within a zone 200 feet to 1,000 feet wide, towards the centre of which the veins are generally thicker. These veins, situated along the legs of the folds, perhaps average from 4″ to 12″ in width, but are often larger.

The bedded veins frequently present a banded structure, and, together with the associated angulars, apparently formed during the slow folding of the gold-bearing series, when the operation of the mechanical forces would tend to cause the strata to open up at points of least vertical pressure. The veins, with the



St. François, Beauce, Que.

adjoining portions of the bands of slate in which they occur, are frequently plicated or corrugated. This plication appears to have been due to a flowage of the less resistant material of the argillaceous beds lying within the more rigid quartzites, towards the points of relief of pressure, situated, in the case of the sharper folds, along the anticlinal axes, but in the case of the broader folds to one side of the axes of folding.

Besides the above described veins, others occur cutting the planes of stratification at various angles. Many of these are auriferous and appear to be later in origin than the bedded veins, and to have formed after the folding of the strata.

The occurrence of alluvial gold in southeastern Quebec has long been known, the first recorded discovery having been made in 1824 at a point about fifty miles southeast of Quebec city, on the Gilbert river, a tributary of the Chaudière. In 1847 mining operations commenced, and since then have been intermittently continued.

Alluvial gold has been found and worked along the valley of the Chaudière, and many of its tributaries, from a point some distance below the mouth of the Gilbert river, eastward almost to the International Boundary. Alluvial gold has also been recovered from the valley of Ditton river, near the New Hampshire border, and along a narrow strip of country extending from Lake St. Francis southwestwards towards the Vermont border.

The total amount of gold recovered from these various areas has been estimated to be in the neighbourhood of $3,000,000, of which sum possibly one-half was obtained from a limited area of a few square miles in the valley of Gilbert river. Much of the gold was comparatively coarse, and from time to time various nuggets of considerable size were found, one being reported to weigh 52·5 ounces. Very small quantities of platinum and iridosmine were detected in some of the washings.

The main source of the gold has been the pre-glacial sands and gravels of the beds of older river systems, now largely concealed by deposits of boulder clay, as well as the sands, etc., of the present waterways that in many cases still occupy the valleys of the older streams. The auriferous gravels of the pre-glacial streams are in many places buried by seventy-five feet or more of glacial and recent deposits. The gold, while sometimes distributed with some degree of uniformity through the old river gravels, is more often locally concentrated, and the disintegrated portion of the underlying rock has often proved to be particularly rich. Gold has also been recovered from recent gravels that, during the natural processes of erosion, appear to have derived the metal from the pre-glacial deposits.

The source of the alluvial gold has not been definitely determined, but it has been shown that the alluvial deposits have generally been found in the neighbourhood of areas of pre-Cambrian volcanic rocks, or in positions where it would have been quite possible for the material to have been transported by streams from such areas. These volcanic rocks frequently carry copper ores, often with important amounts of gold, hence it seems not unlikely that the placer gold may have been derived from the pre-Cambrian volcanics in pre-glacial times, or, in some cases, in post-glacial times.

COPPER.

The presence of copper ores in the Eastern townships of Quebec was known as early as 1841, and by 1866 their occurrence at nearly five hundred localities had been recorded. The metal was extensively mined between the years 1859 and 1866, though during that period copper was the only element sought for, and the lower grade ores were discarded. With the decline in the price of copper that followed, mining operations almost ceased, until between 1875 and 1885, when several properties were reopened; and these, in some cases, have been continuously worked for a period of about thirty years, during which a depth approximately of 3,000 feet has been reached. During the second period of mining operations the sulphur and all the metallic constituents of the ores, except the iron, have been utilized. From 1899 to 1908 the amount of ore annually shipped has varied from 20,000 tons to 40,000 tons.

The main ores—those now being actively mined—consist chiefly of chalcopyrite, with small amounts of chalcocite and bornite, in pyrite. They occur in or closely associated with schistose porphyries and andesites of pre-Cambrian age that form part of a comparatively narrow, discontinuous zone of rocks of this system, extending from Lake Memphremagog northeast as far as Lake St. Francis. Similar deposits also occur to the east and west respectively, in the two remaining zones of pre-Cambrian rocks of this part of Quebec. Active mining is now virtually confined to the district southeast of Lennoxville, where the Eustis, Capelton, and Suffield mines are situated.

The ore deposits form much flattened lenses, lying in conformity with the foliation of the country rock and arranged *en échelon*. The individual lenses seldom exceed 20 or 30 feet in width, approximately 200 or 300 feet in length, with perhaps about the same dimension along the plane of dip. Smaller bodies are common. The walls of the ore bodies are usually ill-defined, the ore gradually disappearing, but sometimes one wall is more distinct than the other. The ores seem to have been associated in origin with the volcanic rocks with which they are now found, and to have been derived from the volcanics subsequent to the folding and shearing of these rocks, and deposited along zones of shearing where they have replaced the country rock.

It has been stated that, in a general way, the ores may be said to carry at the surface 4 per cent copper, 35 per cent sulphur, and $2 to $4 of gold per ton, while at greater depths they yield 3 per cent copper, 45 per cent sulphur, and 3 ounces of silver and a small amount of gold per ton. Apparently there is a surface zone of secondary enrichment, more marked in the case of the gold than in that of the copper.

A second class of copper deposits, consisting of chalcopyrite, bornite and chalcocite, occurs in irregular bodies in Ordovician sediments along a zone stretching northeast from Roxton for a distance of about one hundred miles. Practically all of many, and the greater part of most of the ore bodies lie in sedimentary rocks, generally limestone, and near intrusive dikes. At Acton a large amount of high grade copper ore, sometimes containing 30 per cent copper, was produced for several years.

A third class of copper deposits in southeastern Quebec, consists of chalcopyrite in pyrrhotite, with a little pyrite. These ores occur at various points along the contact of Ordovician strata and intrusive diabase, in the neighbourhood of the areas of pre-Cambrian rocks.

Ores of copper have been found at many places in Nova Scotia, and considerable development work has been done at a number of localities. At Cape d'Or, Cumberland county, native copper occurs in veins and along joints in the Triassic diabase; during

1907, over two tons of copper were produced. Chalcocite and malachite in nodules are found in sandstones, etc., over a wide area between Springhill and Pictou. Considerable work has been done in the chalcopyrite deposits found in pre-Cambrian felsites at Coxheath, near Sydney. Ores, chiefly of chalcopyrite, and carrying gold, have been worked in the Cheticamp district, Inverness county.

In New Brunswick various ores of copper occur at many points in the southern part of the Province, both with sedimentary and igneous rocks. Many attempts at mining have been made, but, so far, with little success.

LEAD.

Galena, usually finely disseminated or in veins and small pockets, occurs at various points in the lower Carboniferous limestones of Nova Scotia, more particularly in Colchester county. The mineral also occurs in veins in the pre-Cambrian rocks of Cape Breton. In New Brunswick veins of galena and sphalerite, with various other sulphides, cut the Silurian rocks along the coast of Chaleur bay; the lead sulphide also occurs at a number of other points in the Province, but in small quantities only. Galena has been found at various localities in the Eastern townships of Quebec, and, farther east, in Gaspé.

TIN.

Cassiterite, accompanied by various rare minerals containing lithium, fluorin, etc., occurs in small quantities, in pegmatitic bodies cutting granite, in the neighbourhood of New Ross, Lunenburg county, Nova Scotia.

CHROMIUM.

The existence of chromite in the serpentines of the Eastern townships of Quebec, and in Gaspé, has long been known. Mining operations, however, did not commence until 1894, though prior to that date several small shipments of the mineral had been made. So far mining has been almost entirely confined to the immediate neighbourhood of Black lake, Coleraine township, one of the centres of the asbestos industry. From 1894 to 1903 the annual production of ore averaged about 2,000 tons, but in 1906 the amount rose to over 9,000 tons, while the production for 1908 is estimated to have been 7,225 tons.

The deposits of chromite occur in pockets of irregular shape scattered through the serpentine bodies. The masses of ore usually appear to be altogether unconnected with one another, though not infrequently it happens that a series of pockets are found following one another, or in close proximity. Sometimes the ore bodies are of considerable size; the largest so far worked was about 80 feet long at the surface, had a variable thickness of from 5 feet to 50 feet, and had been followed to a depth of 340 feet, with an average angle of dip of about 60°. The content of chromic acid in the crude ore often averages above 40 per cent, and reaches, in the case of picked specimens, nearly 60 per cent. The ore bodies seem to represent differentiation products of the peridotite magma that gave rise to the enclosing rock, subsequently largely altered to serpentine. Though occurring in the immediate neighbourhood of the asbestos-bearing serpentine bodies, the chromite-bearing serpentines seldom contain any considerable amount of asbestos.

MANGANESE.

Ores of manganese have been found at many points throughout Nova Scotia, and comparatively small quantities have been mined at various times, it being estimated that, from 1876 to the present date, the total production has been less than 5,000 tons. The ores have been found in various formations, but most commonly occur in the lower Carboniferous limestones, as in Hants county at the Tennycape mine, where the ore consists chiefly of fibrous pyrolusite, with compact and granular pyrolusite, psilomelane and manganite. The ores of this district are very pure and are accordingly highly prized. In the upper part of the Carboniferous limestone the manganese minerals occur in seams and pockets, varying in quantity from a few pounds to a thousand tons or more; in the lower portion of the limestone the ores form seams and veins sometimes six inches wide.

In New Brunswick, ores of manganese, chiefly pyrolusite, and often very pure, occur in association with the lower Carboniferous limestone, and, at one time, were actively mined, especially in the neighbourhood of Sussex, where from one mine, at Mark-hamville, over 25,000 tons were produced prior to 1894, when operations ceased. From one pocket alone, 4,000 tons were taken. Bog ore, or wad, also occurs in New Brunswick, and one deposit a few miles northwest of Hillsboro, is, in places, 25 to 30 feet deep.

TUNGSTEN.

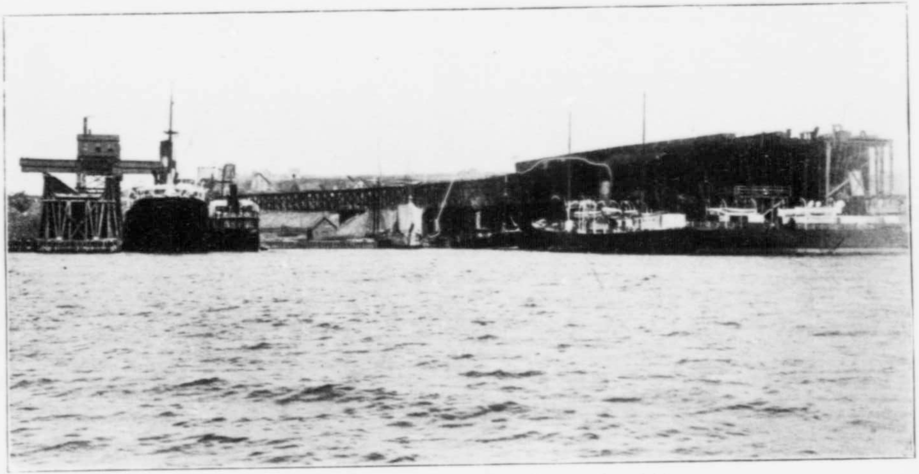
The tungsten-bearing mineral, scheelite, has been found at a number of localities in Halifax county, Nova Scotia. It occurs in quartz veins cutting the quartzites and slates of the gold-bearing series. The veins consist of quartz, mispickel and scheelite in varying proportions, while with these occur lithia mica, tourmaline, etc. Though the veins are of a regular bedded type like the auriferous quartz veins of the Province, they apparently do not carry gold, and are probably of different age and origin. Scheelite occurs also in the Malaga gold mining district, Halifax county; while at one locality in Inverness county from 300 to 500 pounds of hübnerite were recovered from a large detached mass of quartz lying at the outcrop of a lenticular vein of quartz cutting a gneissic or granitic rock of pre-Cambrian age. Scheelite has been found in Quebec, in Beauce county, in a quartz vein traversing pre-Cambrian rocks.

IRON.

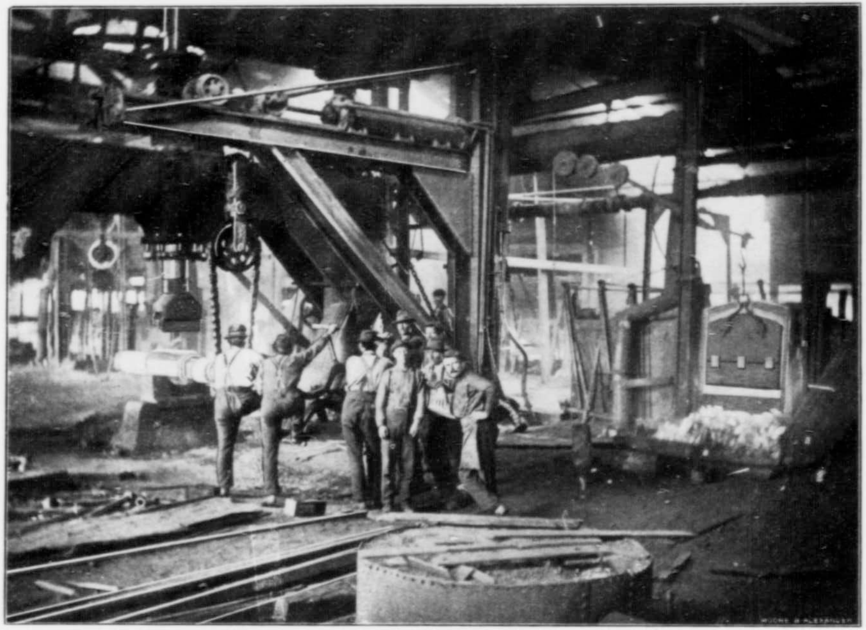
Nova Scotia, though the seat of large iron and steel industries at Sydney, New Glasgow, Londonderry, and elsewhere, does not produce much iron ore, the amount in 1907 falling slightly under 90,000 tons. Deposits of iron ore of various kinds are widely distributed through the Province, but though numerous, are often small, and under present conditions, not of direct economic importance. Larger ore bodies occur near the Nictaux river in southwestern Nova Scotia, and near Londonderry on the south slope of the Cobequid hills.

In the Nictaux-Torbrook district the ores are largely hematites occurring in fossil-bearing beds sometimes five or ten feet wide, and lying conformably within strata of upper Silurian and lower Devonian age. The ores were probably derived from the weathering of old land areas, by which iron from rocks, etc., passed into solution, was deposited as limonite, and afterwards changed to hematite and magnetite.

PLATE XIV.



Nova Scotia Steel and Coal Co's Piers, North Sydney, N.S.



Forge Shop: Nova Scotia Steel and Coal Co.

The iron ores in the neighbourhood of Londonderry lie in Devonian slates and quartzites near the contact with the various acid intrusives, granites, granite porphyries, etc., forming the central portion of the Cobequid hills. The ores occur within a zone of fissuring, sometimes a hundred feet or more wide, that dips steeply and has been traced on the surface for a number of miles. The fissured zone is occupied by a complicated system of veins of ankerite, siderite, etc., often enclosing and surrounding large and small bodies of the country rock. Magnetite, hematite, and limonite are often very abundant, the relative amounts of the iron-bearing minerals varying widely from spot to spot.

In New Brunswick various ores of iron have been found at widely separated points, and in some cases have been worked at intervals for nearly fifty years. Low grade hematite ores with high contents of manganese occur at Jacksonville and elsewhere, near Woodstock in Carleton county. The beds are interstratified with slates of Silurian age, and vary in thickness from 1 to 15 feet. Recently, a large body of magnetite has been discovered on the Nipisiguit river, about twenty miles south of Bathurst. The ore body is exposed in places for a width of 30 or 40 feet, and outcrops over a length of nearly two miles. While the main body of the ore is nearly free of sulphides, iron pyrites is very abundant in the country rock forming the foot wall. The deposit occurs in schistose-quartz porphyry of early Palæozoic or pre-Cambrian age.

ANTIMONY.

Several veins of auriferous stibnite occur in the gold-bearing series at West Gore, Hants county, Nova Scotia. From the time of their discovery in 1880, until 1892, the deposit was worked solely as an antimony mine, and nearly 3,000 tons of ore were shipped. Though it is estimated that the ore carried two to three ounces of gold to the ton, the presence of the gold was long unsuspected. At present the annual shipments of ore average about 2,000 tons.

The ore occurs in nearly vertical veins, one of which has been traced at the surface for at least 1,200 feet, and followed downwards for over 500 feet. It consists of a gangue of slate, calcite and quartz, cut by a number of quartz stringers. Pyrite, mispickel and galena are abundant in places. The ore, sometimes solid stibnite, sometimes stibnite and quartz, varies in width from a few inches up to seven feet, and generally follows the hanging wall, which is always clear cut, while the foot-wall is irregular and indistinct. A varying quantity of gold is always present, and is highest where the proportion of stibnite is greatest. Except where a cross vein of quartz occurs, none of the gold is free, even in ore assaying as high as ten ounces of gold to the ton.

Native antimony and stibnite occur in New Brunswick, at Prince William, about twenty-five miles west of Fredericton. Mining has been conducted at this spot at various times since 1863. The antimony ore occurs in quartz veins cutting slates and quartzites in the neighbourhood of intrusive masses of granite and diabase. The native antimony is apparently largely or solely confined to the upper portions of the veins. Antimony minerals in considerable variety occur at South Ham, Quebec.

BARIUM.

Deposits of barites, widely distributed through north-eastern Nova Scotia; at Five Islands, Colchester county, and elsewhere, have been worked from time to time. But, in general, the deposits have proved to be pockety and difficult to work at a profit. Barite has been found under more favourable circumstances at Lake Ainslie and North Cheticamp, in Cape Breton, and since about 1890 the shipments of the mineral have averaged nearly 2,000 tons per annum.

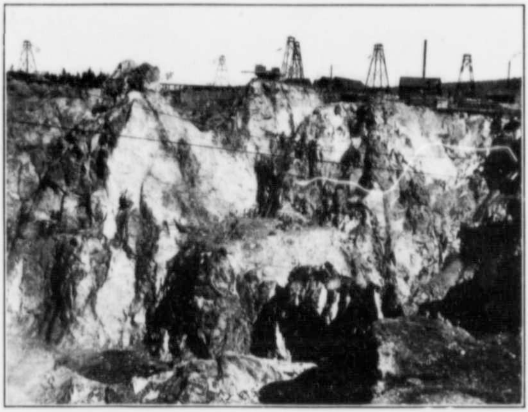
At Lake Ainslie the barites, with some calcite and fluorite, forms a series of roughly parallel veins cutting pre-Cambrian felsites. The veins, though showing many irregularities in size, are comparatively persistent, one nearly vertical vein having a width of 7 to 14 feet for a depth of at least 250 feet, as shown on a hillside. In several instances the veins locally attained thicknesses of 20 feet. At North Cheticamp the barites veins, with a varying content of quartz, calcite, and fluorite, form a group of pinching and swelling veins running parallel with the curving planes of schistosity of the enclosing pre-Cambrian schists.

ASBESTOS.

The mining of asbestos in the Eastern townships of Quebec commenced in 1876. In 1878 some fifty tons were taken out,

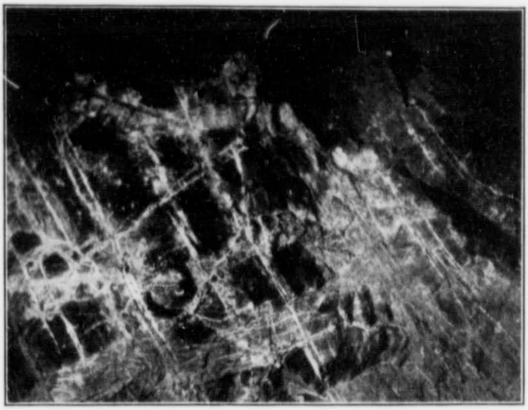
Veins of Asbestos at Thetford, Que., 1889.

PLATE XVII.



Bell Asbestos Mine, Thetford, Que.: view across Main Pit.

PLATE XVIII.

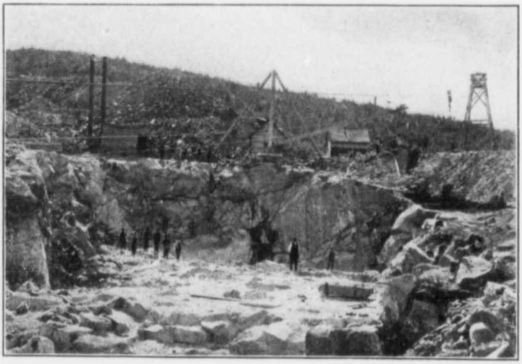


Bell Asbestos Mine, Thetford, Que.: view in cross-cut, showing large veins of Asbestos.

and since then the production has steadily increased, until, in 1908, it has reached over 65,000 tons of asbestos, and above 25,000 tons of asbestic (pulverized rock containing short fibres of asbestos).

The asbestos occurs in certain serpentine masses, usually of small area, that form part of a discontinuous belt of similar rocks reaching northeast from near the west side of Lake Memphremagog nearly to the Chaudière river, a distance of about 150 miles. Most of the mines, however, are situated within a few miles of one another, in the vicinity of Black lake and Thetford. A second centre, East Broughton, lies to the northeast, about twenty-five miles away, while a third centre is at Danville, about forty-five miles to the southwest. The mines are worked as open pits, and one of them, at Black lake, is over 700 feet long by 200 feet broad, and in places 165 feet deep.

PLATE XIX.



Dominion Asbestos Co's Pit, Black Lake, Que.

The serpentine with which the asbestos is associated usually occurs in comparatively small bodies, and has been derived from the alteration of peridotites that, with possibly one exception, appear to be of Ordovician age, and lie between Ordovician sediments on the east, and slates and schists of pre-Cambrian or Cambrian age on the west. Associated with the serpentine are bodies of pyroxenite, hornblende granite, and diabase: the granite is thought to be nearly contemporaneous in age with the serpentine.

The asbestos is of the chrysotile variety, and occurs in gash veins varying in width from mere lines to sometimes 3″ across. The fibres of the mineral usually stand at right angles to the side walls of the veins, and sometimes extend completely across, but often there is, towards the centre, a film of chromite or magnetite.

The veins are exceedingly numerous, in one instance seventy veins were counted in a breadth of only two feet. Their courses often appear extremely irregular and their widths inconstant. The main veins, however, often show an approach to a rectangular arrangement, as though indicating original jointing planes in the rocks, but as the serpentine has been much shattered, there is also a series of minor veins, sometimes more or less parallel with one another. Partings also appear to have developed around the corners and edges of the larger blocks, giving rise to small, crescent-shaped veins.

The asbestos veins are invariably accompanied on both sides by bands of pure serpentine that grade into less altered peridotite. It has been shown that the proportion between the width of the asbestos vein and the combined breadth of the two accompanying bands of pure serpentine is fairly constant, about as 1:5·6. From the preceding statements it has been concluded that the serpentinization of the walls of the asbestos veins preceded the formation of the asbestos, and further, that the asbestos veins represent replacements of the serpentine on either side of fracture lines. Microscopic examination shows the asbestos fibres to grow at right angles outward from both sides of such fractures.

COAL.

Coal is the most important product of the mines of the Appalachian region. With the exception of thin and unimportant seams in the Devonian rocks of Gaspé, its occurrence is confined to New Brunswick and Nova Scotia, and the latter Province is by far the chief producer, yielding, in 1908, nearly two-thirds of the total amount of coal mined in Canada. The coal is all bituminous, of good quality, well adapted to the production of coke and gas, and also good steam coal. In the eastern provinces it has been mined for 200 years or more, though it was not until the close of the first third of the last century that the amount produced became notable. The total annual production first reached a million long tons in the year 1880, in 1900 it had increased to above 3,000,000 tons, and in 1908 had reached nearly 6,000,000 tons. Of the total production in 1908, almost the whole was mined in Nova Scotia, less than one per cent being raised in New Brunswick. The coal districts are five in number and are as follows, the accompanying figures indicating, approximately, the percentage of the total amount mined in each field: Sydney coal field, 71·9 per cent; Inverness county, 6·0 per cent; Pictou county, 12·7 per cent; and Cumberland county, 8·8 per cent; all in Nova Scotia; and Grand Lake in New Brunswick, 0·6 per cent.

The Sydney coal fields extend for thirty-two miles along the sea coast of the northeastern extremity of Cape Breton island. The coal measures have been estimated to underlie a land area of about fifty-seven square miles, as well as a large area, in which mining operations are conducted, underlying the sea. The strata are almost free from faults of any size and have gentle dips. Conformably underlying the productive measures occurs the Millstone-grit, a group of sandstones and shales having a thickness of about 4,000 feet; beneath these lie the sandstones, shales, and limestones of the Carboniferous limestone formation, and below these the basal conglomerates, etc., outcropping to the southward and overlapping pre-Cambrian rocks. The total thickness of the measures beneath the productive coal measures is estimated to be about 8,500 feet.

Since they are cut off by the sea, only a portion of the productive coal measures, in all about 1,800 feet, is exposed. The gently dipping strata are traversed by three anticlines, so that the coal seams lie in four basins—Cow Bay, Glace Bay, Sydney Harbour, and Bras d'Or basins. The strata are largely of shales and sandstones, and contain in all from forty to fifty feet of coal. The total number of seams is twenty-four, and of these, six are 3 feet or upwards in thickness. The similarity and persistence of the seams over the whole area is very remarkable. In a few instances they are split by the gradual thickening of their clay partings; and, sometimes, seams that are of workable thickness and good quality at one place, become unavailable at no great distance.

The coal fields of Inverness county include a series of narrow areas extending for over fifty miles along the western shore of Cape Breton island. The areas of the productive measures form part of the eastern rim of a basin, the greater part of which has been removed by erosion. The productive measures on their easterly side are underlain by the Millstone-grit and the various formations of the lower Carboniferous, in their turn resting on pre-Cambrian rocks. At various localities seams from 2 to 12 feet in thickness occur, usually with rather low angles of dip.

Besides the above mentioned two coal producing districts, coal also occurs on Cape Breton island, in Richmond county, where seams up to 8 feet in thickness, and one of 11 feet—but of poor quality—have been described.

On the mainland of Nova Scotia, the Pictou coal field has an area of about twenty-five square miles. Though the field is small, the coal seams are often of great size, one being 38 feet in thickness. The geological structure of the district is very intricate, faults, often of considerable magnitude, are numerous, and the productive measures are almost completely girdled by faults.

The Pictou field may be conveniently divided into three districts, namely, the central, western, and eastern. In the central or Albion district, four seams have been worked, one 38 feet thick, a second varying in thickness from 22 feet to 38 feet, a third 10 feet to 13 feet thick, and a fourth 13 feet to 20 feet thick. The beds dip at angles of 10° to 30°, are overlain by 1,000 feet of shales, and are conformably underlain by the Millstone-grit. The western or Westville district is separated from the central division by a fault with a throw estimated at 1,600 feet to 2,000 feet. Three seams of the western district are believed to be equivalents of seams in the central district. In the eastern or Vale district, the strata lie in a synclinal basin with a number of coal seams—of which two have been extensively worked—outcropping along the southern side of the basin.

In Cumberland county there are two productive areas: one, situated on the coast, may be called the Joggins area, while the other is at Springhill, about fifteen miles east of the first. In the Joggins area the coal seams occur along one side of a very broad synclinal basin of Carboniferous measures that, towards the centre of the basin, are overlapped by Permian beds. In the remarkable section of strata exposed along the coast of Chignecto

Coal Mine Point, South Joggins, N.S.

PLATE XXI

Dominion No. 2 Colliery, Glace Bay, N.S.: Phalen and Harbour Seams.

PLATE XXII.

Mine at Stellarton, N.S. Old Ford Shaft.

Carboniferous rocks east of Coal Mine Point, Joggins, N.S.

bay over seventy coal seams outcrop. Several seams are 5 to 6 feet thick, while one measures 9′-6″; but with 2′-6″ of shale partings. In the Springhill basin the geological structure is less simple and the strata dip more steeply than in the Joggins area, the seams being worked along slopes of 30°. In the Springhill district eight seams varying in thickness from 2′-4″ to 13′-0″, have been recognized.

In New Brunswick, though Carboniferous measures occupy an area of upwards of 10,000 square miles, the productive measures seem to be localized in a comparatively small area about Grand lake, some seventy miles north of St. John. Outside of this area coal seams have been found at a number of points in the north-east part of the Province, where seams 6″ to 10″ wide are known to occur.

Coal mining has been carried on for many years in the Grand Lake district, where in the nearly flat, gently undulating measures, occur two seams, one of 20″ to 24″, and the second from 6″ to 10″ thick. Sometimes the two seams approach so closely as to be worked as one, the parting being reduced to 6″ of shale. In places the nearly flat seams lie so close to the surface that they are worked by open pits, and nowhere over the one hundred square miles or so occupied by the coal basin, does it seem probable that the coal seams, at present worked, lie more than 60 feet beneath the surface, nor does it seem very probable that the relatively thin measures contain workable seams at any greater depth.

OIL SHALE.

In New Brunswick the Albert oil-bearing shales of very early Carboniferous age are exposed at intervals for about fifty miles, from near Dorchester westward to a point south of Norton. The Albert shales are usually highly inclined, much faulted and folded, and in thickness they often reach over 1,000 feet. At many points in the shale belt occur beds or bands of shales, dark brownish or dark grey in colour, that are very rich in bituminous matter. At least five such bands, varying in thickness from one to five feet or more, have been recognized. When retorted, these richer shales have been found to yield from 30 to 80 gallons of crude oil, and from 65 to 112 pounds of sulphate of ammonia per ton. The dense, crude oils, when further treated, yield lubricating oils, burning oils, and paraffin wax, while by-products, such as naphtha, benzole, aniline, etc., may be produced.

Many years ago, in the Albert shales, at Albert mines in the vicinity of Hillsborough, a large, vein-like body of albertite was found. This vein of nearly pure bituminous matter was mined during a period of twenty years, and yielded in all over 200,000 tons. The vein was worked to a depth of about 1,300 feet, and for a length of about half a mile.

Oil-bearing shales of Carboniferous age also occur at various points in Nova Scotia, as in Hants, Pictou, and Antigonish counties. In Cape Breton somewhat similar dark shales are found at Lake Ainslie and McAdam lake; oil shales are also found in Gaspé.

In Scotland very similar shales, no richer in oil and sulphate of ammonia, have been profitably mined, retorted and distilled for many years.

At some of the localities, both in New Brunswick and Nova Scotia, attempts have been made by means of borings to obtain oil from the shales, but so far without proved profitable results.

A considerable amount of boring for oil has been done in Gaspé, but without commercial success.

GYPSUM.

Beds of gypsum are associated with the lower Carboniferous limestones in New Brunswick and Nova Scotia, more particularly over the territory around the head of the Bay of Fundy, and extending, in Nova Scotia, eastwards around the Bay of Minas, and northeastwards into Cape Breton. The gypsum is mined at a number of points, more notably at Hillsborough in New Brunswick, near Amherst, at Windsor and other places in Hants county, and in Victoria county. In 1907 the two provinces produced nearly 450,000 tons.

The gypsum deposits are often very extensive, forming beds 200 feet or more thick. The mineral is of various colours, often snow-white. With it occurs anhydrite, sometimes in alternating beds, while at other times the two minerals are more irregularly associated.

BUILDING AND ORNAMENTAL STONES.

The bodies of granite, in many cases apparently of Devonian age, found in many districts in the Appalachian region, have been quarried at a number of points. In the Eastern townships of Quebec, near Staynerville and Stanstead, the granite is largely quarried for paving blocks, also for ornamental purposes. In New Brunswick a number of granite quarries have been opened near St. George, and the rock is also quarried at several localities in Nova Scotia.

In the Eastern townships marble for ornamental purposes is extensively worked near Stanbridge and elsewhere. Roofing slate is obtained from near Kingsbury. In New Brunswick and Nova Scotia, the various sandstones of the Carboniferous and Permian have furnished excellent stone for structural purposes, also for grindstones.

MISCELLANEOUS.

Clays and shales suitable for industrial purposes occur, but have not been extensively utilized. Infusorial earth occurs in New Brunswick and Nova Scotia. Moulding sand is produced to a limited extent.

CHAPTER III.

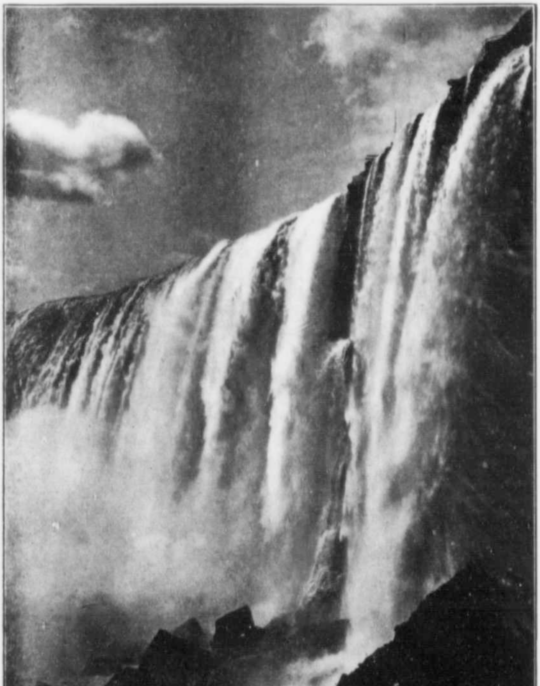
THE ST. LAWRENCE LOWLANDS.

GEOLOGY.

The *St. Lawrence lowlands*, floored with nearly horizontal Palæozoic strata, and bounded on the north by the southern edge of the Laurentian plateau, represent in Canada the northeastern extension of the great plain-like area of the interior of the continent. Commencing near the city of Quebec, the lowlands stretch southwesterly on both sides of the St. Lawrence, with slightly diverging boundaries, until, at Montreal, the level country is approximately 120 miles wide. Beyond Montreal, the northern boundary pursues a westerly course up the Ottawa valley to a point about fifty miles beyond Ottawa city, where a ridge of broken country—a low spur of the Laurentian highlands—projects southerly, crossing the St. Lawrence between Brockville and Kingston to join the elevated Adirondack region of northern New York. Near Kingston, at the foot of Lake Ontario, the lowlands again commence and occupy the portion of the Ontario peninsula lying between Lakes Huron, Erie, and Ontario, and bounded on the north by a nearly straight east and west line from Kingston to the foot of Georgian bay, Lake Huron.

The region thus outlined, with a length of about 600 miles and an area of more than 35,000 square miles, nearly all fertile farming land, is divisible into three portions, each a sloping, plain-like region, usually mantled with heavy deposits of glacial drift, etc., that largely hide the underlying, nearly horizontal sediments. Though essentially a farming region, the portion of the country lying between Lakes Huron and Erie supports valuable petroleum, gas and salt industries.

The most easterly of the three divisions of the St. Lawrence lowlands comprises the portion lying east of the spur of crystalline rocks crossing the St. Lawrence below Kingston. Its northern boundary is, in general, marked by an abrupt rise of the Laurentian



Western end of Canadian Fall, Niagara Falls, before curtailment of 415 feet.

hills, while on the eastern side lies the hilly, semi-mountainous Appalachian tract. Within this roughly triangular area, the land nowhere rises more than 500 feet above the sea, and, below Montreal, the districts immediately bordering the St. Lawrence have a general elevation of less than 100 feet, and, save in the case of a few isolated, abruptly rising hills of igneous origin, the lowlands on either side of the river never rise to 300 feet above sea level.

The second division of the St. Lawrence lowlands fronts on Lake Ontario, forming a plain-like area that at first usually rises rather abruptly from the lake (itself 246 feet above the sea), and then stretches inland with gradually increasing heights, sometimes reaching 850 feet above the sea. This area, comparatively narrow in the east, is bounded on the north by a marked escarpment, with a drop along its northerly facing slope of between 50 and 100 feet. Westward the district is limited by the Niagara escarpment, which runs in a northwesterly direction from the Niagara peninsula through the Indian peninsula separating Lake Huron and Georgian bay, and is continued westerly into Michigan by the northward facing cliffs of the Manitoulin islands.

The Niagara escarpment, the natural dividing line between the two western divisions of the St. Lawrence lowlands, presents a general abrupt rise of 250 to 300 feet. In the Niagara peninsula this amount represents the total rise of the country to the level of the third and westernmost division of the lowlands, but farther northwest the escarpment, though still a distinct feature, is only part of a narrow strip of rapidly rising ground, whose summit reaches in places an elevation of 1,700 feet, nearly a thousand feet above the low, flat-lying country stretching easterly from its foot towards Lake Ontario. The third division, lying between Lake Huron and Lake Erie, and bounded on the east by the Niagara escarpment, has, in the northwest, as already implied, a maximum elevation of 1,700 feet or more, from which point the surface slopes towards the level of the lakes on either side, the waters of Lake Huron standing at 581 feet, and those of Lake Erie at 572 feet above the sea.

The St. Lawrence lowlands are underlain by gently dipping beds of sandstone, shale, and limestone of Palæozoic age (Ordovician, Silurian, and Devonian), appearing to succeed one another without a break. Over certain areas they lie in low, very broad, dome-like folds, and at times they are traversed by faults of considerable magnitude, but, compared with the highly flexed and faulted measures of the Appalachians in the east, they may be said to be undisturbed. This sharp contrast in the general attitude of the beds of the two districts which, in Quebec, directly border one another, is also accompanied by differences in the character of the rocks, and in the fossils embedded in them. The materials composing the two sets of rocks appear to have been laid down under different conditions, and perhaps in separate basins.

In southeastern Quebec, the low, level country bordering the St. Lawrence, and underlain by nearly horizontal stratified rocks, extends eastward into the districts occupied by the highly disturbed measures of the Appalachian region. No marked changes in the physical aspect of the country are apparent in passing from one region to the other, but on approaching from the west the boundary between the two provinces, the effects of disturbances in the underlying rocks gradually appear, and finally they are found sharply folded. The boundary between these two distinct geological provinces runs northeast from the foot of Lake Champlain to the city of Quebec, and is marked by the St. Lawrence and Champlain fault, along which, and accompanying lines of dislocation, were relieved the stresses and strains due to the action of the mountain building forces that, in the east, folded, plicated, and faulted the strata, and, at times, thrust great blocks up and over westerly lying beds. The measures lying on the eastward shelving extension of the crystalline rocks of the Laurentides largely escaped these disturbing forces through the yielding of the strata along the northeasterly trending lines of weakness.

The Palæozoic strata of the eastern division of the St. Lawrence lowlands, in eastern Ontario and Quebec, are almost altogether of Ordovician age. In the districts about the junction of the Ottawa and St. Lawrence rivers, large areas are floored with a sandstone termed the Potsdam, that appears to represent the upper Cambrian of New York state. The Potsdam sandstone is brought to light along the eroded summit of a low, broad dome, and appears to be the oldest rock of the lowlands. A lithologically similar rock occurs at intervals along the northern border of the Palæozoic measures, where they overlap the crystalline rocks of the Laurentide hills. But these lower sandstones are not all of the same age, for, in some cases at least, they mark shore deposits laid down during successive intervals as the Ordovician seas gradually crept up over the land. Above the Potsdam occurs an arenaceous, dolomitic limestone known as the Beekmantown, or, as it was originally called, Calciferous. On the Beekmantown lies a group of shales and sandstones overlain by limestones, known as the Chazy. Above the Chazy occurs the Trenton group, usually composed of limestones and shales, and sometimes divided into three members, Lowville or Birdseye, Black River, and Trenton. Overlying the Trenton is the Utica formation, largely of dark bituminous shales, and these are followed by the dark grey shales, sandstones, and limestones of the Hudson River or Lorraine.

In the Province of Quebec the various divisions of the Ordovician, in a general way, occur in bands of successively younger formations roughly paralleling the edges of the area of ancient crystalline rocks on the north; the oldest members occur to the north and the youngest generally border the St. Lawrence and Champlain fault. In the triangular area lying between the Ottawa and St. Lawrence rivers the disposition of the various members is more basin-like, the younger beds occurring towards the centre of the area. All the divisions appear to succeed one another conformably, though it is quite possible that there may be important breaks masked by this general appearance of conformity. The total volume of rocks composing the Ordovician system is very great; in the neighbourhood of the city of Montreal there are 4,350 feet of strata from the base of the Potsdam to the highest members of the Lorraine there exposed. But the thicknesses of the different members of the system, as well as the characters of the different formations, vary locally.

Although the Ordovician strata occupy almost the whole of the district at present under discussion, there are also areas containing remnants of younger formations. A few, small, isolated basins in the Ottawa district, and in Quebec east of the St. Lawrence, contain considerable volumes of red shales, etc., thought to be of early Silurian age. In places these beds rest unconformably upon the underlying measures, showing, probably, that prior to their deposition the district had been elevated and the strata slightly deformed. Also, near Montreal there are certain limited deposits containing fossils of early Devonian age. These younger members thus furnish evidence that the lower plains were once covered by many hundreds of feet of strata, since almost entirely removed by erosion. This conclusion is strengthened by the phenomena exhibited by the isolated eminences of the Monteregian hills.

The Monteregian hills are eight in number, and six of them, including Mount Royal at Montreal—the most westerly of the group—lie in an approximately east and west line at distances of about ten miles apart. They form eminences circular or oval in outline, only a few square miles in area, and rising abruptly 600 to 1,200 feet above the surrounding level country. The flanks of the hills are formed of sediments variously altered and hardened, while the central portions, the cores, are composed of igneous rocks of alkali types, including different alkali syenites, nepheline syenite, essexite, etc. The igneous portions appear to represent laccoliths, or conduits, that may have led to the old land surface. The character of these igneous hills is such as to indicate that at the time of their formation there probably was an additional thickness of strata over the surrounding country of not less than 2,000 feet, all of which has since been removed. This conclusion is strengthened by the occurrence of fragments of Devonian rocks in dikes from the igneous pipes.

In the second division of the St. Lawrence lowlands, that borders Lake Ontario, and is bounded in the west by the Niagara escarpment, Ordovician measures are again widely exposed. The oldest are generally of Lowville (Birdseye) age, resting on the pre-Cambrian rocks of the north; they dip gently under and are succeeded towards the south by successively higher divisions of the Ordovician, until, in the neighbourhood of Toronto, the highest members of this system disappear beneath the Silurian that occupies the rest of the country, forms the outcropping beds of the Niagara escarpment, and extends farther west over the sloping plain of the western portion of the Ontario peninsula.

The bounding line between the Ordovician and Silurian crosses Lake Ontario from New York state, and runs nearly north from Toronto to the foot of Georgian bay. On the Manitoulin islands the Ordovician measures appear from under the Silurian along the northerly facing cliffs. What is usually considered the lowest division of the Silurian, the Medina, consists of variously coloured sandstones and shales, over a thousand feet thick in the

Niagara peninsula, but towards Georgian bay decreasing to a tenth of this volume. The Medina, possibly in part of Ordovician age, is succeeded by the Clinton, represented in Ontario usually by less than fifty feet of sandstones and shales. Overlying these are the beds of the Niagara group, chiefly limestones, some 200 feet thick in the Niagara district, but double that amount at Cabots head, at the extremity of Indian peninsula.

To the more resistant Niagara limestones is due the formation of the Niagara escarpment, bounding the third division of the St. Lawrence lowlands. The succeeding Silurian formations spread over a considerable part of the Ontario peninsula between Lakes Huron and Erie, where the strata still occur in northward trending bands of varying width. The Niagara limestones are overlain by the limestones and dolomites of the Guelph, represented along the Niagara river by a few feet only, but increasing northward to 100 feet and more. Above the Guelph is the Salina group, 200 to 300 feet thick, and composed of beds of gypsum, salt, dolomite, and dark shales, measures evidently deposited in a slowly evaporating sea. Overlying the Salina is a group of beds, sometimes measuring 40 feet or more in thickness, and composed of dolomites, etc., which, in Ontario, represent the highest Silurian present and apparently indicate a return to marine conditions of deposition.

The lowest beds of the Devonian system are wanting in the Ontario region, which, during the opening epochs of this period, appears to have been uplifted and slightly eroded. The lowest Devonian of Ontario is, in places, represented by the light coloured Oriskany sandstone, seldom more than twenty-five feet thick, while in other places the succeeding Devonian division rests directly on the Silurian measures. The Onondaga consists largely of limestones, often 150 to 200 feet thick. It occupies a narrow strip along the foot of Lake Erie, expanding in the Ontario peninsula into a wide band. The dark shales of the Hamilton succeed the Onondaga, and are, in places, overlain by still younger Devonian strata. West of the band of Hamilton measures, lower divisions of the Devonian again appear at the surface as the result of a low fold, and on the Detroit river Silurian strata appear.

The various ancient seas and embayments in which the Palæozoic strata of the St. Lawrence lowlands were deposited, were not limited to the continuous areas now underlain by the stratified beds of this era. In Ontario, beyond the northern boundary of these beds, occur outliers of similar strata, resting on and surrounded by pre-Cambrian crystalline rocks. These outliers are evidently erosion remnants of a once more extensive covering, which, in the Ottawa valley, seems to have extended as far as Lake Nipissing. An outlier of Niagara limestone also occurs far up the Ottawa valley, at the head of Lake Timiskaming, deposited in a Silurian sea coming either from the south, or, possibly, from the north.

In the east also, the Palæozoic beds once occupied a wider territory. Trenton and Utica beds occur on the shores of Lake St. John, 100 miles west of the St. Lawrence, at the head of the Saguenay river. At intervals along the north shore of the St. Lawrence river and gulf, Ordovician beds occur, while towards the Strait of Belle Isle, Cambrian beds repose on the pre-Cambrian. The large island of Anticosti, in the Gulf of St. Lawrence, is composed of Ordovician and Silurian strata dipping gently southwards.

ECONOMIC MINERALS.

Underlain by slightly disturbed Palæozoic measures, the geological history of the St. Lawrence lowlands has not been favourable to the development of metallic minerals. Southwestern Ontario is, however, the principal seat in Canada of the petroleum and salt industries, while throughout the whole region the brick, tile, and cement industries are becoming increasingly important.

TABULAR DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE ST. LAWRENCE LOWLANDS.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Oil.......	Occurs in natural reservoirs usually at the horizon of the Onondaga (Corniferous) in the gently undulating, nearly horizontal Palæozoic measures of southwestern Ontario....................	Petrolia, Tilbury, Leamington, etc., Ont.
Natural Gas.....	Occurs in natural reservoirs in the Guelph, Clinton, Medina, and Trenton formations in the gently undulating, nearly horizontal Palæozoic measures of southwestern Ontario............	Welland, Haldimand, Essex cos., Ont.
Salt.......	In beds of rock salt (or as brine) in the Salina formation in the gently undulating, nearly horizontal, Palæozoic measures of southwestern Ontario....................................	Windsor, Sarnia, Wingham, etc., Ontario.
Gypsum...	In beds in the Salina formation in the gently undulating, nearly horizontal, Palæozoic measures of southwestern Ontario...............	

OIL AND NATURAL GAS.

The principal oil fields of Canada are situated in the peninsula of southwestern Ontario, between Lake Huron and Lake Erie. The first oil was found in Lambton county in 1862, though it is recorded that Manitoulin island was the site of the first oil discovery in Canada. Until quite recently, the Lambton County fields, in which there have been about 11,000 producing wells, were by far the largest producers, but in 1907, the new Tilbury district, in Kent county, contributed about forty-four per cent of the total production, which for that year reached 27,621,851 gallons of crude oil.

Besides the two oil centres of Petrolia and Oil Springs in Lambton county, and the Tilbury district in Kent county, other important districts are: Bothwell and Coatsworth in Kent, Dutton in Elgin, Leamington in Essex, and Moore in Lambton. The oil districts are all situated within an area underlain by Devonian strata, usually on an anticlinal axis, and the petroleum is largely obtained from horizons in the Onondaga (Corniferous) at varying depths in the different localities. At Petrolia the oil-bearing horizon is usually between 450 feet and 480 feet beneath the surface; at Bothwell it is at about 600 feet. Oil has, in places, been obtained sparingly from the Trenton; while the Leamington oil "pool" was found in the Guelph at a depth of 1,075 feet.

When first drilled, the natural pressure often drives the crude oil to the surface, and sometimes produces gushers, such as one well in Raleigh township, Kent, that for a time yielded 1,000 barrels a day. After the flowing period, the oil has to be pumped to the surface. While some of the smaller districts become exhausted in a few years, in some cases the pool being only a few hundred feet wide and perhaps a quarter of a mile long, others have continued to furnish oil for a long period. The Lambton field, discovered over forty years ago, is remarkable in this respect, and though the average yield per well is small, the district still continues to produce a large amount of oil and some wells have been active producers for forty years. One group of 100 wells at Petrolia, for instance, produces about 150 barrels per month. In the Bothwell field, shortly after its discovery, a group of ninety wells furnished, on an average, about 1,250 barrels per month.

Natural gas is produced and used in large quantities in southwestern Ontario. Although found almost everywhere associated with the petroleum, the yield in many of the oil districts is comparatively small; while in Haldimand and Welland counties a large supply appears to be available. In these counties the gas horizons are in the Clinton, Medina, and Trenton. In Welland county, one group of fourteen wells, drilled to depths of about 3,000 feet, regularly produces over 30,000,000 cubic feet of gas per day. In Essex county a single well driven 1,020 feet to a horizon in the

Guelph yielded gas at the rate of 10,000,000 cubic feet per day. The importance of the natural gas industry is shown by the marked increase of late years in the annual value of the output, that in 1903 was valued at less than $200,000, but had reached a little over $745,000 in 1907.

PEAT.

Large peat bogs occur at a number of points in Ontario and elsewhere in Canada, but not all of the bogs are suitable for the production of fuel, and, ultimately, it seems more than probable that, with the help of artificial fertilizers, many will be turned to agricultural purposes.

SALT.

At present Ontario is the only province producing salt, and the amount for 1908 reached nearly 80,000 tons, while during the last period of five years the annual production averaged about 64,000 tons. The discovery of the salt deposits was accidentally made in 1865 near Goderich during the sinking of a bore-hole in search of oil. Since then the salt deposits have been found to occupy a buried basin along the shores of Lake Huron, underlying an area of over 2,500 square miles in Essex, Lambton, Middlesex, Huron, and Bruce counties. The salt occurs in the Salina formation of upper Silurian age, in which the beds of the mineral sometimes reach a thickness of 250 feet, though then, generally with partings of shale. One well, in Lambton county, penetrated a total thickness of 705 feet of salt in 805 feet of strata, between depths of 1,210 and 2,015 feet beneath the surface.

The salt beds have generally been found in wells ranging in depth between 970 feet and 1,650 feet. The salt is recovered either by forcing fresh water down the wells or by taking advantage of natural flows of underground water, and pumping the resulting brines to the surface to be evaporated. Some of the main salt-producing centres are Sarnia, Windsor, Goderich, Wingham, and Sandwich.

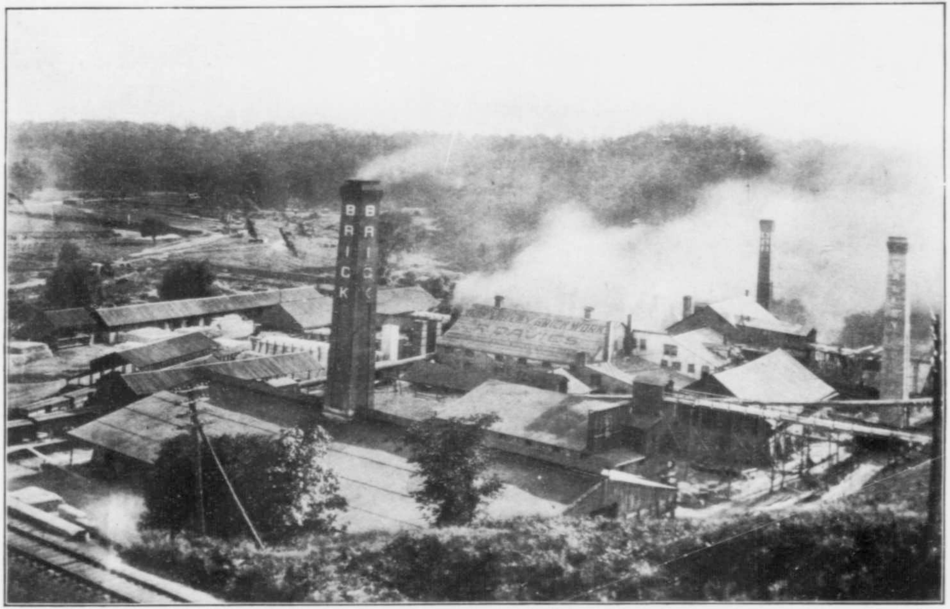
GYPSUM.

Gypsum occurs in western Ontario in the salt-bearing Salina formation of upper Silurian age. The outcrops of the Salina, after running parallel with Lake Ontario in New York state, enter Canada at the Niagara river, where the formation is estimated to have a thickness of between 200 feet and 300 feet. The group there consists of dolomites and soft crumbling shales, with lense-like bodies of gypsum, that, interstratified with the beds of dolomite, sometimes are a quarter of a mile in length. The gypsum beds are worked along the outcrop of the formation over its general northwesterly course from Niagara river to Lake Huron. The Salina evidently formed during a time of excessive evaporation of the sea, when the deposits of salt, gypsum, etc., were precipitated.

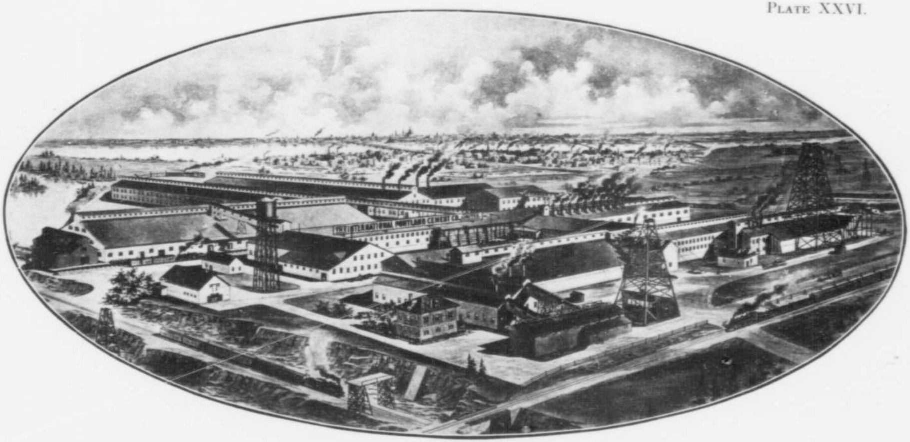
BUILDING AND ORNAMENTAL STONES, ETC.

The widespread clays of glacial and post-glacial age that often completely hide the underlying rocks over considerable areas of the St. Lawrence lowlands have furnished the material for numerous brick and tile industries both in Ontario and Quebec. Advantage has also been taken, for the same purpose, of the shales in various of the lower Palæozoic formations. The raw materials for the manufacture of Portland cement are abundantly displayed in the region, and support a number of large industries. Some of these utilize marls—deposits of calcium carbonate in lakes scattered over the uneven surface of the post-glacial deposits, and the clay beds of these deposits, while others use Palæozoic limestone. These limestones of several of the formations, and more especially of the Trenton group, are also extensively quarried both for building stones and for the production of lime. At several points the limestones are also used in the making of calcium carbide, while the dolomites are used in the manufacture of pulp.

PLATE XXV.



Don Valley Brick Works, Toronto, Ont.



International Portland Cement Works, Hull, Que.

CHAPTER IV.

THE LAURENTIAN PLATEAU.

GEOLOGY.

The *Laurentian Plateau* region, surrounding Hudson bay with a U-shaped form, has an area of over 2,000,000 square miles. Limited in the east by the North Atlantic and by the gulf and estuary of the St. Lawrence as far as the city of Quebec, its southern boundary there passes inland and up the Ottawa river to beyond the city of Ottawa, then turns abruptly to the south and crosses the International Boundary at Brockville. Farther west, at the foot of Lake Ontario, it crosses back into Canada and follows a nearly due east and west line to the foot of Georgian bay, from which point the two upper Great lakes form the bounding line. West of Lake Superior the Laurentian Plateau region extends south into the United States. In southeastern Manitoba the boundary again enters Canada, and from there passes along a general northwesterly course through Lake Winnipeg, Great Slave lake, and Great Bear lake, to the shores of the Arctic ocean.

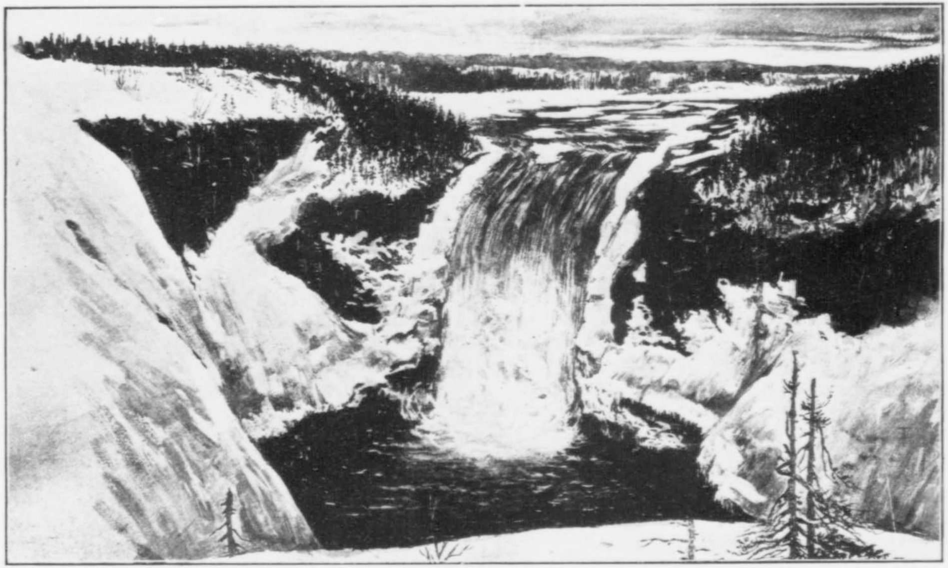
This great region is, for the most part, characterized by its uniform physical features. Considered by districts, the Laurentian plateau is composed of gently sloping regions whose even surfaces, save sometimes for the valleys of the larger rivers, are broken only by low hills rising a few hundred feet or less above the general level. Except in the northeast, along the Labrador coast, the land is generally comparatively low, seldom rising 2,000 feet above the sea. The more extensive elevated stretches of country within the plateau region all lie towards its outer margin, away from Hudson bay. Save towards the headwaters of the Ottawa river in the east, and over the wide depression bordering and extending north of Lake Winnipeg in the west, the higher lands form an elevated belt usually hundreds of miles wide, stretching from the North Atlantic in the east, around the foot of Hudson bay almost to the Arctic in the northwest, with a general elevation always above 1,000 feet, and over large tracts in the Ungava peninsula, approaching 2,000 feet. From this outer, elevated margin the country on all sides slopes inwards towards Hudson bay, surrounding which there is a nearly continuous belt of territory, often 125 miles wide, over which the land never reaches a height of 500 feet above sea level.

The highest land of the Laurentian Plateau region lies along the Labrador coast towards the eastern entrance of Hudson strait, where mountain peaks attain heights of about 6,000 feet. Southward along the coast, the general elevation decreases, but everywhere the shores are high and penetrated by deep inlets, with precipitous sides rising five hundred to several thousand feet above the sea. Along the Gulf of St. Lawrence shore the land is generally bold, rising inland rapidly to heights of 1,000 feet or move, though penetrated by long, narrow valleys occupied by the main waterways.

The abrupt rise of the southern boundary is also a notable feature along its course from Quebec inland up the Ottawa valley. It is repeated along the Lake Superior shores, where for miles bold hills and cliffs rise to heights of 300 to 1,500 feet above the lake. In the west, however, the characteristic sudden uprise at the outer boundary, so prominent in the east, largely disappears, or is replaced by a slight drop from the overlapping sediments to the level of the Laurentian plateau.

The Laurentian plateau is in detail characterized by countless lakes, both large and small, muskegs, and numerous branching streams and rivers that occupy the valleys between the hummocky hills. The territory in the east, south of the latitude of the foot of James bay, is densely wooded, while in the west, the heavily timbered country extends even farther north. Beyond this, to the north, the forest growth gradually decreases, and on the shores of Hudson bay, at about north latitude 59°, the barren lands commence and stretch away to the Arctic ocean. Essentially a forest region in the south, the Laurentian plateau also contains wide areas, the clay belts, that eventually should prove valuable for agricultural purposes.

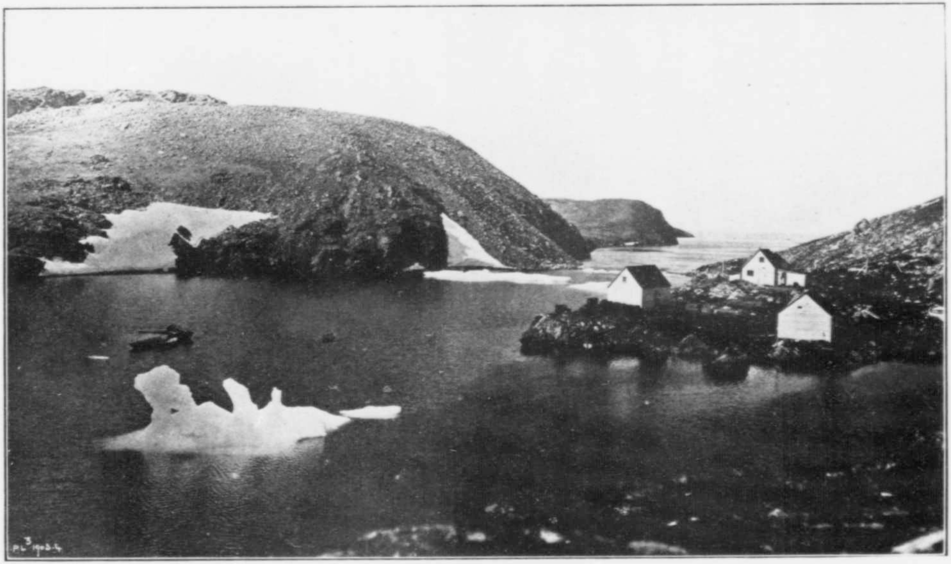
Noted for its timber resources, the Laurentian plateau, where best known, is no less important from the standpoint of mineral wealth. Along the southern margin occur the noted copper and nickel ores of Sudbury, and to the north of these lie the Cobalt



Hamilton Falls, Labrador.

Rapid, Larch River, Ungava.

PLATE XXIX.



Port Burwell, at eastern entrance to Hudson Strait.

silver deposits. In eastern Ontario, and the adjoining portion of Quebec, are numerous and important deposits of graphite and mica. All through the region occur iron deposits, some now being mined, and many in the near future destined to become commercially important. Besides these, many other ores, both metallic and non-metallic, are known, although the country cannot in any sense be said to have been closely prospected. Nor do these mineralized belts seem to be confined to the southern part of the country, but everywhere through the Laurentian Plateau region the general conditions appear to be similar, and it is certain that many deposits of economic value yet remain to be discovered.

The Laurentian Plateau region, save for a zone of Palæozoic rocks bordering the southwestern side of Hudson and James bays, and a few relatively small outliers of the same system occurring elsewhere, is altogether underlain by rocks older than those of the Cambrian period. Collectively these ancient rocks will be referred to as the pre-Cambrian. The vast territory over which they now outcrop is but a portion of the ancient continent of Laurentia that, prior to Cambrian times, it is believed, occupied much of the present area of the North American continent. Rocks in many respects similar to those composing the Laurentian plateau extend far beyond its borders beneath the surrounding sediments deposited in Cambrian and later basins.

The various assemblages of rocks underlying the Laurentian plateau, by their relations and distribution, testify to a long and complicated history in pre-Cambrian times. They show that, at intervals and over wide regions, assemblages of rocks were formed, afterwards subjected to great earth movements, penetrated by vast bodies of deep-seated igneous rocks, then profoundly eroded, and finally depressed, to be again covered by another set of beds volcanic and sedimentary. This great cycle was, in some instances, repeated one or more times, but the extent of the Laurentian Plateau region is too great, and the knowledge of it as yet too elementary, to allow of a definite correlation of the details of its geological history as a whole.

The region is chiefly occupied by large and small bodies of igneous rocks, which at the time of their formation were deeply buried, but now, because of subsequent erosion, are partly exposed. These igneous rocks are often typically granitic in appearance, but, perhaps, more commonly show gneissic structures. Though of widely different relative ages, penetrating one another and later assemblages of pre-Cambrian rocks, yet over the wide expanse of the Laurentian plateau they preserve a general resemblance. By their nature they show they were not the first rocks to occupy the region, and often they may be seen cutting younger strata. Yet, from their wide distribution and the often vast dimensions of the individual masses, it is evident that these essentially granitic rocks form the foundation, as it were, of the whole Laurentian Plateau region, and now, if they do not appear at the surface, are either covered by a comparatively thin mantle of younger rocks, or else underlie, with intrusive relations, older formations.

Throughout the pre-Cambrian region occur other rocks, forming areas sometimes to be measured in yards, sometimes in scores of miles. These have been penetrated by the granites and gneisses, and are, therefore, the oldest rocks of their respective districts. Usually they are highly altered, but often they may still be determined to have been of the nature of sediments and volcanic rocks that formed on or near the earth's surface. The assemblages of these older, usually much altered rocks, vary in general character from district to district, are doubtless of various relative ages and, in some districts, may represent groups of strata that in other places still remain comparatively unaltered and unpenetrated by igneous bodies. Within the pre-Cambrian region also occur, sometimes over wide areas, assemblages of sedimentary beds that are at times scarcely more altered than recently consolidated measures. These younger pre-Cambrian strata frequently may be seen to overlie and to have been partly formed from older, sedimentary and volcanic rocks and the granitic rocks intruding them.

The general history of pre-Cambrian times within Canadian territory has, perhaps, been most clearly determined in the part of the Laurentian plateau lying within the Province of Ontario, and the adjacent portions of Quebec. In northern Ontario, near Cobalt, and in the districts about Lakes Timiskaming and Timagami, occurs a widely distributed group of rocks known as the Keewatin. These rocks, the oldest in the region, are invaded by large bodies of granite. The Keewatin strata are largely of volcanic origin, but with them, though but sparingly, also occur

High Falls of the Rivière du Lièvre, Que., at low water.

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Looking north up the Rivière du Lièvre from Emerald, Que. Mine buildings in foreground.

rocks seemingly of sedimentary origin, such as banded quartzose beds often rich in iron, the Iron formation. The Keewatin, as a whole, is highly altered, its members are frequently in a schistose condition (greenstone schists) and apparently closely folded. Once, doubtless, forming a continuous, wide-spread, nearly horizontal series of rocks, the beds now occupy isolated, relatively narrow bands or areas, underlain and penetrated on all sides by granites and allied rocks.

The Keewatin strata, at the time of their folding, probably rose into mountain masses, while, at about the same time, vast bodies of granitic rocks intruded them from below. Later, as shown by the horizontal, overlying beds of younger conglomerate still occupying parts of the district, the complex assemblage was subjected to intense erosion and much of the Keewatin entirely removed; the once deeply buried granite masses were partly exposed, and the whole region reduced to a gently undulating country, much like that of the present time. The beginning of this great erosion period marked the close of what appears to have been the first pre-Cambrian era of which there is definite knowledge.

Towards the close of the first prolonged erosion interval, the Timagami district appears to have been depressed, and a widespread group of sedimentary rocks deposited, covering the Keewatin and the granites. This sedimentary group, the lower Huronian, still occupies much of the country. It consists of thick beds of conglomerate overlain by and passing upwards into slates, above which sometimes occurs a quartzite or arkose member possibly belonging to a second division, the middle Huronian. With the sediments are associated widely extending, often thick, sheet-like bodies of diabase, of later date, that sometimes cut the sedimentary beds, but more often rest on top of them. The Huronian series, though affected by faults and comparatively gentle folds, is, on the whole, flat-lying, and beneath its basal members may be traced the old, gently undulating, pre-Huronian land surface of Keewatin rocks and intrusive granites.

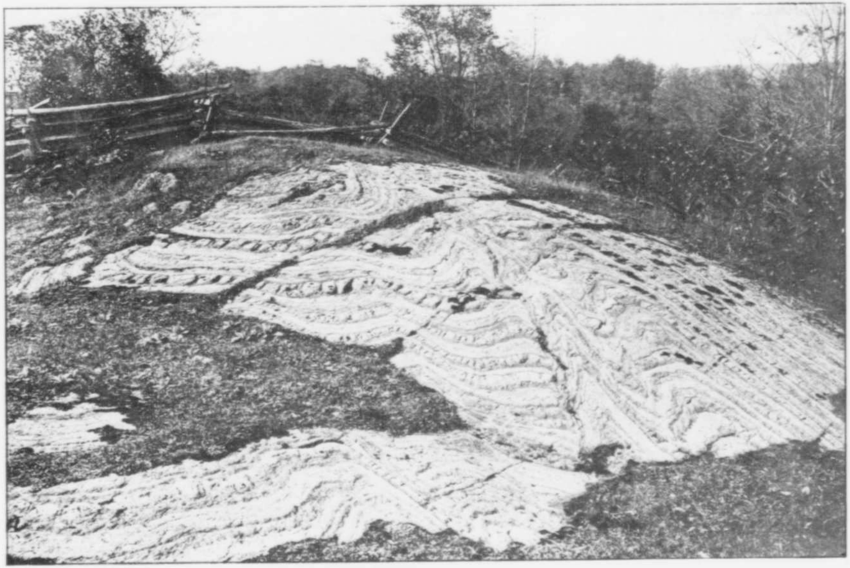
The conditions obtaining in the Timagami district seem, in part, to be duplicated through much of northern Ontario, and throughout the Laurentian plateau occur rocks like those of the Keewatin, sometimes occupying large areas and exhibiting many varieties of volcanic rocks in varying degrees of deformation.

Often the areas form gigantic meshworks enclosing, or partly enclosing areas of intrusive granites or gneissic rocks occupying many square miles of country. At times the Keewatin rocks are greatly changed, and sometimes form wide zones of gneissic or schistose varieties intermingled and interbanded with the granitic intrusives. But though the condition of the Keewatin and its relations to the granitic intrusions is, broadly speaking, everywhere alike, the same is not true of the widely distributed Huronian.

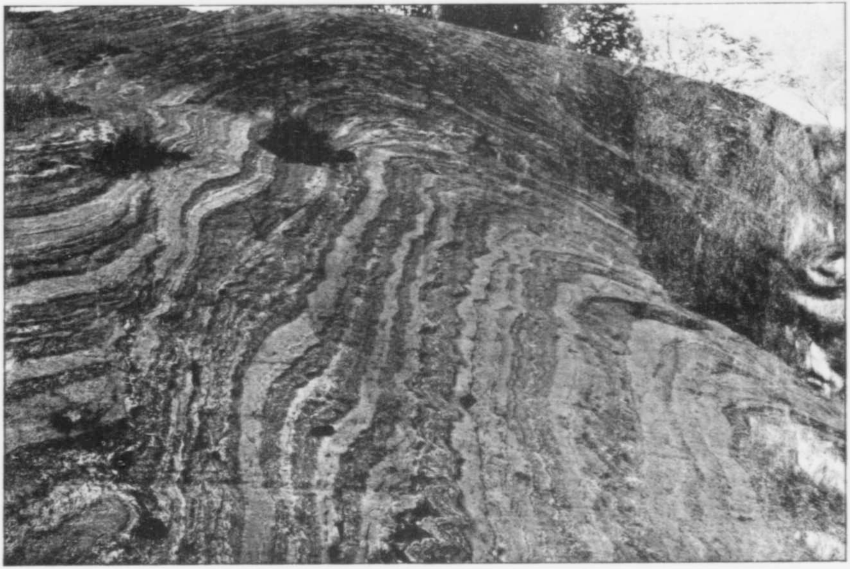
Strata similar to the but slightly disturbed lower Huronian of the Timagami district, and younger than the associated Keewatin, are found to the south and west, as, for instance, near Sudbury and in the Michipicoten district. In these districts the Huronian beds are found to be much disturbed, in places schistose and cut by granites, though not all of the granites of these districts are post-Huronian. Farther west, to the north of Lake Superior, the lower Huronian is as highly disturbed, and as much altered as the intricately associated Keewatin which has furnished detrital material to the Huronian, and both series appear to be cut by the same granitic bodies. In these western districts the Huronian and Keewatin appear to have been conjointly folded, elevated into mountainous areas, and penetrated by immense granitic masses. Subsequently the complex was deeply eroded and planed down to a gently undulating surface. This erosion period marks the close of the second recognized pre-Cambrian era.

After the second great erosion interval, portions of the ancient continent were again depressed, and, as exemplified near Port Arthur, heavy deposits of sediments, largely dark slate, sometimes with a horizon containing iron ore formation, were formed. This series, known as the upper Huronian or Animikie, occupies a large district in Canada, west of the head of Lake Superior. It overlies the older complex of Keewatin, Huronian, and intrusive granitic rocks with a marked unconformity. The upper Huronian beds are virtually unaltered and lie in what appear to be a series of fault blocks, forming ridges with southerly sloping tops and steep northern faces. As in the case of the lower Huronian, extensive, often very thick sills and sheets of intrusive diabase are associated with the Animikie.

After the deposition of the upper Huronian beds in the Lake Superior region, the land was once again elevated, the strata



Contorted Gneiss near ferry landing, Alfred township, Prescott Co., Ont.



Contorted Gneiss near ferry landing, Alfred township, Prescott Co., Ont.

The Narrows, Lake Timiskaming.

Notch or gorge near mouth of Montreal river, Lake Timiskaming.

subjected to earth movements, and eroded; but the deforming effects of these forces were slight when compared with the earlier deformation of the lower Huronian and Keewatin. After this third marked period of uplift and erosion the Keweenawan series was formed. This series consists of a sedimentary portion of red sandstones and conglomerates, calcareous shales, and dolomites, well exposed on the Lake Superior shore east of Port Arthur and about Lake Nipigon, and of a volcanic portion exhibited on Michipicoten island as an assemblage, many hundreds of feet thick, of tuffs and volcanic flows.

The Keweenawan is classed by some as of early Cambrian age, perhaps representing desert conditions, but for present purposes it is most conveniently regarded as late pre-Cambrian, the last of the sedimentary groups of that age. Associated with the Keweenawan beds about Lake Superior are immense sheets and sills of diabase, ranging in thickness up to perhaps 1,000 feet. These igneous rocks are distinctly younger than the Keweenawan, in places occurring in sills, or, more prominently displayed, as immense sheets overlying the whole sedimentary group and sometimes extending beyond, over the older rocks.

The account of the more striking features of pre-Cambrian history in Ontario may be supplemented by the discussion of other lines of evidence, but the deductions drawn from these are less certain. The lower Huronian measures already described, are paralleled along the north shore of Lake Huron by a somewhat similar assemblage containing a considerable volume of limestone. These beds are overlain unconformably, but not strikingly so, by a second group of somewhat similar measures, known as the middle Huronian. Possibly the middle Huronian beds were deposited during a portion of the erosion interval that, elsewhere, separated lower and upper Huronian times.

Along the Hudson Bay shores of the Ungava peninsula, also in the central portions, and again towards the Atlantic side of this territory, occur extensive areas occupied by a considerable thickness of sandstones, slates, dolomites, and siliceous iron ore beds. These measures, though faulted and tilted, are otherwise little changed from their original state, and, with some degree of definiteness, may be correlated with the upper Huronian of the Lake Superior region. To the north, along Hudson strait, are areas of apparently once similar beds, but now much disturbed, altered, and penetrated by bodies of granite. It is not impossible that the period of deep-seated igneous intrusions and deformation of these upper Huronian beds of Hudson strait was contemporaneous with the interval of uplift, and comparatively slight deformation and erosion separating the upper Huronian and Keweenawan periods in the Lake Superior district.

In eastern Ontario, and over a very extensive region reaching northeastward through Quebec, occurs a group of rocks whose relations with the various members of the pre-Cambrian system in the districts about Lake Superior are still uncertain. These rocks, first described from the district in the Province of Quebec bordering on the lower Ottawa river, and named the Grenville group, comprise large volumes of crystalline limestone associated with quartzites and various types of gneisses believed to have had a sedimentary origin. The measures are tightly folded, and are penetrated by great bodies of granite and gneiss. Traced westwards, the members of the Grenville group seem to occur in a less altered state, and in eastern Ontario have been thought to be represented by the Hastings series, though possibly the eastern Ontario assemblage of rocks includes more than the original Grenville. The relations of these Grenville-Hastings rocks with the Keewatin and Huronian rocks farther west has not yet been established. They may include the Keewatin, a portion of the Huronian, or some series not yet recognized in the Lake Superior region.

Other areas throughout the Laurentian Plateau region are underlain by strata whose definite correlation is still impossible. In the Ungava peninsula there are areas of gneisses and schist resembling sometimes the Keewatin, sometimes the Grenville, while in some instances they may represent greatly altered Huronian beds. Near Sudbury, Ontario, occurs a great volume of sediments and tuffs, overlying and cut by the intrusive nickel-bearing eruptive. These stratified beds, so far as is known, are not exactly paralleled by any other pre-Cambrian series, though they have been correlated with the upper Huronian. Northwest of Lake Superior, large areas are occupied by peculiar, uniform quartzose biotite gneisses, sometimes appearing to underlie and be older than the Keewatin, at other times appearing to be its equivalent.

Fly River, three miles trom mouth.

PLATE XXXVII.

10

Hills on Montreal River, two miles above Wapus River, Ont.

PLATE XXXVIII.

Contorted gneiss at Fullerton, Hudson Bay.

The Nastapoka group, the probable equivalent of the upper Huronian in the Ungava peninsula, has already been mentioned. Similar measures outcrop over a limited area projecting through the Palæozoic beds just south of Hudson bay. Nearly identical rocks occur over large areas about Great Bear and Great Slave lakes. A large district bordering the southern shores of Lake Athabaska is underlain by sandstones supposed to be the equivalents of the Keweenawan. Farther to the northeast are considerable volumes of acid and other volcanic rocks, probably also of Keweenawan age. Possibly in the district extending from Great Bear lake to the mouth of the Coppermine river, on the Arctic ocean, both the upper Huronian and the Keweenawan are represented.

Although sedimentary and volcanic rocks are so widely distributed over the Laurentian plateau, yet their volume, as a whole, is much less than that of the associated plutonics, which, though not the oldest rocks, everywhere form the foundation on which the others rest. Frequently these bodies are typical granites, syenites, etc., but often they are composed of, or insensibly merge into gneisses, whose structures in many cases appear to be original. In other cases the gneissic structure is indisputably the result of pressure and the resulting crushing. These granitic rocks show an infinite number of varieties, ranging from very acid to very basic forms. Pegmatite dikes are an almost constant feature. The ages of the rocks must vary widely, though over large areas they often all seem to be approximately of one period, post-Keewatin, post-Huronian, etc., as the case may be. In eastern Ontario a considerable area is characterized by the presence of batholitic bodies of nepheline syenite, alkali syenites, and related rocks. Over the whole eastern portion of the Laurentian highlands, from the Great lakes to the Labrador coast, occur bodies of anorthosite, sometimes 10,000 square miles in extent.

ECONOMIC MINERALS.

Though only a very small part—the southern border only—of the Laurentian plateau may truly be said to have been prospected, the region has already proved to be one rich in mineral wealth. In Ontario, along the outer margin of the great pre-Cambrian region, many and varied deposits of economic importance have been discovered, though even this relatively limited area has been only imperfectly prospected. Within its bounds occur the noted nickel-copper mines of Sudbury, which now outrival in their production of nickel the New Caledonia deposits. Within 100 miles of Sudbury lies the Cobalt district, containing one of the richest and most easily worked silver camps in the world. In many districts are deposits of iron ore, often low grade, but doubtless soon to become commercially important. Ores of gold, copper, lead, sulphur, and arsenic are worked, while the mica, graphite, and many other mining industries are important.

The mineral wealth of the better known southern part of the Laurentian plateau is virtually confined to those districts in which are found members of the various Huronian, Keewatin, and Hastings-Grenville formations, though the mineral deposits not infrequently lie in igneous rocks, and often seem to have been connected in origin with the intrusion of plutonic bodies. Thus, the silver ore occurs in or near diabase intrusions, and many ores occur in the older rocks along the contact of an intrusive granitic rock. In the better known southern part of the vast pre-Cambrian area the formations with which the mineral deposits are associated collectively occupy very large areas, as, for instance, in the case of an irregular zone that stretches northeast from Lake Huron to Lake Mistassini, a distance of 600 miles. West of Lake Superior to the Manitoba boundary is another noted region of such rocks, while eastern Ontario and the adjoining portions of Quebec form a third.

In the northern, virtually unprospected and by far the larger portion of the Laurentian plateau, the same general geological conditions seem to hold as in the case of the better known south-

Atikameg River, Keewatin.

Wanapitei River below Welcome Lake.

ern part. Though in the north the plutonic rocks seem to bulk far greater than in the south, it is highly probable that, with advancing knowledge of the country, the older formations will be found to occupy large areas, and, reasoning by analogy, many of these areas should prove to be rich in mineral wealth.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold, Arsenic	Free gold and auriferous mispickel occur in quartz veins cutting schists and basic igneous rocks of the Hastings-Grenville series, usually near granitic intrusions.	Deloro, Ont.
Gold	Free gold and auriferous pyrite with pyrrhotite in quartz veins and stringers cutting altered gabbro of the Hastings-Grenville series	Belmont, Ont.
	Free gold with pyrite and chalcopyrite in quartz veins in Keewatin schists, etc.	Larder lake, Shakespeare mine near Webbwood, western Ontario.
Platinum	In the mineral sperrylite in the nickel-copper deposits of Sudbury. *See* under nickel	Sudbury, Ont.
Copper	Native in Keweenawan diabase, Lake Superior shores, also in diabase about Coppermine river, northwest of Hudson bay	
	Chalcopyrite, with, towards the surface, bornite in veins of quartz with some calcite, cutting Huronian sediments and post-Huronian diabase	Bruce Mines, Ontario.
	Bornite, chalcocite, chalcopyrite, pyrite, etc., in impregnated zones in schistose diorite, garnetiferous gneiss, etc.	Parry Sound, Ont.
	Chalcopyrite. *See* under nickel	Sudbury, Ont.
Silver	Native silver and argentite in veins of calcite and barite with varying amounts of quartz and fluorite, traversing Animikie sediments and post-Animikie diabase	Silver Islet, L. Superior.
	Native silver with argentite, smaltite, cobaltite, niccolite, native bismuth, etc., in narrow veins of calcite lying chiefly in Huronian sediments and post-Huronian diabase	Cobalt, Ont.
	Native silver and argentite with hematite and various sulphides in aplite dikes cutting post-Huronian diabase	South Lorrain, James township, etc., Ont.
Lead	Galena in calcite veins traversing mica schists of the Hastings-Grenville series.	Hastings co., Ont.
Zinc	Zinc blende and galena in irregular bodies in crystalline limestone of the Hastings-Grenville series	Frontenac co., Ont.
	Zinc blende with iron and copper sulphide forming irregular, lenticular bodies in Keewatin schists.	Rossport, Ont.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

(Continued)

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Nickel-copper.....	Pentlandite, chalcopyrite and pyrrhotite, in very large irregular deposits situated at the edge of a norite body intruding pre-Cambrian sediments and igneous rocks..........................	Sudbury, Ont.
	Niccolite, etc., occurring in the silver-bearing veins of cobalt. *See* under silver..................	Cobalt, Ont.
Iron......	Bog ore deposits, still under formation..........	Three Rivers, Que.
	Magnetite and, to a lesser extent, hematite interbanded with variously coloured quartz, forms long bands associated with Keewatin schists often cut by granites, etc....................	Lake Nipigon, Lake Timagami, Ont.
	Bands of magnetite, locally impregnated with sulphide, lie in Keewatin schists.............	Atikokan range, Ont.
	Irregular bodies of magnetite with hornblende and epidote in a formation of magnetite and siliceous material, lie in Keewatin schists.......	Moose mountain, Ont.
	Concretionary-like hematite and limonite with large, sharply defined bodies of iron pyrite in a sandy state, forming a large body associated with banded siliceous rocks containing magnetite, iron carbonate and pyrite, and surrounded by Keewatin schists.......................	Helen iron mine, Ont.
	Irregular, often large masses of magnetite with varying amounts of pyrite, lying along the contact of crystalline limestone (Hastings-Grenville series) and intrusive granites, etc., or within bodies of basic igneous rocks................	Hastings co., Ont.
	Large and small, irregular bodies of titaniferous magnetite associated with bodies of anorthosite.	Quebec.
	Iron sands derived from the titaniferous magnetites of the anorthosite bodies.............	Lower St. Lawrence.
	Bodies of hematite and limonite in beds of cherty iron carbonate belonging to the Animikie sedimentary series..........................	Loon lake, Ont.
	Seams and layers of magnetite and hematite interbanded with layers of variously coloured quartz forming part of the Nastapoka sedimentary group..................................	East shore of Hudson bay.
Sulphur...	Large elongated lenses of pyrite and quartz in Keewatin schists.........................	Near Missinaibi, Ont.
	Pyrite associated with iron ore. *See* under iron.	Helen iron mine, Ont.
Arsenic...	Auriferous mispickel accompanied by pyrite and chalcopyrite and forming large and small bodies in Keewatin schists, in gneisses, etc., of Hastings-Grenville series.....................	Net lake, near Lake Timagami.
	Deposits of mispickel. *See* under gold-arsenic.	Deloro, Ont.
	Smaltite, etc., in silver veins. *See* under silver.	Cobalt, Ont.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

(*Continued*)

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Cobalt....	Cobaltite, etc., in silver veins. *See* under silver.	Cobalt, Ont.
Mica......	Muscovite in pegmatite dikes.................	Buckingham district, Que.
	Phlogopite, commonly accompanied by apatite, in veins of calcite, pyroxene, etc., cutting rocks of the Hastings-Grenville series................	Eastern Ontario.
Graphite..	In plates disseminated through bands of gneiss, quartzite, etc., of Hastings-Grenville series, usually near intrusive granites. Graphite in veins in granitic rocks, or in irregular deposits in crystalline limestone......................	Buckingham district, Que.
Corundum.	Richly disseminated in various alkali syenites, anorthosite, etc., cutting members of the Hastings-Grenville series........................	Renfrew co., Ont.
Apatite...	Associated with phlogopite. *See* under mica....	
Feldspar..	Coarse pegmatite dikes cutting pre-Cambrian gneisses, etc............................	Frontenac co., Ont.
Talc......	In serpentines associated with Hastings-Grenville series....................................	Hastings co., Ont.

PRECIOUS AND SEMI-PRECIOUS STONES.

Though it can scarcely be said that there is, as yet, any established source of precious or semi-precious stones in the Laurentian Plateau region, yet many beautiful minerals have been found in various localities. There is even a possibility that diamonds may eventually be discovered somewhere in the northern region, for in the glacial drift of Wisconsin, small diamonds up to a few carats in size have been found, and it has been contended that these have been transported by ice during the glacial period from some point in the Laurentian region in the neighbourhood of Hudson bay.

Admirable specimens of the feldspar labradorite have been recovered from the anorthosite masses on the east coast of Labrador. The mineral shows a brilliant play of colours and has been used in jewellery. Labradorite showing many of the qualities of the mineral of the original locality, has been found at various points in a number of the large anorthosite bodies occurring all the way from Wisconsin to Hudson strait.

The pegmatite dikes so common throughout the Laurentian plateau often hold splendidly developed crystals of various minerals, such as tourmaline, idocrase, apatite, zircon, etc. Many such localities are known in the districts bordering the lower Ottawa, also in eastern Ontario, and, doubtless, these crystals eventually will be found in many other districts. Garnets of gem quality have been recovered from Charlevoix county, Quebec. Blue sodalite from the nepheline syenites of eastern Ontario is used as an ornamental stone, as is also perthite and other varieties of feldspar.

GOLD.

The known occurrences of gold within the Laurentian plateau are almost entirely confined to the southern border of the region in Ontario. There is, however, every reason to believe that eventually, as prospecting progresses, the mineral will be found throughout the pre-Cambrian region. Amongst the various gold-bearing districts of Ontario may be mentioned the eastern Ontario region in Hastings and neighbouring counties, Larder lake, Parry Sound, Wanapitei lake, the district north of Lake Huron, Michipicoten, Shebandowan lake, Sturgeon lake, and Lake of the Woods.

Though gold has been found and worked at many points in Ontario, from the Lake of the Woods on the west to the Hastings district in the east, a distance of roughly 650 miles, yet in spite of often highly promising showings no permanent gold industry has yet been established. First discovered in 1866, in Hastings county, the annual production of gold rose to a maximum in 1899, when 27,594 ounces were recovered, but in 1907 the amount was only 3,810 ounces.

In eastern Ontario the auriferous deposits appear to be confined to a belt of varying width and about seventy miles long, extending through Peterborough, Hastings, Addington, Frontenac, and into Lanark county. This region is occupied by crystalline limestones, various types of schists, and bodies of dark basic rocks, all commonly grouped as the Hastings-Grenville series, and cut by bodies of granite. The gold deposits occur in the older rocks, generally near granite intrusions and along lines of fissures containing quartz veins or lenses, and, commonly, with abundantly associated mispickel, sometimes mined for arsenic.

The Deloro mine, near the village of that name, in Hastings county, is situated on an area of schists, sometimes dolomitic, and quartzites cut by granitic dikes and surrounding a central mass of intrusive granite. The ore occurs in a series of quartz veins lying parallel to the foliation of the schist, and also cutting the granite dikes. The veins consist of a series of lenses lying along fissures and connected by cracks. The quartz veins sometimes carry considerable dolomite, mispickel, lesser amounts of iron pyrites, at times chalcopyrite or fluorite, and free gold. One vein that may be considered a typical example is 7 to 10 feet wide, and dips at an angle of 30°. It consists largely of quartz, with mispickel and some dolomite. The mispickel is sometimes coarsely crystalline, with gold adhering to the faces, but more commonly is fine and compact, and the associated gold invisible. The mine is worked both for arsenic and gold; assays of the ore have yielded $30 of gold to the ton, while several analyses of the mispickel showed that it carried gold at the rate of from $300 to $3,000 per ton.

At another locality in the eastern region, at the Star of the East mine, in Frontenac county, two veins, about twenty yards apart, lie in crystalline limestone. Each vein consists of isolated but nearly touching lenticular masses of quartz, 6″ to 24″ wide, and lying towards the centre of an altered zone 8 to 10 feet wide. With the auriferous quartz occurs pyrite, magnetite, calcite, a little galena, etc.

At the Belmont mine, in the county of Peterborough, a series of gold-bearing veins lie in a body of gabbro cut by a large number of ramifying granitic dikes, varying in width from merely a thread to several inches. In the neighbourhood of the gold-bearing quartz veins, the gabbro, sometimes over a zone fifty feet wide, has been altered to a chlorite schist carrying introduced quartz, calcite, and feldspar.

The gold occurs in a free state in lenses of quartz lying along fissures towards the centre of the zone of chlorite schist. The precious metal is also found in numerous quartz stringers in the schist, and in the iron pyrites with which the rock is impregnated. The larger ore bodies occur at the intersections of two or more fissures. Mispickel, though so characteristic of the eastern gold belt in general, is not present. Galena and chalcopyrite occur, but apparently only towards the surface. Pyrrhotite is present and carries gold, but not so abundantly as the pyrite, for while one specimen of pyrrhotite carried only $13 of gold to the ton, an assay of a mixed specimen of pyrite and quartz yielded gold at the rate of from five to six ounces per ton.

In the Larder Lake district, some distance northeast of Lake Timiskaming, many specimens of quartz carrying visible gold have been found. The best showings seem localized in a band of schistose rock, possibly representing an altered impure dolomite or limestone. This band, cut by pegmatite and porphyry dikes, is seamed with quartz stringers, sometimes with gold values, and carrying pyrite, chalcopyrite, and a few specks of galena. The quartz stringers are usually only a few inches wide. One vein carrying free gold, and several feet wide, yielded gold at the rate of about $8 per ton in a mill test of 1,600 pounds of ore.

Gold discoveries have also been made farther north, on the shores of Lake Abitibi. On an island in lower Abitibi lake there has been found, cutting a diabase, a vein of auriferous quartz varying from a few inches to four feet in width. The quartz carries free gold, frequently visible, iron pyrites, a little copper pyrites, and some zinc blende.

Along the Quebec side of upper Abitibi lake, the Keewatin schists are cut by a number of fine-grained, acid dikes, varying in width from a few inches to fifteen feet or more. The dikes have been shattered, and the resulting cracks, mostly pursuing transverse courses, filled with quartz. The dikes are impregnated with iron pyrites, apparently gold-bearing.

The only auriferous alluvial deposits in Ontario that have attracted any considerable amount of attention are those of the Vermilion river, not far from Sudbury. The auriferous gravels there apparently lie at the surface, and the small amount of gold in them is in a very fine state, though increasing in coarseness when traced northwards.

Prospects and partially developed gold mines occur in the district immediately north of Lake Huron, and at various points on the Lake Superior shore. The Shakespeare mine, one of the few mines at present producing gold, is situated near Webbwood, not far from Lake Huron. The ore is iron pyrites and chalcopyrite, carrying free gold, in quartz. In the Michipicoten district, in certain areas, the Keewatin schists are cut by swarms of veins and stringers of quartz, sometimes carrying free gold in visible quantities, but often quite barren.

In western Ontario, over a wide area extending westward from near the head of Lake Superior to Lake of the Woods, and northward from the International Boundary to Sturgeon lake, are many gold prospects and mines. Some of the mines have been extensively worked, and amongst these the St. Anthony, seventy-five miles north of Ignace, and the Laurentian, some twenty miles south of Wabigoon, together with the Shakespeare mine of the Lake Huron district, were the chief producers in 1907, in Ontario.

The mines of western Ontario embrace a number of classes, but are all situated in Keewatin rocks or in intrusive granites and gneisses. At one locality, a band of fine grained gneiss, half a mile wide and several miles long, contains pyrite, rather sparingly disseminated, and is auriferous throughout, the amount of gold varying from a mere trace to 50 cents a ton. In other localities granitic or gneissic rocks are, along shattered zones, sometimes several hundred feet wide, seamed with gold-bearing quartz veins.

Development work in the Sultana mine, about seven miles north of Kenora, and at present unworked, reached a depth of 600 feet. The deposit consists of a series of large lenses of quartz, sometimes twenty feet or more thick, lying in gneiss. The lenses are surrounded by biotite schist, itself sometimes auriferous. The quartz carries free gold, sometimes visible, and entirely apart from the iron pyrites also present.

Other types of deposits consist of parallel quartz veins in Keewatin schists impregnated with pyrite. In a number of instances fine-grained, acid dikes, traversed by quartz fissures, have proved to contain gold. The granites and gneisses of the region are sometimes traversed by clean-cut quartz veins carrying free gold.

Throughout the region the gold, or a high percentage of it, is generally free milling, and with it iron pyrites always occurs. Pyrrhotite is commonly present, though it seldom carries gold. Copper pyrites is nearly universal, and in some cases its presence is associated with the occurrence of high gold values. Galena occurs sparingly at very many points. Zinc blende, when present, always seems to be associated with the richest gold ore.

Native copper is comparatively common, and native silver has been found. Bismuthinite is abundant in one vein; mispickel is but rarely found. One vein in Moss township carried some sylvanite, and another vein, in the Lake of the Woods district, contained hessite.

PLATINUM.

Native platinum has been reported to occur in gold-bearing quartz veins in the Lake of the Woods district. In the Sudbury nickel-copper ores, platinum is present in the mineral sperrylite, that apparently is largely, if not solely, associated with the chalcopyrite. In 1906 the value of the platinum, with palladium and associated elements, recovered from the Sudbury ores, amounted to $5,652.

COPPER.

Most of the copper won in the Laurentian plateau comes from the nickel-copper mines of Sudbury, that are described under the heading of nickel. In 1907 these mines produced slightly over 14,000,000 pounds of copper, while the production of the other working mines of the region amounted to about 300 tons. The latter mines are situated in the district bordering the north shore of Lake Huron.

Outside of Ontario important deposits of sulphide copper ores have so far been found at only a comparatively few localities in the Laurentian region. Native copper has been described by explorers as occurring on the Coppermine river, flowing into the Arctic west of Hudson bay. The copper-bearing rocks of this northern region perhaps correspond to the Keweenawan of the Lake Superior district.

In Ontario, the occurrence of copper ores at different localities about the shores of Lake Superior was known from a very early date, about 1767. Native copper has been found in the diabases, probably of Keweenawan age, on the Lake Superior shores not far north of Sault Ste. Marie.

Copper ores are widely displayed through the district bordering the north shore of Lake Huron, and at Bruce mines mining commenced as early as 1846. The Bruce and Wellington mines in this neighbourhood produced, during the period from 1858 to 1878, over 8,000 tons of copper, but are now idle. These mines are situated, in each case, on a pair of closely parallel veins cutting uralitic diabase that is intrusive in the sedimentary rocks of this, the original Huronian area. The veins, with widths varying from a few feet to twenty feet or more, have been traced for a length of over a mile and a half. They consist of a gangue of quartz, in places with much dolomite, carrying copper sulphides, chiefly chalcopyrite, but with much bornite, especially towards the surface. A number of other copper-bearing veins of somewhat similar composition, and often of considerable dimensions, have been found at many points in the district north of Lake Huron, sometimes cutting diabase, sometimes cutting sedimentary beds. Chalcocite occurs on the Mississagi river.

In the Parry Sound district a number of discoveries of copper ore have been made. At a point about two miles east of Parry Sound a schistose diorite is more or less charged with bornite, chalcocite, and chalcopyrite, over a zone about 1,000 feet long and 250 feet to 400 feet wide. In places the ore is associated with stringers of quartz, but in general it occurs in bunches or pockets through the impregnated rock. At another locality in the same district, about eight miles south of Parry Sound, a garnetiferous gneiss is impregnated with copper and iron sulphides, over a band about 1,000 feet long and 30 to 75 feet wide.

SILVER.

The known occurrences of silver ores in the Laurentian plateau are almost entirely confined to Ontario. As early as 1846 veins carrying this metal were found on the shores of Lake Superior, in the district about Port Arthur, but at that time, copper, rather than silver, was the metal sought, and it was not until 1866 that silver began to be actively prospected for. From this time onwards, until 1903, the Port Arthur district produced silver, but in the latter year the production had dwindled to 16,688 ounces, and the last mine closed down. In the same year, 1903, the silver-bearing veins of Cobalt, lying about 100 miles northeast of Sudbury, were found, and in 1904 over 200,000 ounces of silver were recovered, while in 1907 the production had risen to slightly over 6,000,000 ounces, extracted from 14,788 tons of ore. This camp, at the same time, controls the world's market for cobalt.

The silver mines of the district in the neighbourhood of Port Arthur, while no longer actively worked, were at one time the centres of much activity. The ore-bearing veins, in general, occupy distinct lines of faulting or fissuring in the sedimentary Animikie beds, and cross the associated dikes and sills of diabase. The gangue of the veins is largely calcite or dolomite, and barite, with a varying amount of quartz. The relative proportions of these minerals vary widely, and sometimes much fluorite is present. The veins fluctuate in width, more especially in the sedimentary rocks, where they often pinch out or seem to disappear, though, when searched for, they are generally found to continue downwards.

Through the gangue occur various sulphides, zinc blende, galena, iron and copper pyrites, with silver both as argentite and in a native state. These minerals are usually irregularly distributed; sometimes they are very plentiful along streaks, or in bunches, while long stretches of vein matter are often free from them.

The most famous silver mine of the Lake Superior region was known as the Silver Islet, and was found on an island, some 90 feet square, lying near Thunder cape. The ore-bearing veins of carbonates and quartz traversed a large dike of diabase, cutting it along a fault plane. Only where the vein traversed the diabase did it carry silver; elsewhere, besides gangue material, it bore only sparingly disseminated galena. The Silver Islet vein varied in width from one foot to twenty feet or more, and held various compounds of nickel and copper, arsenical and antimonial ores of silver, as well as the more ordinary minerals of the other veins of the district. The distribution of the native silver and silver minerals was irregular; sometimes they formed large masses, and in one instance, such a body was over five feet wide and sixty feet, or more, deep. When the mine was abandoned in 1884, work had been carried on to a depth of 1,160 feet, and it is estimated that $3,250,000 of silver had been extracted.

The phenomenal silver district of Cobalt was discovered in 1903, during the progress of railway construction. Most of the veins lie in slightly inclined, lower Huronian greywackes or slates, and conglomerates, but they also occur in the sill-like bodies of intrusive diabase, and at times in nearby Keewatin schists. The veins generally occupy clean-cut, nearly vertical fissures, but

PLATE XLI.

Larose Mine, Cobalt, Ont.

PLATE XLII.

Vein in Larose Mine, Cobalt, Ont.

Vein No. 7, Kerr Lake Mine, Cobalt, Ont.

their courses are often quite irregular, the veins splitting, coalescing, or dividing into a series of stringers confined to a narrow zone. The gangue is largely of calcite carrying native silver, argentite, and other silver compounds: smaltite, niccolite, cobaltite, native bismuth, etc. The native silver occurs in a variety of forms, sometimes in large flakes or sheets a foot or more in diameter. In places the silver is intricately mixed with the various mineral compounds of cobalt, nickel, and arsenic. In some cases the veins are almost void of silver, and are mined for their cobalt contents alone. The veins are sometimes quite long, as in the case of the main vein of the La Rose mine, which has been traced for more than 1,000 feet; usually they are quite narrow, a vein one foot wide being relatively quite gigantic. From one vein on the Trethewey, in an open-cut about 50 feet long and 25 feet deep, ore to the approximate value of $200,000 was extracted from a vein never more than 8″ wide.

Besides the original Cobalt district, other silver-bearing camps have been found in South Lorrain and at a number of points in the region to the westward, as in James township, at Bloom lake, and Gowganda lake. In some of these localities, besides the more ordinary calcite veins, others of a different character have been discovered. These are of the nature of aplite dikes, often containing much calcite, and carrying, besides silver and various arsenides and sulphides, considerable quantities of galena and hematite.

LEAD.

Veins carrying galena and other sulphides occur on the north shore of Lake Superior, where, at one time, they were worked. Within recent years mining has been conducted on certain lead properties in eastern Ontario, in the belt of Hastings-Grenville rocks. In the case of one of these mines—the Hollandia mine, near Bannockburn, Hastings county—the country rock is a fine-grained mica schist. The lead occurs in a nearly vertical fissure with well-defined walls, and traceable for over 1,000 feet. Where worked the vein varies in thickness between two feet and seven feet; but in places is filled with country rock or divides into numerous veinlets. It consists of calcite carrying galena in particles ranging in size from minute grains to others more than a foot in diameter. Some marcasite and siderite is present, and occasional grains of zinc blende, pyrite, etc.

ZINC.

Zinc blende, usually accompanied by galena, occurs in workable deposits at a number of points in Quebec and Ontario. The Olden or Richardson mine, in Frontenac county, has been worked in recent years. The ore consists of a mixture of zinc blende and argentiferous galena. The deposit is irregular, and occurs in a band of crystalline limestone of the Hastings-Grenville group. Some work has been done on zinc deposits at Calumet.

Zinc blende has been mined at several points in the neighbourhood of Rossport, on the north shore of Lake Superior. At the Zenith mine the ore consists of irregular bodies of sphalerite with associated copper and iron pyrites, lying in greenstones. At one point a surface of solid ore 20 feet × 15 feet was exposed. The ore apparently occurs in irregular, lenticular bodies, varying in size and lying along the strike of the foliation of the enclosing rock, presumably belonging to the Keewatin.

NICKEL.

Though nickel occurs with the silver ores of the Cobalt district, the mines, as a rule, are not paid for the nickel contents of the ores. The greater part of the production of the metal in Canada is derived from the Sudbury nickel-copper ores. In 1907 the amount of Sudbury ore smelted was 359,076 tons, containing 10,602 tons of nickel and 7,003 tons of copper, while considerable amounts of gold, platinum, and palladium were also recovered.

The Sudbury deposits were first noticed in 1856, but did not attract attention until 1883, during the period of construction of the Canadian Pacific railway, and a year later a railway cutting was made through the small hill on which the Murray mine was afterwards located. During the first few years the deposits were exploited for their copper contents alone, and not until 1886 was the presence of nickel determined and the true value of the ores made known. The Sudbury mines, and those of New Caledonia, now practically supply the whole of the nickel produced in the world.

The Sudbury ore deposits, consisting largely of pyrrhotite and chalcopyrite, form part of the edge of a great eruptive sheet of norite grading into micropegmatite, and having a length of

Creighton Mine, Canadian Copper Co., Sudbury district, Ont.:
the largest Nickel Copper Mine in the world.

Main Pit, Creighton Mine, Sudbury district, Ont.

Roast Yard, Canadian Copper Co's Smelter, Copper Cliff, Ont.

thirty-six miles, with a breadth of sixteen miles. This large igneous body, with an estimated thickness of a mile and a quarter, rests in a synclinal basin on upturned Huronian and Keewatin strata, penetrated by granitic, gneissic, and basic igneous bodies. The central part of the norite-micropegmatite body is covered by an open, synclinal basin of stratified rocks, agglomerates, tuffs, shales, and sandstones, so that the ore-bearing norite outcrops as an irregular, oval band, varying in width from a little over half a mile to slightly more than four miles.

Around the inner margin of the ore-bearing, igneous rock, that is, along the upper portion of the sheet-like body, the rock is of an acid type, micropegmatite. Passing outwards, the micropegmatite is found to gradually change to norite, while about the outer margin, at the lower part of the body, occur the ore bodies. There is a complete, though sometimes rather quick gradation from norite to ore, so that in places the rock might be termed a pyrrhotite norite. While there seems to be very little doubt that the ore bodies are primarily of igneous origin, directly derived by some process of segregation from the norite body, there is also evidence, at various places, of the former action of a more or less active process of redistribution and concentration of the metallic minerals.

The ore bodies occur only at the outer margin and in offsets of the eruptive body, and for miles along the edge there is no important break in the rusty band marking the presence of sulphides. The presence of the gossan does not, however, always indicate the presence of ore deposits of workable size, for, in general, the ore bodies are confined to parts along the edge where the norite projects outwards, either bay-like, or as a narrow, sometimes discontinuous, offset or dike.

The ore bodies in places reach an enormous size; the Creighton ore body, for instance, situated on a bay-like projection, forms a mass that, towards the surface, measured roughly 150 feet by 200 feet, and was proved by drilling to extend for at least 400 feet beneath the surface. The deposits are usually sharply defined against the outer edge, except where faulting, etc., may have taken place, but on the inner side they gradually change to norite.

The second class of deposits, those formed along offshoots from the main norite mass, may be exemplified by the body of the

Copper Cliff mine. In this mine an ore body, irregularly oval in cross-section, has been followed downwards for over 1,000 feet, with an average width of 50 feet to 90 feet, and a length of 75 feet to 200 feet.

The ores consist of pyrrhotite and chalcopyrite, and though the copper sulphide is almost invariably present, and usually in considerable amounts, the pyrrhotite decidedly predominates. The two sulphides, as a rule, are commingled in spots, bunches, or threads, and sometimes the iron sulphide is comparatively free from chalcopyrite. The nickel of the ores is mainly, if not solely, contained in the mineral pentlandite, that is usually very finely and evenly distributed. Pyrite is also present, and much of it is nickeliferous. A varying amount of gangue, usually of the mineral constituents of the norites, is always present.

IRON.

The occurrence of iron ores in the Laurentian region has long been known. The bog iron ores in the neighbourhood of Three Rivers, on the lower St. Lawrence, in part situated in the Laurentian region, in part on the plains of the St. Lawrence lowlands, were reported on as early as 1681. The smelting of these ores commenced in 1733, and has continued until the present day, about 11,000 tons of ore being mined and smelted in 1908. Some of these bog ore deposits, as in the case of that at Lac à la Tortue, grow so rapidly that they form a practically continuous supply of ore.

In Ontario, the earliest efforts at mining and smelting of iron ores seems to have been in 1800, in Leeds county. Later, in 1820, an attempt was made at Marmora, Hastings county, to treat the iron ores of that district, and from that time onwards the smelting and mining of the ores of Hastings and the more easterly counties of eastern Ontario, has been intermittently pursued. The first successful furnace was at Normandale, which smelted the bog ores of Norfolk county, and for a time supplied the Ontario Great Lakes trade. In later years, modern blast furnace plants have been erected at a number of points through the Province of Ontario, while iron ores have been discovered in districts scattered over the whole of the pre-Cambrian area of the Province. The amount of Ontario ore—and none save the bog ores are now produced elsewhere in the Laurentian plateau—raised and shipped in 1907, amounted to 205,295 tons, of which three-quarters was derived from the Helen mine, Michipicoten district.

The iron ores of the Laurentian plateau occur at a number of horizons, but the deposits have been found chiefly in the better known part of the region contained in the Province of Ontario. Iron ores are widely displayed in the Keewatin, and are present at many points in the districts underlain by the Hastings-Grenville group of eastern Ontario, and the adjoining districts of Quebec. The Animikie, or upper Huronian, of the Port Arthur district, contains iron ores, and the same is true of the Nastapoka formation, the probable equivalent of the Animikie in the Ungava peninsula. Titaniferous iron ores also occur associated with the anorthosite masses of Quebec, and probably these bodies are the source of the immense quantities of titaniferous iron sands found along the lower St. Lawrence and the rivers tributary to it on the north.

The great iron ore deposits of the Lake Superior iron district, south of the lake, occur in the iron ore formation at points where the iron has become concentrated by secondary action into large masses of comparatively pure ore, sometimes exposed on the surface, sometimes only revealed below the banded jaspilite by drilling. The iron ore formation occurs in the Keewatin, lower and upper Huronian, in these great ranges.

Bodies of iron ore have been discovered in the widespread Keewatin, west, north, and east of Lake Superior. An especially characteristic type is that of the jaspilites as found about Lake Nipigon, and farther east in the district about Lake Timagami. These deposits, frequently spoken of as the Iron formation, form narrow bands often several miles long, lying in and surrounded by various schists and greenstones penetrated by granitic and igneous bodies. The Iron formation is highly siliceous, often banded grey, brown, and dark from the presence of magnetite, and, to a lesser extent, hematite. At times streaks, lines or wider bands are largely of iron ore. The deposits such as these have generally been regarded as having had a sedimentary origin.

Another type of iron ore occurring in the Keewatin in Ontario is represented in the Atikokan range, about 128 miles west of Port Arthur. At this locality, enclosed in a belt of chlorite schists, are three nearly vertical bands of magnetite, respectively 40 feet, 10 feet, and 16 feet wide. The bands lie parallel with one another within a breadth of less than 250 feet. Considerable iron pyrites occurs with the magnetite, enough to necessitate the roasting of the ore.

The Iron formation of the Moose Mountainr ange, about twenty-five miles north of Sudbury, is also closely associated with various types of Keewatin schists, and is, in places, cut by granites. The Iron formation consists of magnetite ores usually interbanded with siliceous material, including cherts and phases resembling greywacke. The richer ore occurs in irregular bodies, often of considerable size and comparatively free from quartz, though frequently containing hornblende and epidote; while in places complete gradations exist between masses of magnetite and of hornblende. The Atikokan and Moose Mountain ores have been referred to the pegmatite type, and are supposed to have been brought to or near the surface in magmas and extruded from them much as in the case of pegmatite dikes. The banded material probably belongs to the so-called iron ore formation.

The deposit of the Helen mine in the Michipicoten district, the largest iron ore deposit worked in Ontario, has been described as having had an aqueous origin, possibly being of the nature of a chemical precipitate. A large amount of iron pyrites is associated with the ore.

The ore body lies towards one end of a strip of the Helen iron formation, about one and three-quarters mile long by a thousand feet wide. The band is surrounded by Keewatin schists, rising in hills on all sides but one. The Iron formation, supposed to be lying in a closely folded syncline, consists on one side of a banded siliceous rock containing siderite and magnetite, and on the other, of impure siliceous siderite containing pyrite in small crystals, grains, and masses.

The ore body lies in or on the band of impure carbonate, and consists chiefly of hematite and limonite in a porous concretionary-like state, and much pyrites usually segregated in distinct, sharply-defined bodies. At first the iron sulphide occurred in isolated, irregular masses of all sizes, up to some containing several hundred tons or more of pyrite in a finely granular state, mixed with quartz and behaving like unconsolidated sand. But as the workings have deepened, the iron pyrites, always occurring in the same state, has been found to greatly increase in volume, so that of a horizontal section of the body about one-half is iron sulphide.

Throughout eastern Ontario and adjoining portions of Quebec, in the districts in which the Hastings-Grenville series occurs, are numerous deposits of magnetite. Many of these have been worked for years, and some are being mined at the present time. The deposits, though usually irregular in shape and distribution, are often of considerable size. In one instance, at the Mayo mine, Hastings county, the ore has been worked from an open pit 1,100 feet long by 220 feet broad, while a drill hole was sunk 140 feet without passing out of ore.

In many cases the ore bodies lie along the contact of crystalline limestone and granitic or other igneous bodies. At times considerable pyrite is present, necessitating the cobbing of the ore. The general conclusion is that the ores are of contact metamorphic origin. Other iron ore deposits of the Hastings-Grenville districts lie within bodies of basic igneous rocks, are characteristically irregular in their occurrence, and doubtless are of direct igneous origin. Somewhat related in type are the masses of highly titaniferous magnetites so often associated with the various anorthosite bodies occurring throughout the eastern part of the Laurentian plateau. In size these titaniferous ore bodies vary widely, sometimes reaching large dimensions.

The gently dipping beds of the Animikie, in the Port Arthur region, sometimes contain iron ores probably of sedimentary origin. At Loon lake, about twenty-six miles east of Port Arthur, the formation contains two iron-bearing horizons separated by a zone of dark slates. The upper of the iron horizons is 200 feet to 250 feet thick, and is composed of cherty iron carbonate. A common phase of this horizon is a banded rock composed of alternating layers of iron oxide or partly altered carbonates, and cherts of various shades and colour. The lower iron horizon, between 50 feet and 60 feet thick, is distinguished from the upper by the presence of small granules embedded in carbonate material or in a greenish or dark greyish matrix. In places the rock is replaced by hematite and limonite, thus giving rise to ore bodies.

The Nastapoka group, found along the east coast of Hudson bay, is composed of usually gently dipping beds of sedimentary rocks several thousands of feet thick. Towards the middle of the series, and exposed at many points, are siliceous, iron-bearing beds; the upper of these beds, in places, hold ankerite or various carbonates, while the lower ones are banded and composed of layers of red and grey quartz impregnated with and alternating with seams and layers of magnetite and hematite. Bodies of low grade ores, resembling these and associated with similar strata, occur towards the centre of the Ungava peninsula, and perhaps west of Hudson bay, about Great Bear and Great Slave lakes.

SULPHUR.

The mining of iron pyrites for the production of sulphuric acid is becoming an industry of increasing importance in Ontario. During 1907, over 15,000 tons of pyrites were raised from various deposits in eastern Ontario, at the Helen iron mine, at James lake in the district of Nipissing, and from several deposits in western Ontario.

In eastern Ontario the sulphides generally occur in lense-like bodies, often in schists or gneisses, or within basic igneous bodies, or along their contacts with older strata. The occurrence of the iron pyrites at the Helen mine has already been referred to under the heading of iron. Near Missinaibi, large deposits, perhaps the largest known in Ontario, lie in Keewatin schists. The bodies consist of pyrite, often with considerable quartz, and in shape are generally elongated, with widths varying from a few feet to 250 feet. A number of pyrite deposits of notable size occur in the Keewatin rocks of western Ontario, and there, as elsewhere in the Province, often occur in the neighbourhood of iron ore deposits.

ARSENIC.

In 1907, in Ontario, 348½ tons of arsenic were produced, mostly from the ores of the Cobalt district, but some also from the mispickel ores of the Deloro mine in eastern Ontario, already described under the heading of gold. Mispickel deposits occur at a number of points in eastern Ontario, and elsewhere in the Province, as at the Big Dan mine on Net lake, near Lake Timagami. At this place, the mispickel is gold-bearing, and is accompanied by pyrite and chalcopyrite. The ore occurs in nearly solid bodies, distributed through Keewatin schists over a zone perhaps a third of a mile long, and varying in width up to a hundred yards.

COBALT.

Cobalt is obtained from the Cobalt silver ores; but figures for the amount of the element recovered are not available. The mines receive but little compensation for the metal, except when sorted to bring the cobalt content up to a certain grade, and, indeed, the actual cobalt contents of the ores produced in 1907 was much above the world's annual consumption.

MICA.

The known workable deposits of mica in the Laurentian plateau are largely confined to three districts in eastern Ontario, and the neighbouring portions of Quebec. In Quebec, one considerable district lies north of the Ottawa river, along the lower portions of the Lièvre and Gatineau rivers. The remaining two districts are situated in Ontario, one about the lower Rideau lakes south and west of Perth, and the other extending from Sydenham to the vicinity of Sharbot lake. In 1907 the amount of mica produced was about 775 tons.

Of the two varieties of mica that have been mined, muscovite and phlogopite, the latter is the one now chiefly produced. The muscovite variety occurs entirely in pegmatite dikes, such as the 50 foot one at the Villeneuve mine twenty miles north of Buckingham, on the lower Ottawa. The mica often occurs in large masses, and one crystal from the above mine weighed 281 pounds and measured across the face 30″ × 22″. Another noted locality for muscovite was the Maisonneuve mine, in Berthier county. In these pegmatite deposits the mica sometimes occurs in isolated crystals, or sometimes in accumulations near the walls of the dikes cutting the gneisses, etc., of the Grenville series and the associated igneous bodies.

The phlogopite mica, commonly accompanied by apatite, lies in vein-like bodies lying parallel to the plane of foliation of the surrounding gneissic rocks, or cutting these planes transversely. Pyroxene and calcite form the gangue. The veins sometimes exhibit a banded or zonal structure, with bands of nearly pure pyroxene, frequently accompanied by mica or apatite. Sometimes the calcite gangue, with varying amounts of the other minerals, occupies nearly the whole vein, or may occur towards the central part, or at one side. The phlogopite frequently forms large aggregates or crystals, at times occurring in pockets, or following the contact of the vein, or lying in or next a zone of calcite. The crystals of mica and apatite sometimes attain colossal dimensions. In the mine near Sydenham crystals of mica up to 9 feet in diameter have been found. The country rock adjoining the vein is often pyroxenized, forming the so-called pyroxenite rock characteristic of many of the occurrences.

GRAPHITE.

Mining for graphite in Canada commenced in 1847, near Grenville, and has since been pursued with a varying degree of success. In 1907, the production of graphite in Canada was all from districts occupied by the Hastings-Grenville series in eastern Ontario and adjoining portions of Quebec, and amounted to about 580 tons, while the production for 1908 was probably less than half this amount.

The most important graphite-bearing districts lie in the counties of Labelle, Argenteuil, and Ottawa, in Quebec; and in Ontario in the counties of Lanark, Leeds, Frontenac, and Addington. All these districts are situated within the region of the Hastings-Grenville series. The graphite deposits are largely confined to the bodies of crystalline limestone and associated quartzites and gneisses, the latter being often rusty weathering, sillimanite gneisses. Graphite deposits have also been found within bodies of the various types of igneous rocks that are so common throughout the region. In many cases it has been noticed that the graphite deposits are richer in the neighbourhood of such intrusive bodies.

The graphite occurs in three general ways, of which the first to be mentioned is, from an economic standpoint, the most important. The mineral frequently occurs in small, scaly particles disseminated through bands or beds of gneiss, quartzite, etc. In such cases, the graphite is often largely confined to particular bands, layers or veins, varying in thickness from 1 foot to 30 feet or more, and these bands alternate with others containing comparatively little of the mineral. Such bands or layers of graphite-bearing rock, frequently carry ten to fifteen per cent of the mineral, while the amount sometimes rises to thirty or forty per cent, and the rock may appear quite black.

In the case of the second class of deposits, the graphite occurs in a fibrous or laminated form, filling veins that commonly are confined to igneous rocks or occur in their immediate vicinity. These veins are usually narrow, irregular, and discontinuous, and vary in thickness from a mere thread to eighteen inches or more.

In the graphite deposits of the third class, the mineral forms numerous but scattered, irregular, vein-like or lenticular masses of small size, usually lying in crystalline limestone. Sometimes the graphite occurs in small, spheroidal masses with a radiating structure, lying in limestone. It has also been found as a constituent of pegmatites cutting the Grenville.

LIGNITE AND GYPSUM.

Thin seams of lignite are found along some of the northern rivers, and beds of gypsum occur in the Devonian area lying within the Palæozoic basin south of Hudson and James bays.

CORUNDUM.

Corundum was discovered in 1896, and since that time has been shown to occur at intervals over a belt about seventy-five miles long stretching through Haliburton, Hastings, and Renfrew counties, as well as in several isolated areas in the same region. The mineral is, in general, associated with various types of alkali syenites, nepheline syenites, corundum syenites, anorthosites, etc., that occur both in large and small bodies cutting members of the Hastings-Grenville series.

Corundum is now mined at several places, and in 1907, 2,683 tons were produced. The Craig mine, in Renfrew county, is one of the chief producers. At this locality, the corundum occurs in a foliated, nepheline syenite. The mineral is scattered through layers varying in thickness from a few inches to more than twenty feet, with intervening barren bands. The corundum is irregularly distributed through the individual ore-bearing bands, in crystals of all sizes up to sixty pounds in weight.

APATITE.

The apatite deposits of the districts bordering the lower Ottawa on the Quebec side were, at one time, actively mined;

but at present the industry has almost ceased, except as a by-product of the mica mines. The apatite deposits in general are associated with those of mica in the same districts, occurring under the same conditions and in the same veins, so that in some cases the dumps of the apatite mines have been worked over for their mica contents, and mines formerly worked for apatite are now operated for mica.

FELDSPAR.

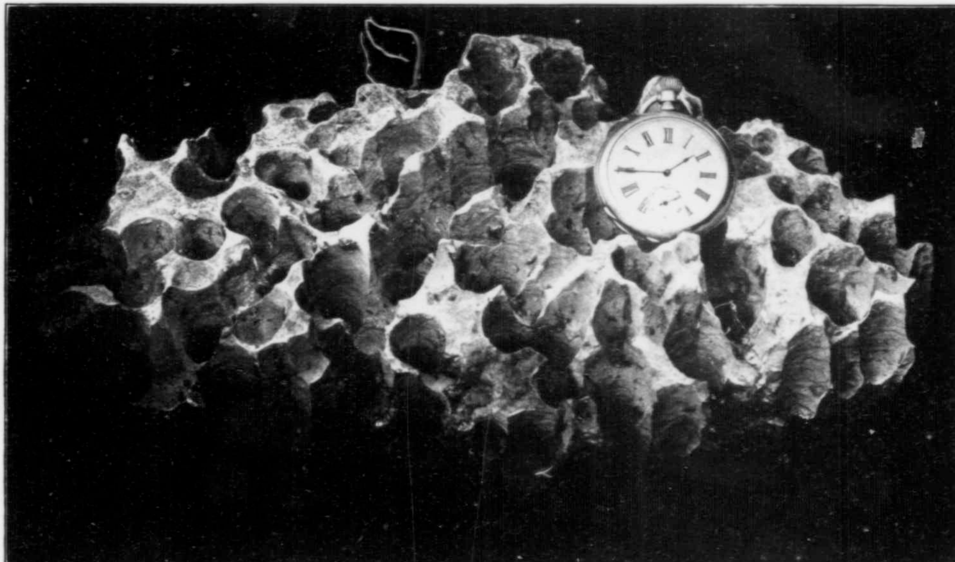
In 1907, potash feldspar, to the amount of 12,328 tons, was recovered in Frontenac county at several localities, from large coarse pegmatite dikes cutting gneisses, etc. The pure feldspar crystals may attain the dimensions of a small house, and the quartz grains, also pure, ten or more feet in diameter.

TALC.

Near Madoc, Hastings county, considerable deposits of talc associated with certain serpentine bodies are being worked, and in 1907 yielded 1,870 tons.

BUILDING AND ORNAMENTAL STONES.

Throughout the Laurentian plateau are numerous bodies of stone suitable for structural and ornamental purposes, and quarries have been opened at many points in the southern part of the area. Massive igneous rocks, granites, syenites, diorites, anorthosites, etc., are available for both building and ornamental purposes; while various kinds of marble, often handsomely marked with serpentine, etc., as well as beautiful blue sodalite, occur in central Ontario, and are eminently suitable for ornamental purposes.



Honeycomb limestone from below water level Georgian Bay.

CHAPTER V.

THE ARCTIC ARCHIPELAGO.

GEOLOGY.

The *Arctic archipelago*, with an area of above 500,000 square miles, lies between the 125th meridian on the west, and Baffin bay and Davis strait on the east. It extends north from the north side of Hudson bay and Hudson strait to 83° N. latitude, a distance of about 1,500 miles, while along the 70th parallel it has a width of over 1,300 miles. The archipelago includes at least twenty islands having areas of over 500 square miles, of which, Baffin island, 211,000 square miles, Ellesmere island, 76,600 square miles, and Victoria island, 74,000 square miles, are the largest.

Though the interiors of the islands are virtually unknown, and even their coast lines imperfectly explored, yet their broad physical and geological features have been fairly definitely determined. In a general way, the elevated country already described as forming an eastern rim to the Laurentian highlands is continued northward through the eastern Arctic islands. The eastern coast of Baffin island is generally high, the land rising quickly to elevations of 1,000 feet or more, after which the upward slope to the interior tableland is more gentle. In the south, the general elevation of the tableland ranges from 2,000 feet to 3,000 feet, while northward, it increases to about 5,000 feet, with hills rising perhaps 1,000 or 2,000 feet higher. Still farther north the general elevation sinks to perhaps 3,000 feet, and so continues into North Devon and on into Ellesmere island, where, however, peaks sometimes rise as high as 5,000 feet.

The western portion of Baffin island has a general elevation of about 1,000 feet. In the islands lying west of Baffin island, and south of Barrow strait, Melville sound, and McClure strait, the same general elevation continues in the case of the more easterly islands, but sinks to 500 feet or less on Victoria island.

It rises again in Banks island, the most westerly of the Arctic islands, to 1,000 feet, and there considerable areas have elevations of 3,000 feet or over. The islands lying north of Melville sound, the Parry and Sverdrup groups, are comparatively low, with general elevations in the interior of 1,000 feet or less, though the eastern members of the Sverdrup islands are high, like the adjoining Ellesmere island.

The physical features of the Arctic islands are reflected in the geology of the region. The elevated districts of the large eastern islands are largely underlain by pre-Cambrian formations resembling those of the Ungava peninsula. Pre-Cambrian strata occupy the greater part of Baffin island and extend northward, but not continuously, through North Devon and Ellesmere islands. The lower, western portion of Baffin island and the islands to the west and northwest are floored with usually flat-lying or gently dipping Palæozoic measures, while the northward lying Sverdrup islands and portions of Ellesmere island are occupied by Mesozoic strata of the Triassic period.

The northwestern portion of Baffin island, and the islands to the west, including Victoria island and part of Banks island, are occupied by Ordovician and Silurian strata, chiefly limestones and dolomites with, sometimes, sandstones and shales. The Ordovician measures are largely confined to Hudson strait, and the northern shores of Hudson bay, while the Silurian measures are more fully developed farther north. The lower members of the Ordovician have been generally ascribed to the Galena-Trenton, a formation found also on the southeastern shores of Hudson bay and in Manitoba. Palæozoic strata older than the Ordovician are known to occur at only one locality in the Arctic region, on the east coast of Ellesmere island, fronting on Smith sound, where Cambrian measures underlie the Ordovician.

The Silurian limestones on Banks island are overlain by Devonian beds, in their turn covered by Carboniferous strata. On North Devon island, and in the southern portion of Ellesmere island, the Silurian beds are conformably overlain by Devonian strata; one section on Ellesmere island indicating a volume of about 8,000 feet, representing beds ranging in age from middle Silurian to upper Devonian.

The Devonian measures extend westward into the Parry group, although these islands are mainly occupied by Carbon-

Plate XLVIII.

Glacier, Bylot Island, Baffin Bay.

iferous measures conformably succeeding the Devonian strata. The lower portion of the Carboniferous consists largely of sandstones, with important seams of coal, while the upper part is composed of limestones, etc. The Sverdrup islands, to the north, are chiefly occupied by Triassic sediments, with, in the interior, volcanic rocks. These measures also occur on Ellesmere island. Lignite-bearing Tertiary beds have been found occupying low-lying areas at a number of points in the Arctic region, on Baffin and Ellesmere islands and elsewhere.

The Palæozoic strata of the Arctic basin were evidently formed in a sea that, advancing southward, flooded a depressed area, now marked by Hudson bay and the surrounding lower lands. This sea, perhaps at first confined to the far north, seems, in mid-Ordovician times, to have been greatly extended and to have reached Manitoba. Possibly in Ordovician times, but more probably in later Silurian or Devonian periods, the Palæozoic basin may also have extended south of James bay, across the Laurentian uplands, to the region of the Great lakes.

The southern extension of the Arctic Palæozoic sea is indicated by the measures of this system occupying the low-lying country bordering Hudson and James bays, from the mouth of the Churchill river in the west to the foot of James bay in the east, a distance of about 750 miles. The area thus occupied, though generally comparatively narrow, reaches southwest of James bay to within 125 miles of Lake Superior. Towards the west, Ordovician limestones appear on the shore of Hudson bay, but farther east these are succeeded by Silurian limestones and shales, that in places probably rest directly on the pre-Cambrian. South and west of James bay the Silurian is covered by Devonian strata, limestones, dolomites, etc., with beds of gypsum. Southward of the Devonian area the Silurian measures outcrop in places, while in others the Ordovician beds form the southern, outer border of the Palæozoic basin.

ECONOMIC MINERALS.

There is but a slender fund of information bearing directly upon the occurrence of economic minerals in the Arctic region. Gold has been reported to occur at the head of Wagner inlet. Specimens of native copper have been brought back from Baffin island. Mica is mined in a small way on the north side of Hudson strait. This mineral also occurs in quantities on Cumberland sound. Lignite occurs in the Tertiary beds of the northern and eastern shores of Baffin island, as well as on Bylot island. Thin seams of a good quality of bituminous coal occur in the Carboniferous measures of the islands north of Lancaster sound.

On road, north of Swift Current, Sask.

CHAPTER VI.

THE INTERIOR CONTINENTAL PLAIN.

GEOLOGY.

The Interior Continental plain embraces a large tract of comparatively level, rolling country lying between the Laurentian Plateau region on the east, and the Cordilleran Mountain system on the west. Along the 49th parallel, here constituting the southern boundary of Canada, the plain has a width of about 800 miles, but it is reduced to less than 400 miles on the 56th parallel, and may be said to terminate on the shores of Great Bear lake, on the 65th parallel.

The southern portion of this region includes the wide prairie country of western Canada, extending, in Alberta, nearly 400 miles north of the International Boundary, and including an area of above 150,000 square miles of open grass land, bordered on the north by a strip of mixed prairie and woodland. To the north the country, except locally, is at first wooded, but farther north is occupied by gradually thinning forests.

The whole of the Interior plain, save a very narrow strip of about 12,000 square miles in southern Alberta and Saskatchewan, drains northward to the Arctic ocean or eastward to Hudson bay, and the general slope of the land is, therefore, eastward or northeastward from the Rocky mountains to the edge of the Laurentian plateau. A line drawn from the base of the mountains near the 49th parallel to Lake Winnipeg, shows an average descent of over five feet to the mile, fully accounting for the rapid courses of the rivers of the region and their often marked valleys.

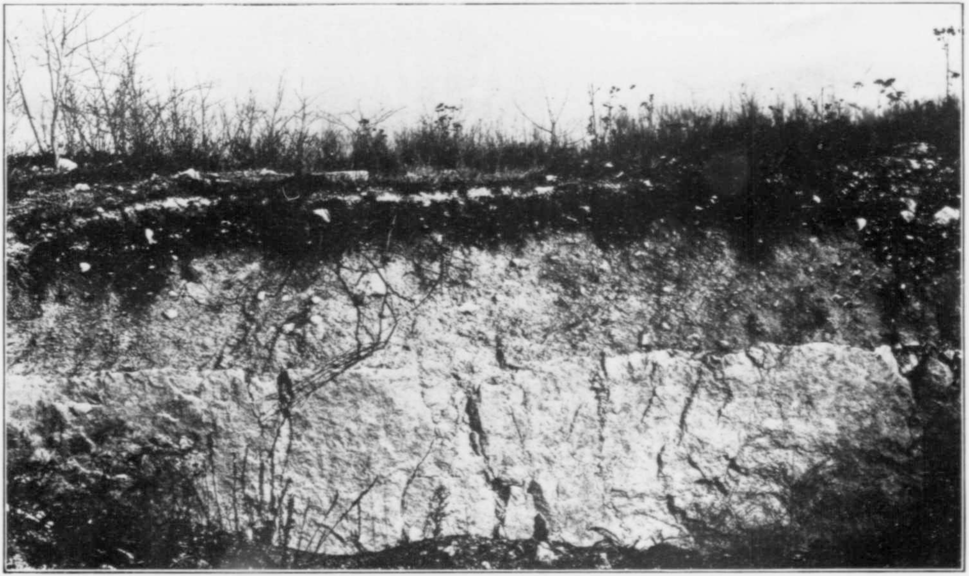
There are in the area south of the 54th parallel two lines of escarpment or more abrupt slopes, which divide this portion of the plains into three parts. The first, or lower prairie level, is that of the Red River valley and the Winnipeg system of lakes. Its average elevation is about 800 feet above the sea, and to the south of Lake Winnipeg it comprises some 7,000 square miles of prairie land, appearing to the eye absolutely flat, although rising uniformly to the east and west. The plain is bounded on the west by the Manitoba escarpment, a remarkable series of highlands, extending over 300 miles northwest from the International Boundary. The summits of this escarpment, broken through by wide valleys cut by the eastward flowing rivers, rise from 500 to 1,000 feet, in places more, above the low plain to the east, once the bed of the glacial Lake Agassiz.

From the Manitoba escarpment, the second prairie level stretches westward for 250 miles to a second escarpment, the Missouri côteau, that extends to the northwest, nearly parallel to the first escarpment. The second prairie level has an average elevation of about 1,600 feet, and its surface is diversified by gentle undulations and low hills rising a few hundred feet above the general level, while the river valleys are often deeply cut and wide.

The Missouri côteau, with a fairly abrupt rise of 200 feet to 500 feet, forms the eastern boundary of the third prairie level, that stretches to the foot of the Rocky mountains. The third level has a general elevation of 2,000 feet to 2,500 feet along its eastern margin, but rises to over 4,000 feet along the borders of the mountains in the west. The surface of the plain is much more irregular than the last, with table-lands, like the Cypress hills and Wood mountain, rising 1,000 to 2,000 feet above the general level, and representing the outlying remnants of a once higher plain, since largely destroyed by erosion.

The region of the Interior Continental plain has had a comparatively peaceful history since early geological times, having been left almost undisturbed by mountain building processes or by the intrusion of igneous bodies, and affected only by continental movements. The country is largely mantled by superficial deposits of soil, etc., concealing, over wide areas, the underlying, gently dipping, very broadly folded, stratified beds, that, in their turn, doubtless rest on the westward extension of the rocks of the Laurentian plateau.

Along the eastern margin of the plains, strata of Palæozoic age rest directly on the pre-Cambrian formations. On the western shores of Lake Winnipeg, and to the south of this body of water, Ordovician measures outcrop. Westwards these are overlain by Silurian beds, in turn covered by Devonian strata



Niagara limestone overlain by till, Gunn's Quarry, Stonewall, Man.

that outcrop to the foot of the Manitoba escarpment, where the Palæozoic measures are overlapped by the much younger Cretaceous sediments that stretch westward to the Rocky mountains, and northwestward for over 1,200 miles. Overlying the Cretaceous beds are others of Tertiary age, occurring in the neighbourhood of the International Boundary, and occupying, in Alberta, a very large area south of the 56th parallel.

The Ordovician measures about Lake Winnipeg consist of sandstones overlain by magnesian limestones, with higher beds of shale and limestone. In age the rocks appear to range from mid-Ordovician to upper Ordovician. They occupy a band of varying width stretching northward from the International Boundary, through Lake Winnipeg, and thence northwestwards for many miles. On the eastern side they rest directly on the pre-Cambrian rocks, while their western edge is formed by the conformably overlying Silurian, or the overlapping Devonian or Cretaceous.

The Silurian consists largely of flat-lying magnesian limestones and dolomites, holding fossils of Niagara and Guelph age. These beds, for the most part, are overlain conformably by others of Devonian age, consisting largely of limestones and shales. It is not certain, however, that either the highest or lowest Devonian beds are present. The measures of this system appear from beneath the Manitoba escarpment of Cretaceous strata that in some places, however, repose directly on the Silurian, concealing the Devonian from view. Farther northwest the Devonian beds again emerge, resting along their eastern margin on the pre-Cambrian, and north of the latitude of Athabaska lake occupying an immense area stretching northward to Great Bear lake and down the Mackenzie valley. The measures of this great northern area, lying in gentle folds, consist of almost 2,000 feet of limestones and dolomites with some quartzites, succeeded by several hundred feet of shales and shaly limestone. The lowest beds of this region are possibly of Silurian age, while the upper division corresponds to the Hamilton, and perhaps to the highest Devonian of all.

The flat-lying Palæozoic measures outcropping from beneath the Cretaceous beds along their eastern border probably extend everywhere beneath the younger rocks of the plains, for they again appear in the west amongst the faulted and folded strata of the Rocky mountains. This mountain range was not elevated until

Tertiary times, and before this period the area of at least the eastern portion of the Rockies was part of the central, level region, submerged beneath the interior sea in which formed the Palæozoic measures of Manitoba. In the west, however, the invasion of the Palæozoic seas appears to have taken place earlier, and to have lasted longer than in the east, for in the Rocky mountains the stratified measures range in age from the late pre-Cambrian to high in the Carboniferous. Since there appears to be such an intimate connexion between the geological history of the strata of the Rocky Mountain front and the measures of the interior plains, the geology of this mountain range will be described conjointly with that of the plains.

In the mountains of southern British Columbia, and adjoining portions of Alberta, occurs a great group of sediments, with a total thickness of over 20,000 feet, largely of quartzites and argillites. These measures are of pre-Cambrian age, apparently deposited in an early sea that continued to exist through Palæozoic times. North of the main line of the Canadian Pacific railway, within the Rocky mountains, a conformable series of over 13,000 feet of fossiliferous strata, largely limestones and shales, represents nearly the whole of the Cambrian system and is directly overlain by Ordovician beds. Along the Bow River pass, the Ordovician measures are conformably succeeded by over 1,000 feet of quartzites and limestones of Silurian age. Above the Silurian beds are several thousand feet of Devonian measures, chiefly limestones and shales, while these are overlain by 5,000 feet to 7,000 feet of Carboniferous beds, divisible into four groups—at the bottom limestones, then shales, then limestones, and, at the top, a series of sandstones and shales.

This great section of Palæozoic measures, some 25,000 feet in all, and the underlying great thickness of pre-Cambrian sediments, appears to be represented, though variously modified both as regards volume and lithological character, throughout the whole length of the Rocky Mountain range. Not only is the total thickness much greater than in the case of the eastern representatives in Manitoba, but lower and higher divisions lacking in the east are present in the west. At the close of the Palæozoic era, most of the region of the Interior plains was withdrawn from the sea, and was not again invaded by it until upper Cretaceous times. But in places, at least, the western portions of this region and the

Gunn's Quarry in Niagara limestone, Stonewall, Man.

site of the Rocky mountains towards the south was at least thrice again a region of deposition: first in Triassic times; secondly in Jurassic times when the Fernie shales were formed; and thirdly, when in early Cretaceous times the coal-bearing, Kootanie group of shales, sandstones and conglomerates, in places 5,000 feet thick, were laid down. It does not appear that either the Fernie or the Kootanie extends far east beneath the overlapping Cretaceous beds, for, followed eastward to where the last exposures are seen, they are found to continuously and rapidly decrease in thickness.

Thus it seems not unlikely that the Interior plain had emerged from the sea before the close of the Palæozoic era. The region was doubtless subjected to erosion, probably sweeping away considerable volumes of strata, yet the process seems to have been such as to preserve the original plain-like surface of deposition. In upper Cretaceous times, when detrital beds again formed in the region, they were received upon a nearly flat surface, so that now there is no marked structural unconformity between the overlying and underlying series. Though lower Cretaceous strata are present in the west, in the east the oldest division of this system is of upper Cretaceous age, and is represented by the Dakota sandstone, that varies in thickness from a few feet to several hundred, and outcrops along the Manitoba escarpment. Farther north, in Alberta and elsewhere, the formation is represented by the tar sands, consisting of rather homogeneous sands cemented by a tarry substance. These beds are also paralleled in the Rocky mountains, but by coarser material of greatly increased thickness. The Dakota sandstones seem to be largely, if not entirely, of freshwater origin, and probably were deposited mainly through the agency of rivers. Though only exposed about the borders of the great Cretaceous basin, they doubtless extend continuously beneath the younger beds of the plains region.

During the succeeding, or Colorado period, the region of the plains was invaded by a sea reaching from the Arctic in the north to the Gulf of Mexico in the south. In this mediterranean sea were deposited dark shales, followed by calcareous shales and shaly limestone, that, along the Manitoba escarpment, increase in thickness northwards to a maximum of about 700 feet. In northern Alberta these measures seem to be represented by several thousand feet of sandstones and shales that, traced westwards into the mountains, become coarser and more arenaceous as they approach the site of the old sea coast. South, near the International Boundary, the beds are, in part, represented by tuffs and volcanic agglomerates.

The marine conditions of the Colorado period continued into the succeeding Montana period, and, in places, perhaps, held throughout this division of Cretaceous time. In the east the beds of this series are represented by a group of shales capped by sandstones of a shoaling sea. These marine beds are, perhaps, also represented in the far north, but over a wide region commencing about the latitude of Edmonton and extending to and beyond the International Boundary, the country during a part of Colorado time was in a fluctuating state, so that brackish and freshwater deposits, with seams of lignite, were formed, and finally were succeeded by true marine deposits. The non-marine beds, the Belly River group, have been brought to light by a broad, anticlinal fold. They consist chiefly of clays and sandstones forming an immense lense, thick in the centre but wedging out east and west. They are underlain by marine shales and sandstones, and overlain by similar beds passing up into more arenaceous measures.

The shallowing seas at the close of the Montana seem to have forecasted a general withdrawal of the marine waters, and the inauguration of freshwater conditions over a large part of the plains region during the time of deposition of the succeeding Laramie group. These measures occupy a large area in Alberta, south of Lesser Slave lake, and, as shown by erosion remnants, were once continuous eastward into Manitoba. The Laramie beds in Canada succeed one another conformably, and apparently were continuously formed during late Cretaceous and early Tertiary times, bridging the gap elsewhere found between the two systems. The Laramie group is very variable in thickness, and may be divided into two portions, a lower one, named the Edmonton, and an upper one, called the Paskapoo. The Edmonton consists largely of argillaceous measures and is coal-bearing. The Paskapoo is much more arenaceous in character, has a thickness of above 3,000 feet, and is considered to be of early Eocene age.

Towards the close of the Laramie, in early Tertiary times, the western margin of the then interior plain-like region was subjected to tremendous earth movements, whereby the Rocky mountains were formed. The strata, traversed by immense dis-

PLATE LII.

Dirt Hills, Sask.

PLATE LIII.

Sod Houses, Eagle Creek, Sask.

locations, were tilted and shoved upwards and eastwards over one another, sometimes for miles. Eastward of the main range, the effects of this mountain building epoch gradually disappear in a series of lower, and lower wave-like ridges; but far eastward the disturbances were still felt, and during this interval the Interior plains appear to have been subjected to erosion.

After the mountain building epoch of Tertiary times the Interior plains again became a region of deposition. The Cypress hills and Wood mountain are formed of argillaceous strata and sandstones overlain by beds of water-worn pebbles with lenses of sand. These measures, formed in Oligocene times, were apparently deposited by detrital-laden, eastward flowing rivers. Probably the present areas are but remnants of a once widely extending tract of beds of similar origin, since destroyed by the processes of erosion that commenced in Tertiary times and have continued to the present day.

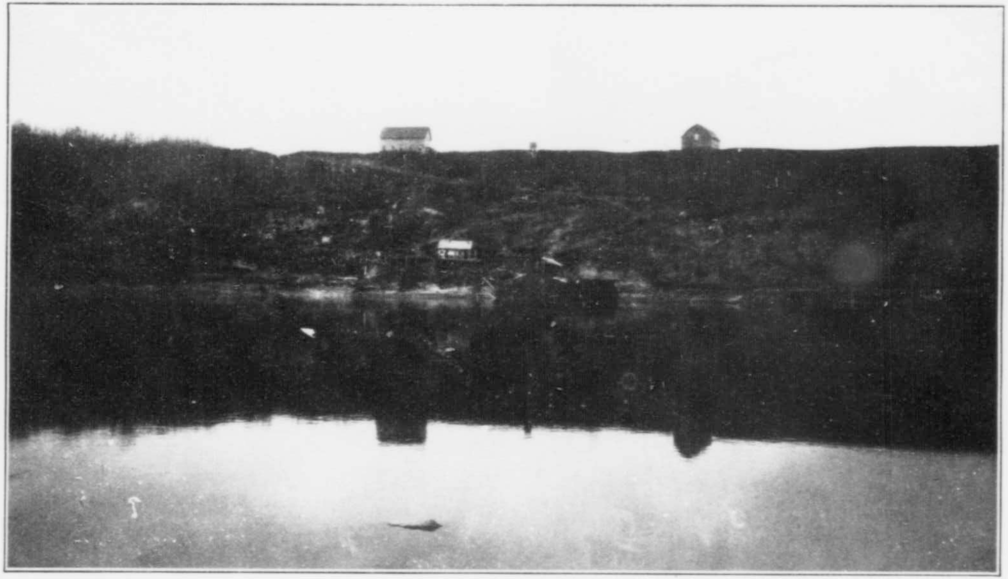
ECONOMIC MINERALS.

The great areas of farming and ranching land of the Interior plain are markedly deficient in metallic mineral wealth, as might be expected, since they are underlain with a thick blanket of almost undisturbed Cretaceous and Tertiary sediments. Gold dredging is carried on in the sands and gravels of the North Saskatchewan river, below Edmonton; gypsum is mined from the Devonian of Manitoba; salt occurs in Manitoba and in the lower Athabaska; but with the exception of these and materials used in cement, clay manufactures, and building trades, the mineral production is almost entirely confined to fuels, which, however, are very important.

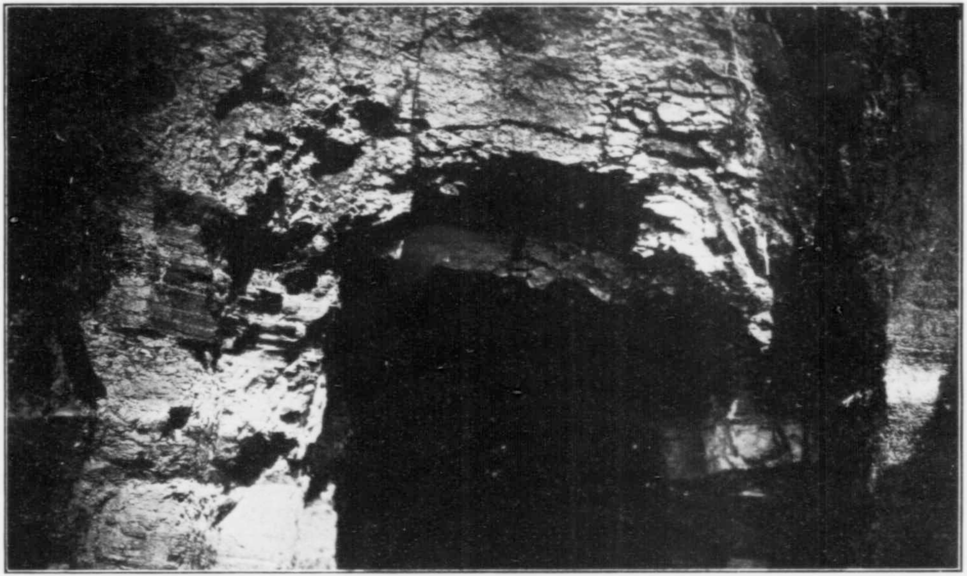
COAL.

Lignite occurs within two horizons of the gently undulating Cretaceous and Tertiary measures of the plains. These horizons are the Belly River, of upper Cretaceous age, and the Edmonton, belonging to the Tertiary. The coal-bearing horizons underlie almost the whole of Alberta south of latitude 55° N., and extend some distance westward into Saskatchewan. In southern Saskatchewan lignite-bearing beds of Tertiary age form the elevated plateaus of the Cypress hills and Wood mountain. The same Tertiary beds form Turtle mountain in Manitoba.

The Belly River formation outcrops over a great curving band, 125 miles broad at the International Boundary and stretching northwards for 300 miles, partly in Alberta, partly in Saskatchewan., North of the Red Deer river, a tributary of the South Saskatchewan, the lignite beds have not been found, or occur but sparingly; but in the south they outcrop at many points, in places, as along the Saskatchewan, in seams 18 feet thick; while at Lethbridge and Taber, about 350,000 tons of a somewhat high grade lignite are annually produced from seams of the Belly River measures. The lignite beds worked are in the neighbourhood of five feet thick.



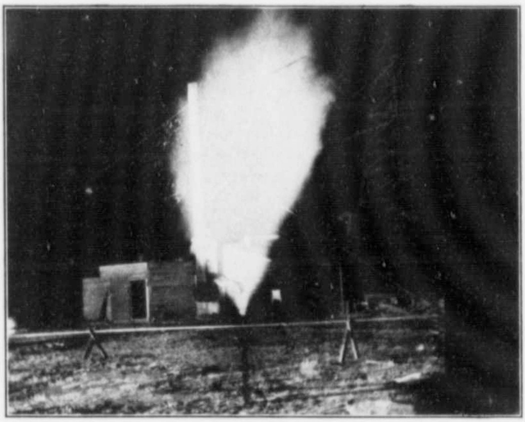
Clover Bar: opening on river, near Edmonton, Alta.



Tunnel on branch of Eagle Creek, Sask.

The coal-bearing Edmonton formation, of Tertiary age, with the overlying Paskapoo, occupies an immense basin, gradually widening towards the north and reaching from the International Boundary almost to Lesser Slave lake. Coal seams outcrop in the Edmonton on both sides of the area of younger Paskapoo, lying basin-like in the centre of the Tertiary area. The lignites have been found outcropping as far north as Edmonton, the

PLATE LVI.



Gas Well, Dunmore, Alta.

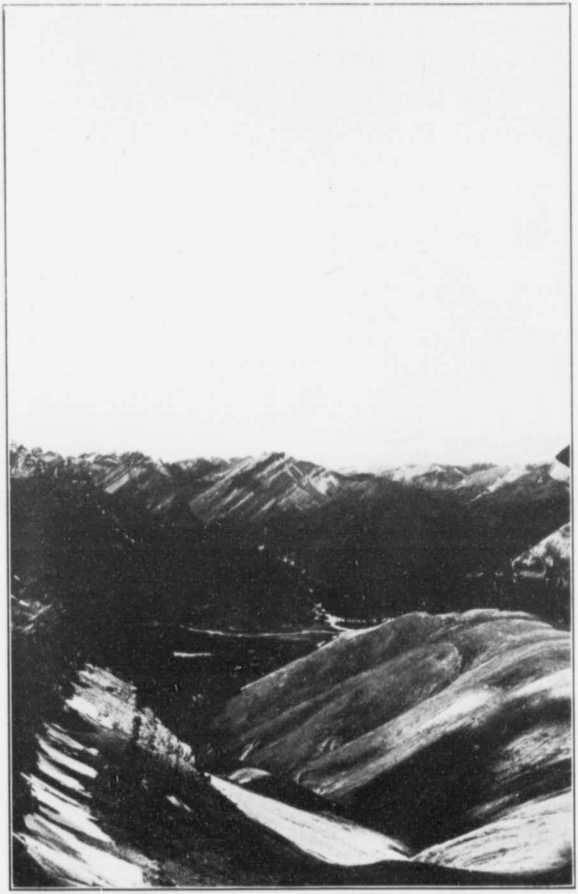
principal mining centre of this coal horizon. In this district, in 1907, over 100,000 tons of lignite were produced, chiefly from one seam that varies in thickness from five to fifteen feet. This lignite seam in places outcrops at the surface, while at other places it lies at depths of 100 to 200 feet.

In Saskatchewan, lignite seams outcrop on the borders of the areas of Tertiary beds that there form elevated districts, apparently representing erosion remnants of a once continuous covering. The Tertiary coal horizons of these areas have been correlated with the Edmonton of the west. In one of these areas, all situated in the south towards the International Boundary in the Cypress hills, a 4 foot seam has been mined. Farther east, at Wood mountain, two seams are known to occur, respectively 6 feet and 8 feet thick. In Manitoba, it has been claimed that the Tertiary area of Turtle mountain also contains coal.

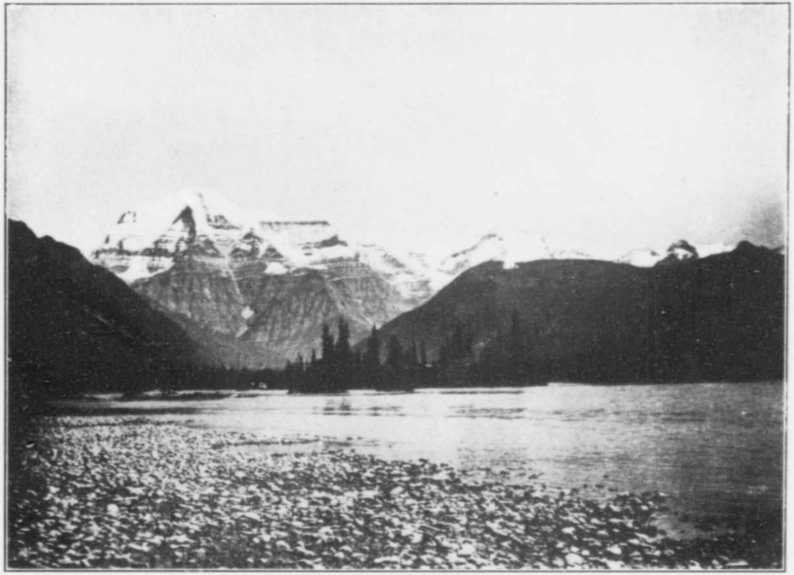
NATURAL GAS AND PETROLEUM.

Natural gas has been found in northern Alberta along the Athabaska. In the south, near Medicine Hat, at several wells drilled to a depth of 1,000 feet, gas was found in the Niobrara, and yielded, in the case of one well, at the rate of 1,500,000 cubic feet per day. Recently a well 1,900 feet deep on Bow island struck a rich gas vein.

Along the Athabaska, in northern Alberta, the basal member of the Cretaceous is known as the tar sands, a formation saturated with great quantities of bituminous matter. There is thus evidence of the probable existence of a petroleum field in the north. Oil seepages also occur in southwestern Alberta. The oil or gas possibilities of the lower Cretaceous measures where capped by the upper members, but not so deeply as to be beyond commercial accessibility, may be considered to be exceptionally good.



Clearwater River : showing typical transverse valley, Rocky Mountains.



Mount Robson, one of the loftiest of the Rocky Mountain peaks, Yellowhead Pass.

CHAPTER VII.

THE CORDILLERAN REGION.

GEOLOGY.

The *Cordilleran region* in Canada embraces the mountainous country bordering the Pacific coast, and having an average width of over 400 miles. It is but a portion of a great mountain system that, commencing in the south and extending northwesterly, occupies nearly the whole of Mexico, and stretches along the Pacific border of the continent through the United States and Canada into Alaska. In Canada, the region includes all of British Columbia, parts of western Alberta, the whole of Yukon Territory, and a large tract in the adjacent western portion of the North West Territories, an area in all of approximately 600,000 square miles.

The western mountain region of Canada, when viewed in detail, appears as a complex assemblage of mountain groups and elevated tracts apparently prohibiting an orderly description. But the presence of several broadly developed, though not always clearly defined structural elements permits the drawing of a generalized picture. Along the eastern front of the Cordilleras, the Rocky mountains, with many peaks in the south rising to heights of about 11,000 feet or 12,000 feet, form a fairly definite range, extending from the International Boundary northwestward to the Liard river, a distance of about 850 miles. The range is bounded on the west by a deep, nearly continuous depression, composed of a series of valleys occupied in the south by the headwaters of the Columbia and Fraser rivers, which empty into the Pacific, and in the north by the tributaries of the eastward flowing Peace and Liard rivers.

North of the Liard river, the mountainous country projects eastwards for a hundred miles or so, and, designated as the Mackenzie system, continues northwards, occupying a large, almost unknown territory some three hundred miles wide between the valleys of the Mackenzie and Yukon rivers. East of the Mackenzie system, whose highest peaks probably do not exceed 7,000 feet in height, a second projection of the mountains forms the Franklin range, bordering the Mackenzie valley on the east between latitudes 63° N. and 66° N. The highest points of the Franklin mountains probably do not reach much above 5,000 feet, and the mountains, dying away to the northward, are succeeded by a great stretch of plain that reaches to the Arctic ocean on both sides of the Mackenzie river.

Along the Pacific border, the Coast range forms a definite mountain range, rising steeply from the ocean to heights of 8,000 feet to 9,000 feet, though broken by numerous, deep, transverse valleys occupied by rivers draining the interior of British Columbia. Westward of the mainland, the mountains of Vancouver and the Queen Charlotte islands to the north may be regarded as part of an outer range separated from the continent by a submerged valley.

Lying between the Rocky Mountain range, with its northward continuations, on the east, and the Coast range on the west, the interior of British Columbia may, broadly speaking, be divided into three portions. In southern, central British Columbia a large area lying east of the Coast range has been designated as the Interior Plateau. Near the International Boundary it is terminated southward by a coalescence of rather irregular mountain ranges, while on the east it is separated from the Rocky mountains by various groups of mountains divided from one another by long, often pronounced valleys. Amongst these subordinate groups may be mentioned the Selkirks, with peaks rising to heights of 9,000 feet to 11,000 feet and over.

Though the Interior Plateau region is, strictly speaking, a mountainous district, yet it is in marked contrast with the more lofty bordering mountain ranges. The country, with a general average elevation of perhaps 3,500 feet in the lower, northern part, is traversed by great valleys, whose bottoms, in the case of those occupied by the major streams, do not lie more than 1,000 feet above the sea. Everywhere the district is broken by ridges and groups of mountains, but these seldom rise higher than 5,000 feet above sea level.

Northward, the Interior Plateau is bounded by an imperfectly known country, occupied by various groups of mountains lying

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Typical Selkirk scenery, B.C.

Interior Plateau, Southern British Columbia.

between the Coast range and the Rocky mountains. This broken, more elevated belt continues north to the boundary between British Columbia and the Yukon. There begins a second plateau region, known as the Yukon plateau, that stretches down the valley of the Yukon into Alaska, bounded on one side by the Coast ranges, on the other by the Mackenzie Mountain system. The use of the term plateau as applied to this northern area is much more appropriate than in the case of the southern area of British Columbia. Though the country is broken by deep valleys sunk 1,000 to 3,000 feet below the surrounding country, yet everywhere the uplands form broad, gently sloping areas, apparently remnants of a once continuous, plain-like region that, with a general elevation of 4,000 feet or more in the south, gradually decreases in height northward to 1,000 feet or less.

The Cordilleran region, except in the far north, is largely a forested country. In the southern interior, however, are wide stretches of open, grass-covered hills and valleys, noted for their fertility. Various districts have long been known to be rich in mineral wealth, and new ones are constantly engaging attention. Large coal mines have been opened up at various points along the Rocky Mountain front, where coal fields are known to occur at intervals for hundreds of miles north of the boundary. Coal mines have long been in operation on Vancouver island. Other coal fields are known to exist in the central interior of British Columbia, and the Yukon Territory. The alluvial gold fields of the Klondike are well known. In southern British Columbia are the notable, immense, copper-bearing sulphide ore bodies of Phœnix, the Rossland gold-copper mines, and the lead mines of Moyie. These are but a few of the better known mineral deposits, and whole districts may be said to be rich in mineral wealth, including ores of platinum, gold, silver, copper, lead, zinc, iron, etc.

The geological history of the Cordilleran region has been complicated in the extreme. Various formations, ranging in age from pre-Cambrian to recent, are widely displayed. At different periods, and often over extensive areas, huge deposits of volcanic matter were poured forth, while at intervals, immense batholitic bodies of igneous rocks invaded and altered the strata. The region from very early geological times appears, during successive epochs, to have been affected by great earth movements that folded and faulted the strata and elevated them into mountain masses, afterwards subjected to intense erosion.

The results of the action of the mountain building forces of the various periods seem to have, in the main, given rise to elevated tracts, whose axes followed a general northwesterly course, like the mountains of the present day. The basins of deposition also seem to have been extended parallel to the same direction, so that now the same general assemblage of formations may be followed for long distances in a northwest or southeast direction, while along sections at right angles to the courses of the mountain ranges a succession of formations is crossed.

The Rocky mountains, and the ranges of the Mackenzie system to the north, are almost entirely composed of sedimentary measures, chiefly of Palæozoic age, but in places including great thicknesses of stratified pre-Cambrian rocks; while in the Rockies, infolded and infaulted basins of Mesozoic strata are common. The Coast range is essentially a complex batholite of granitic rocks of Jurassic age, penetrating Triassic and older rocks such as form Vancouver island. In places along the coast and on the Queen Charlotte islands are basins of Cretaceous and Tertiary beds.

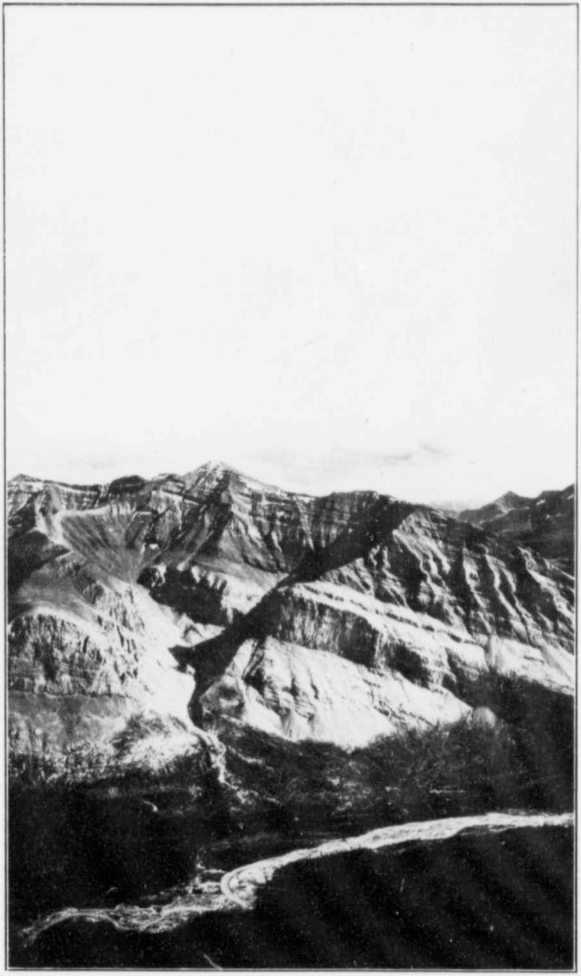
Between the Rocky mountains and the Coast range the country is fundamentally underlain by Palæozoic and early Mesozoic measures, often largely of volcanic origin, folded and faulted, and invaded by granitic bodies frequently of great size, and, perhaps, chiefly of Mesozoic and Tertiary ages. Though Palæozoic and early Mesozoic strata are widely displayed throughout the interior of British Columbia and the Yukon, yet over large tracts of country they are concealed by later Mesozoic and Tertiary beds. In the southern part of British Columbia, Tertiary strata, largely of volcanic origin, occupy whole districts, while in the northern half of the Province, Cretaceous, with, perhaps, late Jurassic beds, are equally prevalent.

The Franklin range is probably largely of younger Palæozoic rocks. The upper Mackenzie valley is chiefly floored by Devonian measures, with a few basins of Cretaceous or Tertiary beds. Farther north the level country on either side of the Mackenzie is occupied by Cretaceous rocks extending a long distance westward.

In southern British Columbia, in the Selkirks and neighbouring ranges on the west, a very large area is occupied by various types

Delta of the Duncan River at the head of Howser Lake, B.C.

Howser Lake, B.C., occupying a north and south longitudinal valley.



Red Deer River: second range, Rocky Mountains.

of schists and gneisses with crystalline limestones and quartzites, all highly disturbed and intricately associated with large bodies of granite, diorite, etc. This complex assemblage, known as the Shuswap group, is probably, in part at least, of pre-Cambrian age, but very likely also includes younger formations. Somewhat similar rocks occur about the headwaters of the Peace river, inside the Rocky Mountain range. Formations presenting certain points of resemblance to these occupy large areas in the Yukon Territory, where, however, it is not at all certain that the rocks are as old as the pre-Cambrian, though they are generally classed as pre-Ordovician.

The great thickness of shales, limestones, etc., of Cambrian age, and the underlying pre-Cambrian beds found along the southern front of the Rockies have already been mentioned. Similar measures seem to be represented along the whole course of the range, and Cambrian and later Palæozoic strata have been found within the Mackenzie Mountain system. The largely calcareous and argillaceous Cambrian measures of the front of the Rocky mountains, when followed westerly through the range along the main line of the Canadian Pacific railway, become less calcareous, and the sediments, on the whole, coarser. In the mountain groups of southern British Columbia, west of the Selkirks, occur several great series of sediments, with an estimated thickness of about 40,000 feet, composed of a lower division largely of calcareous shales with limestones and quartzites, overlain by an upper portion of quartzite, conglomerates and various schists. Traced westwards, the upper division is found largely replaced by volcanic rocks, often in a schistose condition. These extensive assemblages of beds have been described as of Cambrian age, but it is not improbable that at least a considerable portion will yet be found to belong to other series.

Limestones and fossiliferous shales of Ordovician age have been found at wide intervals along the course of the Rocky mountains, and also far north in the Mackenzie mountains. Beds of this age probably also occur in the Yukon. A great series of quartzites and mica schists, some 25,000 feet thick, occurs in southern British Columbia west of the Selkirks and has been placed in the Ordovician, but solely on stratigraphical grounds. As yet, Silurian measures have been recognized at only one locality in the Cordilleran region, along the pass traversed by the main line of the Canadian Pacific railway through the Rocky mountains. Devonian limestones, shales, etc., sometimes forming sections thousands of feet thick, appear to occur everywhere along the Rocky Mountain range. They are present in the Mackenzie system of mountains, and in the northern portion of the Yukon Territory. Fossiliferous Devonian beds have also been found on Vancouver island. Elsewhere, save for the presence of measures possibly of late Devonian age, the beds of this system have not been recognized in the Cordilleran region.

In the Rocky mountains, the Devonian is conformably succeeded by Carboniferous beds largely limestones, and shales, in places 5,000 to 7,000 feet thick. From the palaeontological evidence available, these beds seem to represent only the lower part of the Carboniferous system. Carboniferous strata with, perhaps, conformably underlying Devonian beds, are extensively developed throughout central British Columbia, and continue into the Yukon territory. The beds sometimes consist largely of true sediments, but, more commonly, are represented by great thicknesses, sometimes 5,000 feet or more, of tuffs and various effusive volcanic rocks often overlain by great volumes of limestones, in places 3,000 feet or more thick.

In the Rocky mountains the Carboniferous beds usually are directly overlain by Cretaceous strata, though sometimes beds possibly of Triassic age also occur. In the interior of British Columbia, the Carboniferous strata are often surmounted by immense thicknesses of volcanic material of Triassic age. In the neighbourhood of Kamloops lake these measures, apparently the products of submarine volcanoes as many of Carboniferous times appear to have been, have a thickness of 10,000 to 15,000 feet. Similar beds have been found all through central British Columbia, and, separated by the granite bodies of the Coast range, appear along the Pacific coast and on Vancouver island. Everywhere the Triassic strata, so largely of volcanic origin are closely folded, and on the coast, as well as elsewhere, are usually associated with older measures of Carboniferous age. Possibly in many districts the volcanoes of Carboniferous times may have continued in action with but slight interruptions until the Triassic period.

In a few localities in southern British Columbia, the Triassic volcanoes seem to have remained active into Jurassic times.

Cascade Mountain, Alta., typical Selkirk peaks and transverse valley. The scars on the valley slopes show the courses of avalanches through the timber.

With the exception of the deposits so formed, no formations definitely determined as belonging to the earlier Jurassic epochs are known to occur in the Cordilleran belt, where sedimentation does not appear to have again commenced until late Jurassic times.

During the Jurassic interval, the Triassic and older measures occurring west of the site of the Rocky mountains were faulted and folded, and probably elevated into mountainous masses. At about the same time took place the invasion of the great batholitic bodies forming nearly the whole of the Coast range, extending along the border of the continent for nearly 1,000 miles. The granitic rocks of this range are doubtless not all of the same age, and vary much in composition from basic gabbros to acid granites. Possibly it was also at this time that many of the large plutonic bodies of southern British Columbia formed; though the evidence to the south, in the United States, points to a Cretaceous age for them. They are chiefly of granites, grano-diorites and allied types, and are largely confined to the central portion of British Columbia, south of the main line of the Canadian Pacific railway. Probably they continue much farther north, concealed beneath Cretaceous and Tertiary measures, for they seem to be represented in the northern part of the Province, and in the Yukon Territory.

Before the close of Jurassic times, the deposition of material had again commenced in the Cordilleran region, and continued, over increasing areas, into Cretaceous times. In the southern part of the Rocky mountains the Fernie shales, of late Jurassic age, have a maximum thickness of 1,500 feet, rapidly decreasing eastward. They rest directly on Carboniferous strata, and are overlain by early Cretaceous beds, the coal-bearing, non-marine Kootanie series, in places composed of 5,000 feet of shales and sandstones. In the Queen Charlotte islands a section of over 9,000 feet of strata, representing both the upper Jurassic and lower Cretaceous, rests unconformably on folded Triassic beds. The section consists largely of sandstones and shales, holding coal seams towards the top, and with a thick, intermediate, volcanic group.

Lower Cretaceous rocks also appear in southern British Columbia, largely along the lower course of the Fraser river, east of the Coast range. They sometimes attain a volume of 5,000 feet or more, but show rather wide variations in thickness and character. They seem to be largely littoral deposits, shales, sandstones, and conglomerates. In the central interior of British Columbia, about the headwaters of the Skeena and Nass rivers, occurs a thick volcanic series, possibly of late Jurassic or early Cretaceous age, overlain by a comparatively thin series of shales and sandstones holding seams of coal. In northern British Columbia, and the southern portions of Yukon Territory, occur volcanic and coal-bearing sedimentary beds of late Jurassic and, probably, early Cretaceous age.

At the close of lower Cretaceous times the Canadian Cordilleran region appears to have been withdrawn from the sea, eroded, and doubtless subjected to mountain building forces. Certain plutonic bodies in the interior seem to be of this period. Along the Pacific coast, however, sedimentation continued, and the lower Cretaceous beds of Queen Charlotte islands are there followed by about 3,500 feet of conglomerates, sandstones, and shales. At the same time portions of the coast of Vancouver and adjacent islands were submerged, and a series of coal-bearing sandstones and shales, over 5,000 feet thick, were formed.

Towards the close of the Cretaceous period, or in very early Tertiary times, the formation of the Rocky Mountain range took place. The hitherto flat-lying Palæozoic and Mesozoic beds of the western border of the Interior Continental plain were upturned in long, anticlinal folds, whose axes ran in a general northwest and southeast direction. The forces continuing to act, the folds were overturned, the western limbs thrust over the eastern. In places, segments of the measures were displaced horizontally for as much as seven miles, and the strata have been folded and faulted to such an extent that it has been estimated that they now occupy but half their original width.

The effect of the forces causing the uplift of the Rocky mountains doubtless extended through the whole of the Cordilleran region, but with varying degrees of intensity. During late Cretaceous, and the opening periods of the Tertiary, the region, as a whole, appears to have been undergoing erosion, and during this time the topographic features of the present day were outlined.

During Oligocene, and probably Miocene times, freshwater deposits of shales, sandstones, etc., were deposited in valleys and lake basins over much of southern, central British Columbia. In places these deposits are of but slight extent, but in others they

PLATE LXV.

Northern end of Big Horn range, Alta.: foothills in distance.

Model of Cascade Basin, Rocky Mountains.

occupy large areas. The sediments vary greatly in thickness, at times yielding sections of 5,000 feet or more, and with them sometimes occur beds of lignite. Following the time of sedimentation came a period of volcanic activity, with the formation of beds of tuffs and great sheets and flows of rhyolite, basalt, etc. In places these volcanic beds are 5,000 feet or more thick. Frequently they appear overlying the Tertiary sediments and extending beyond them, filling in old inequalities of the ancient land surface. Similar Tertiary beds occupy an extensive region in central British Columbia, north of the main line of the Canadian Pacific railway, and extend to the Cretaceous basin commencing about the headwaters of the Skeena river.

Though some volcanoes remained active during the Pliocene period and until a very recent date, the Tertiary and more recent epochs appear to have been, in the main, times of active erosion of the land. During the periods from Miocene times onwards, the Cordilleran region apparently was subjected to regional uplifts and depressions, and mountain building processes may still be expected in the Cordillera. In places the Tertiary strata have been folded, and in certain districts in southern British Columbia, occur large bodies of plutonic rocks of Tertiary age.

ECONOMIC MINERALS.

The Cordilleran region is pre-eminently a mining district. Its mines already furnish virtually all the lead mined in the country, almost all the gold, nearly three-quarters of the copper, a quarter or more of the coal, and a considerable proportion of the silver. This high rank has been reached in spite of the fact that prospecting of even the most desultory fashion has been carried out only over a very small, almost insignificant part of the area, chiefly in those districts lying south of the main line of the Canadian Pacific railway.

The comparatively limited amount of prospecting already done has, in the districts covered, marked out various regions as being characterized by the occurrence of certain classes of deposits. The Rocky mountains, and the flanking foothills on the east, contain vast quantities of coal, but apparently are not otherwise rich in mineral wealth. Coal also occurs over other districts in central, southern British Columbia, on Vancouver island, on the Queen Charlotte islands, in the Skeena River country, and in the Yukon Territory and elsewhere.

Rich silver-lead deposits characterize the country lying south of the Canadian Pacific railway, and between the Rocky mountains and the Arrow lakes. To the west and south of this, almost to the Fraser valley, is a district of gold-copper deposits. Along the Pacific coast, both on the mainland and the islands, are many deposits of gold-copper, also in the country of the basin of the Skeena. Iron deposits occur along the coast. Copper and silver deposits mark the southern interior of the Yukon, while placer gold districts, sometimes fabulously rich, extend through the central region from the Klondike in the north, almost to the International Boundary in the south.

Plate LXVII.

Pine Creek, Atlin, B.C.

PLATE LXVIII.

Hydromagnesite Beds, Atlin, B.C.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE CORDILLERAN REGION.

Element or Mineral sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold......	Alluvial gold in pre-glacial sands and gravels, and in more recent deposits derived from these....	Klondike, Y.T.; Atlin, Cariboo, B.C.
	Auriferous mispickel with varying amounts of copper and iron pyrites occur in bodies replacing country rock along or near contact of igneous rocks of dioritic affinities and in a gangue of garnet, epidote, calcite, etc............	Hedley, B.C.
	Free gold with a little pyrite and some galena and zinc blende, in quartz fissure veins cutting carbonaceous phyllites.....................	Lardeau district, B.C.
	Free gold, argentiferous tetrahedrite, galena, zinc blende, iron and copper sulphide in quartz veins cutting carbonaceous phyllites...............	Lardeau district, B.C.
	Free gold in schistose pyritiferous diabase, and in quartz veins holding mispickel, galena, and pyrite....................................	Poplar Creek district, B.C.
	In copper-gold deposits. *See* under copper-gold.	
Platinum..	Native platinum occurring sparingly in gold placer deposits..........................	Klondike, Y.T.; Tulameen river, B.C.
Mercury...	Cinnabar in irregular veins of calcite and quartz, cutting Tertiary volcanics and also impregnating sandstones..........................	Near Kamloops lake, B.C.
Copper-gold....	Magnetite, chalcopyrite and pyrrhotite in varying proportions occur in large bodies replacing Palæozoic tuffs and limestone, in a gangue of garnet, hornblende, calcite, quartz, etc., in neighbourhood of bodies of granodiorite and Tertiary syenite..........................	Boundary district, B.C.
	Chalcopyrite and pyrrhotite with some pyrite and mispickel, occur in veins or in large bodies replacing augite porphyrite near contact with monzonite and in neighbourhood of bodies of granodiorite and Tertiary syenite...........	Rossland, B.C.
	Chalcopyrite, bornite, pyrite, and pyrrhotite with a little calcite in a fissured zone on or near contact of sediments and monzonite............	Copper mt., near Princeton, B.C.
	Chalcopyrite, pyrite, mispickel, and magnetite with calcite in zones of fissuring in monzonite and sediments.........................	Copper mt., near Princeton, B.C.
	Chalcopyrite and pyrite with a little galena and zinc blende in small veins and lenses within a mineralized zone in a quartz sericite schist cut by granitic body of Coast Range batholith....	Britannia mine, Howe sound, B.C.
	Chalcopyrite and pyrite with galena and zinc blende in a gangue of barite with quartz and calcite, forming flattened lenses in schist....	Tyee mine, Vancouver island
	Bornite with subordinate chalcopyrite, a little pyrite and pyrrhotite replacing limestone in a gangue of pyroxene, garnet, and calcite, near granite contact.........................	Texada island, B.C.

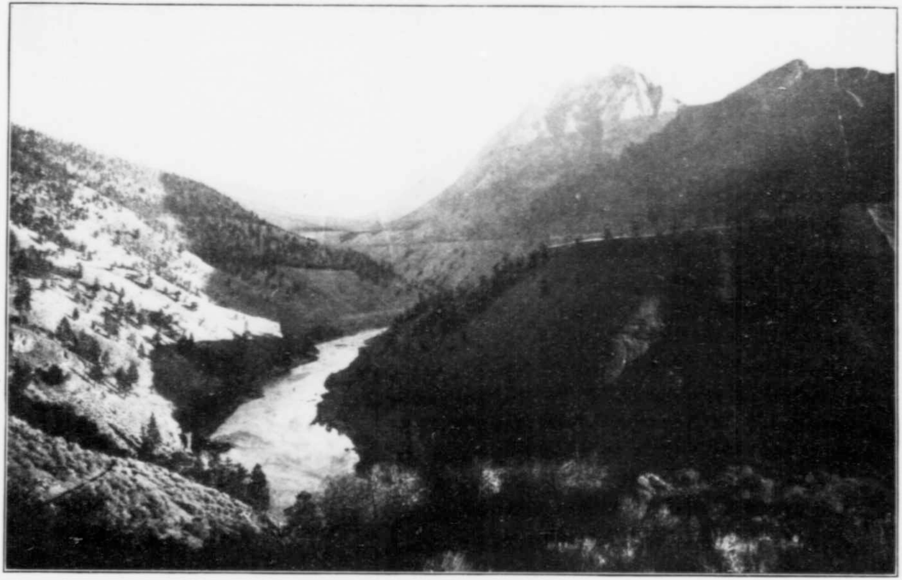
TABULAR DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE CORDILLERAN REGION.

(Continued.)

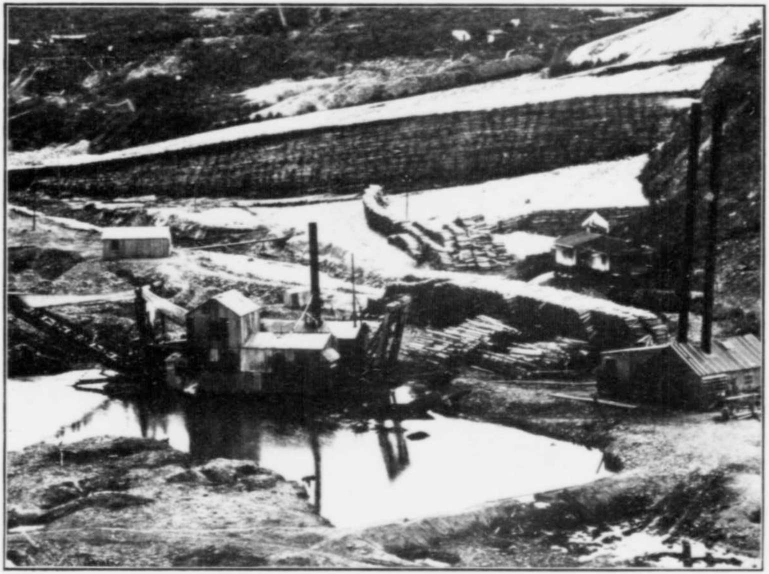
ELEMENT OR MINERAL SOUGHT.	CHARACTER AND MODE OF OCCURRENCE OF DEPOSIT.	EXAMPLE.
Silver-Lead	Argentiferous galena with some zinc blende and a little pyrite forming irregular lenses in a fissured zone within pre-Cambrian quartzite..........	St. Eugene mine, Moyie, B.C.
	Argentiferous galena, argentiferous tetrahedrite, native silver and gold, argentite, zinc blende, copper and iron pyrites, in a gangue of quartz, siderite and calcite in veins cutting sediments.	Slocan, B.C.
	Galena, zinc blende, pyrite, and pyrrhotite in varying proportions, replacing crystalline limestone along a zone of shearing................	Kootenay lake, B.C.
	Native silver, argentite, pyrargyrite, argentiferous galena, pyrite, copper minerals, etc., in quartz fissure veins cutting porphyrites............	Windy Arm, Y.T.
Iron......	Vein-like bodies largely of hematite with some magnetite cutting pre-Cambrian quartzites....	Kitchener, B.C.
	Magnetite in a gangue of calcite, feldspar, and epidote in veins traversing a plutonic rock....	Cherry bluff, Kamloops lake, B.C.
	Magnetite in places with copper and iron sulphides in irregular vein-like bodies, replacing country rock, usually limestone, and commonly along contact with intrusive granites...............	Texada island, B.C.
Coal......	Anthracite, in Kootanie formation (lower Cretaceous)..	Bankhead, Alta.
	Bituminous coal in Kootanie formation........	Fernie, Blairmore, Frank.
	Bituminous coal approaching lignite, in Belly River formation (upper Cretaceous), and in Edmonton formation (Tertiary)............	Foothills of Rocky mts.
	Bituminous in upper Cretaceous..............	Nanaimo, Comox, Vancouver island.
	Lignite, in Tertiary beds....................	Princeton, Bulkley valley, B.C.; Tantalus, Y.T.

GOLD.

The discovery, between 1855 and 1857, of placer gold on the Fraser, Thompson, and Columbia rivers, and the ensuing rush in 1858, was a primary cause in attracting the attention of the mining world to British Columbia. In 1860 the extraordinarily rich placer deposits of Williams and Lightning creeks in the Cariboo district were discovered, and in 1863, the year of maximum



Fraser River, near Fountain, B.C.



Discovery Dredge, Bonanza Creek, Yukon.

Hydraulicing frozen material on a small scale on Gold Creek, a tributary of Flat Creek, Yukon.

production for this area, nearly $4,000,000 gold was recovered, while up to date the total production has amounted to about $39,000,000.

In 1874, the Cassiar gold field was discovered, and in the first year produced gold to the value of $1,000,000. Some of the other placer gold districts discovered in later years are: Dease lake, Omineca, Atlin in 1897, Big Bend and upper Columbia, Wild Horse creek, Granite creek, and still more recently, Ingenica river, a tributary of the Finlay. In 1907 the total production of placer gold in British Columbia amounted to $828,000, derived, in the main, from the Atlin and Cariboo districts, while the total production of placer gold in British Columbia from 1858 to 1907 has been estimated to have amounted to about $70,000,000.

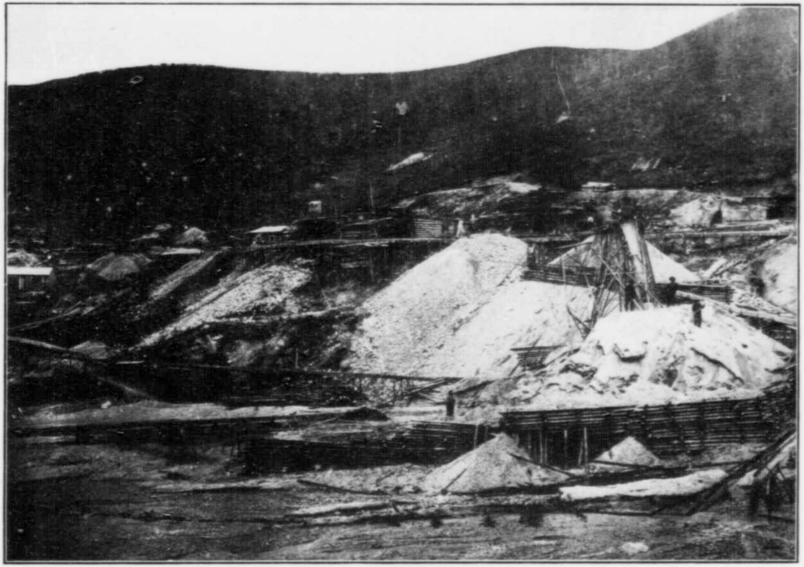
The placer gold deposits of British Columbia, rich as they have proved to be, have been surpassed by those of the Klondike. As early as 1878 miners began to enter the Yukon district, and finds were made in various districts from year to year until, in 1896, the very rich deposits on the Klondike river and tributaries became known, and in 1897 and 1898 there took place a probably unparalleled rush of gold hunters from all parts of the world. In 1900, the year of maximum production, gold reaching the value of $22,275,000 was brought from the Yukon. In 1907, the amount had decreased to $3,150,000. Following the installation of machinery the gold production is again increasing. The total production of the Klondike district up to, and including the year 1908, has been estimated at $225,000,000, and it has been calculated that placer gold to the value of about $60,000,000, and capable of being extracted, still remains.

The Klondike district lies within the unglaciated region of the Yukon, and is part of the upraised, dissected Yukon peneplain. The oldest gravels in the district, the auriferous White Channel gravels, vary in thickness up to about 150 feet. They were deposited at a time when the Klondike river probably flowed in a direction opposite to that now followed. At the close of the White Channel period, the district was depressed and the Klondike then probably broke into its present valley; and, bringing down immense quantities of material, it rapidly built up a wide gravel bed, that rested upon the White Channel gravels, and is still, in places, fully 150 feet thick.

The depression was followed by an uplift of approximately 700 feet, that affected the whole region bordering the Yukon from the Stewart river northward to the Alaska boundary and beyond. The upraising of the district gave new life to the streams, causing them to deepen their channels, usually along the course of the old valleys, until now they have cut through not only the older gravels, but down into bed-rock to a depth of from 150 feet to 300 feet. During the carving of the present valleys, the process was, at times, arrested, and rock benches cut and floored with gold-bearing gravels; in places these are still partially preserved. The more recent lower creek gravels are also auriferous, and it was in them that many of the fabulously rich claims were staked.

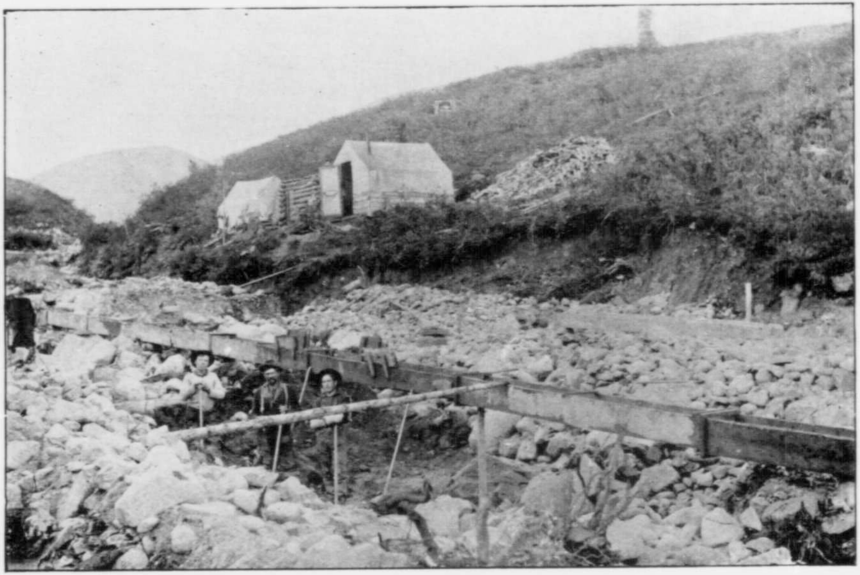
The White Channel gravels, standing at higher levels than the recent stream deposits, are still largely preserved. They are composed chiefly of rounded boulders and pebbles of quartz, embedded in a matrix essentially of sericite scales, and fine, angular quartz grains. The gold they bear, and the quartz they are so largely composed of, were probably all derived from the breaking up of the slightly auriferous quartz veins so abundant in the district. The gravels of the present stream beds, and of the terraces, are largely composed of fragments of schists, etc., derived from the country rocks, while their gold contents have been obtained from the older, White Channel gravels, whose age must date back at least to the Pliocene. The gold in all the gravels is irregularly distributed and often largely concentrated in pay streaks. It always occurs on or near bed-rock, either in the lower five to six feet of gravel, or sunk for some distance in the bed-rock itself. The gold is commonly coarse and the grains quite often angular and sometimes crystalline.

The placer deposits of the Atlin and Cariboo districts are, in a way, analogous to those of the Klondike, since the gold-bearing gravels are of two periods, and the present streams, in general, lie in the broad valleys carved by the older waterways. In both districts the older auriferous gravels are pre-glacial in age and are sometimes heavily buried by glacial drift. The gold contents of the younger, post-glacial deposits seem to have been derived from the older gravels. Gold-bearing quartz veins occur in both districts, thus furnishing a possible explanation of the origin of the placer gold. Other placer districts continue to furnish a small supply of gold, and new diggings will no doubt from time to time be discovered, especially in old pre-glacial valleys.



Typical hillside diggings on Trail Gulch, a tributary of Bonanza Creek, Yukon.

Open-cutting on Eldorado Creek, a tributary of Bonanza Creek, Yukon.



Gold fields, Atlin, B.C.: Claim 2 and 3 below Discovery.

Gold fields, Atlin, B.C.: Claim 37 above Discovery.

Gold fields, Atlin, B.C.: Claim 93 below Discovery, Spruce creek.

Though the bulk of the gold obtained in the Cordilleran region has been derived from the placer deposits of the central portion of the region, from the Klondike in the north almost to the International Boundary in the south, yet a large amount, reaching $4,000,000 annually since 1900, is obtained by lode mining, largely of the gold-copper ores of Rossland and the Boundary district. Various essentially gold-bearing properties, however, occur at many points. Near Nelson, to the west and south of the city, are quartz veins carrying pyrite, chalcopyrite, galena and blende, with gold both free and combined. Similar veins occur in the Salmon River country, but there, also, hold tungsten-bearing minerals.

In the Boundary district gold-bearing veins lie on the outskirts of the low grade, gold-copper deposits, and also between such areas. The veins vary in width up to 10 or 12 feet. The gangue is largely quartz, with calcite and, more rarely, siderite. With these usually occur small quantities of metallic minerals such as chalcopyrite, pyrite, galena, tetrahedrite, rarely argentite, silver, and gold.

The Nickel Plate and Sunnyside gold mines of Hedley are notable, since the deposits consist so largely of mispickel, with which the gold is always associated. Various sediments, limestones, etc., probably of Carboniferous age, form the country rock, and are cut by dikes, and more particularly by igneous bodies of dioritic affinities lying sheet-like and parallel, or approximately parallel, with the bedding planes of the sediments. The ore occurs along the contact of the igneous bodies and the sediments, the latter being highly altered and yielding a gangue largely of garnet, epidote, calcite, etc., in which occurs the mispickel, with varying amounts of iron and copper sulphides, pyrrhotite, hematite, etc. In places the pay ore is as much as 80 feet wide, fading away into country rock on one side, but sharply defined against a dike on the other.

In the Lardeau district are many deposits, with principally lead and silver values, but some are high in gold. One lead, on the Eva group of claims, was first located as a silver-lead property, but afterwards was found to carry high gold values. The deposit consists of two veins lying along nearly perpendicular and parallel fault planes, cutting a band of carbonaceous phyllite belonging to a series of highly altered sediments of Palæozoic or possibly older age. The main veins are connected by numerous cross veins and stringers. The gangue is largely of quartz, with calcite, feldspar, siderite, and sericite, that in places form practically the whole vein, or else carry some pyrite, a little galena and zinc blende, and fine gold in places lying vein-like in the quartz along the margin of the vein. The high grade ore is usually found at the junction of the main veins with laterals.

At the Silver Cup, in the Lardeau district, the deposit also consists of two parallel veins with numerous connecting leads lying in a carbonaceous phyllite, but the gangue is largely quartz carrying argentiferous tetrahedrite, often in considerable masses and still present at a depth of 600 feet. Galena, zinc blende, and some copper and iron pyrites accompany the tetrahedrite. Besides silver and lead, the higher grade ores carry gold to the amount of $12 per ton. The ore is largely localized in lenticular shoots, some of large size, and they frequently occur at the junction of the main and cross veins.

Veins with gold contents occur in the Poplar Creek district. On one property in schistose diabase more or less impregnated with pyrite, there outcrops an almost perpendicular quartz vein, 2 to 5 feet wide, carrying arsenopyrite, galena, pyrite, and free gold, both visible and invisible. The gold forms masses, fibres, and plates, both in the country rocks, the sulphides, and the gangue.

PLATINUM (GOLD).

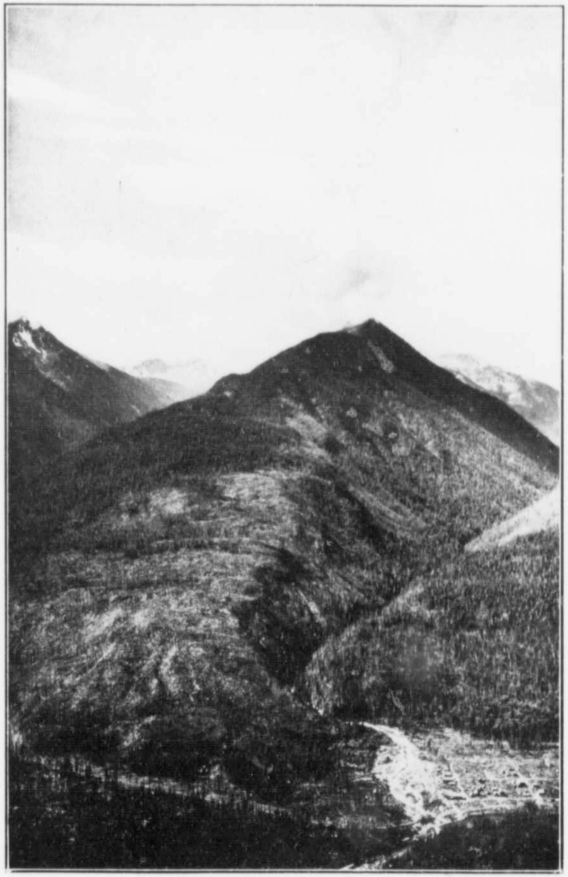
Platinum occurs with gold in many of the placer deposits of the Cordilleran region, as in the Klondike district, and on the Tulameen river, in southern British Columbia.

MERCURY.

Cinnabar has been found in irregular veins of calcite and quartz, traversing Tertiary volcanics and impregnating sandstone, on Copper creek, flowing into Kamloops lake.

COPPER.

The production of copper in 1907, in the Cordilleran region, amounted to nearly 41,000,000 pounds, of which the Bound-



Poplar Bluff, town of Poplar, Poplar Creek valley (a transverse valley) and Lardeau valley.

ary district furnished about three-quarters. The mines of Rossland accounted for about one-eighth of the total product, while the bulk of the remaining eighth came from Vancouver island. In almost all the districts it is the associated gold, and, to a lesser extent, silver values that allow of the profitable working of the deposits. Besides the copper deposits mentioned in the following paragraphs, many others are known, and not a few are being worked or developed in the southern portion of British Columbia, along the Pacific coast, in the Skeena River district, on the Queen Charlotte islands, and near Whitehorse, Yukon Territory. Most of the deposits of commercial importance are of the contact metamorphic type, formed in the older rocks near the contact of an intrusive body by the gases and mineralizers given off during the formation of the igneous rocks.

In the Boundary district it was not until 1891 that the first of the distinctive ore bodies was located, though previously several less characteristic properties had been found. The deposits, which are of the contact metamorphic type, occur within a series of Palæozoic sediments cut by dikes and comparatively small bodies of syenite of Tertiary age, and near a batholite of granodiorite. The ore bodies are mainly confined to beds of limestone and tuff, that in the mineralized areas are largely changed to aggregates of garnet, hornblende, calcite, and quartz. The ores consist of magnetite, chalcopyrite, pyrrhotite, and small quantities of pyrite and hematite. They are associated with the secondary rock minerals and occur in fissured zones, replacing the country rock.

The ore bodies as a rule have no well defined walls, but instead, gradually give way to country rock. They are of all sizes and in certain cases have exceptionally great dimensions. In the larger bodies, magnetite is not evenly distributed, but segregated, though in the case of the Emma mine, the deposit from the surface to the greatest depth yet obtained, about 250 feet, has proved to be practically a continuous body of magnetite, but carrying low copper and gold values. In the more typical mines, the distribution of the various ore minerals, in bands or masses in which one or more of the minerals largely predominates, gives rise to magnetitic ore, calcareous ore, and siliceous ore, that are mixed in suitable proportions to form a self-fluxing ore for smelting. As a rule, magnetite and pyrrhotite are not both abundant at the same time. The chalcopyrite is usually disseminated in points and small stringers, but also occurs in masses of considerable size. In 1908, the average values contained in the 858,432 tons of ore produced by the Granby company were: copper, 1·171 per cent; gold, 0·0503 ozs., and silver, 0·2865 ozs., per ton.

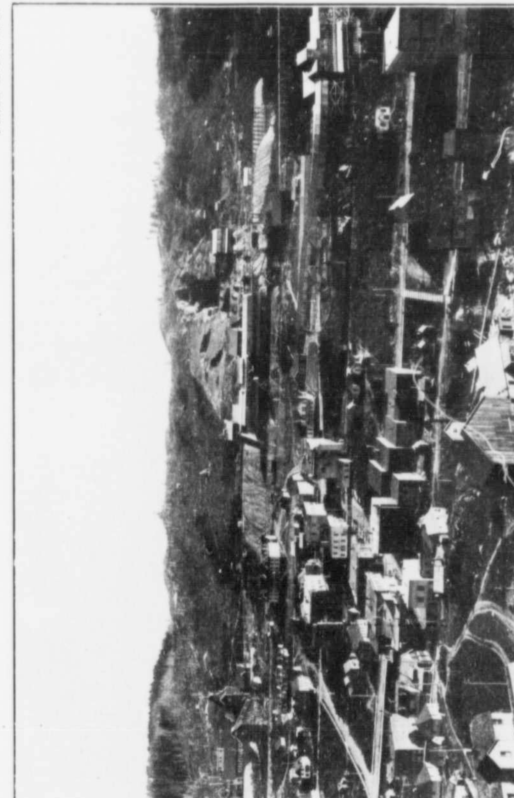
The Boundary deposits are generally characterized by their lack of secondary concentration. In places, however, as at the head of Copper creek, oxidation and secondary concentration have taken place, and at the surface, hematite and limonite occur with malachite, azurite, cuprite, native copper, etc., while deeper down and within masses, appear chalcopyrite and bornite, and below these the unoxidized deposits.

The main mines of the Rossland camp, which during its comparatively short active history of about fifteen years has produced about $40,000,000, are situated near the contact of a body of monzonite and a wide band of augite porphyrite intruded into a group of Carboniferous sediments. The deposits of the Le Roi, and War Eagle, lie within the augite porphyrite body. The main ores consist of pyrrhotite and chalcopyrite, with small quantities of pyrite and arsenopyrite, and occasionally a little magnetite. Free gold occurs and may constitute as much as fifty per cent of the total gold value.

Typical ore consists of country rock more or less altered, containing secondary biotite, etc., with quartz and, in some places, calcite, and cut by reticulating veins, irregular masses and impregnations of the sulphides. There are transitions from typical ore to solid sulphides, or to rock matter, or to gangue with little apparent mineralization but carrying values. In the early days the ore averaged 3 per cent copper, 1½ ozs. of gold, and 2 ozs. of silver per ton; but now the values on an average range from 0·7 per cent to 3·6 per cent copper, 0·4 oz. to 1·2 ozs. of gold, and 0·3 oz. to 2·3 ozs. of silver per ton.

The ore occurs in (1) fissure veins without any accompanying replacement of the country rock; (2) in zones of shearing in which the ore occurs in a network of veinlets eating into and replacing the country rock; (3) in irregular impregnations of the country rock. The last class is the least important. The transition from pay ore to waste is usually rapid, and pay ore is generally localized in shoots varying in width up to, in exceptional cases,

PLATE LXXVIII.



Phoenix, B.C., showing position of Granby mine.

130 feet, and in length from 50 feet to 500 feet or more, while on an average, the vertical dimension is the greatest.

At Copper mountain, not far from Princeton, two classes of gold-bearing copper deposits occur. The mountain is part of a batholitic body of a general monzonitic character, intruding and altering a series of sediments probably of Carboniferous age. One class of deposits occurs at or near the contact of the monzonite, principally with limestone beds. Along the contact both the sedimentary and igneous rocks are traversed by a host of fracture planes, that, away from the contact, are filled with calcite, but near it, are occupied by chalcopyrite, pyrite, pyrrhotite, bornite, and a little calcite.

In the case of the second class of deposits of this locality the ore occurs along zones of fracturing, both in the igneous body and in the sediments. In these zones, the country rock is often brecciated and re-cemented by calcite, or is traversed by a network of calcite veins, sometimes individual veins measuring two feet across, but more generally only an inch or two. The veins, besides calcite, carry pyrite, chalcopyrite, mispickel and magnetite, and sometimes the magnetite entirely replaces the calcite and then forms the gangue of the vein.

A noted copper deposit is that of the Britannia mine situated on the east side of Howe sound on the Pacific coast. The immediate district is occupied by highly disturbed and metamorphosed sediments, possibly of Palæozoic age, with intercalated sills and masses of porphyrites and porphyries, intruded by bodies of granite, etc., belonging to the immense Coast Range batholite. The deposits occur in a quartz sericite schist, in part, at least, derived from carbonaceous slates, while in other places it may represent some of the intercalated intrusives. The ores occur in a mineralized zone that is at least four miles long, and towards its central portion has a variable width of from 300 feet to 600 feet.

The iron and copper sulphides of the ore bodies, with at least part of the quartz, appear to have been deposited during the development of the schistose structure in the quartz schist, during an interval following the period of the granitic intrusions. At a later date, concentration took place in parts of the zone, and lenses of chalcopyrite with quartz were formed in a parallel arrangement along the strike of the schist The lenses range in width from an inch to several feet. The ore consists of finely disseminated pyrite, chalcopyrite in small masses and lenses, and a little galena and zinc blende. At the surface small amounts of secondary bornite and covellite occur. The ore is essentially low grade, but besides copper carries several dollars gold and silver to the ton.

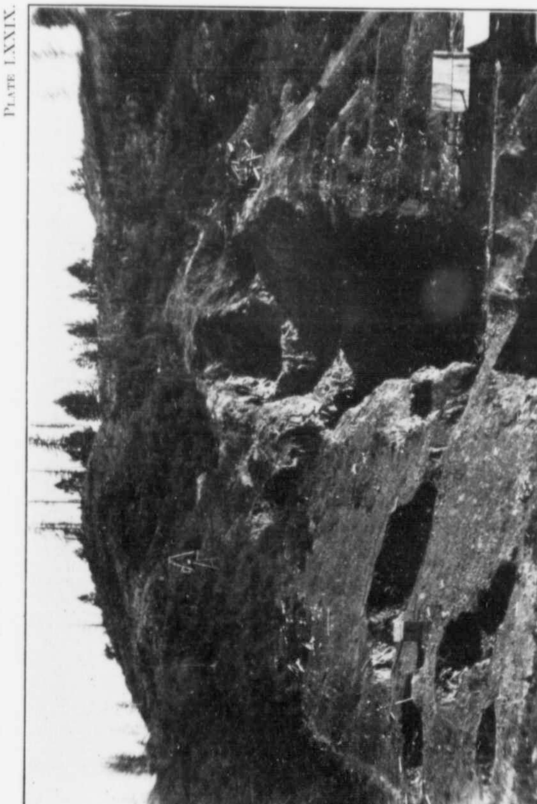
Many copper deposits are known at various places on Vancouver island. The most noted is that of the Tyee mine now largely worked out. The country rock is a schist representing a metamorphosed sediment possibly of Mesozoic age. The deposits occurred in flattened lenses following the strike of the foliation of the enclosing schists. The ore bodies appear to have been greatly elongated; one had a maximum width of 50 feet of clean ore, and a mean width of 20 feet for a depth of at least 150 feet. The ore consisted of chalcopyrite, pyrite, galena, and zinc blende, in a gangue of barite with some quartz and calcite. In the case of about 220,000 tons of ore, the average contents were: 4·5 per cent copper, 7 per cent zinc, and 3 ozs. of silver, and 0·14 oz. of gold per ton.

Other copper deposits occur on Vancouver island, such as those on Sooke inlet. There the ore occurs along zones of shearing within a gneissic diorite. In the case of one such zone, having a width of 200 feet and traceable for at least 4,000 feet, the country rock is traversed by innumerable quartz stringers with sulphides of iron and copper, usually in small patches, but occasionally in small veins and lenses.

Another class of copper deposits found on Vancouver island is such as that occurring at Mount Malahat, where sulphides of iron and copper, with considerable magnetite, occur with various contact minerals in limestone near the contact of dikes and bodies of granitic rocks. Similar deposits occur on Texada island, and are described under the heading of iron.

Near Van-Anda, on Texada island, there are considerable copper deposits, such as that of the Marble Bay mine. At this mine the ore body lies in a zone of brecciation in crystalline and semi-crystalline limestone. From the surface to the 260 foot level, the ore occurs in subordinate shoots, but from that level down to the 771 foot level it forms a continuous body, varying in length from 70 feet to 205 feet, and in width from 5 feet to 45 feet.

PLATE LXXIX.



Open cut, Granby mine, Phoenix, B.C.

Plate LXXX.

Granby mine, Phoenix, B.C.: stope showing pillars of ore.

The ore is bornite with subordinate chalcopyrite and a little pyrite, pyrrhotite, molybdenite enclosed in a gangue of pyroxene, garnet, and calcite. The ore is finely disseminated through the pyroxene or occurs in rather large, pure masses with calcite. The deposit is believed to be of pneumatolytic origin, and probably formed during the period of intrusion of the Coast Range batholite. The ore is high grade, the shipping ores averaging 8 per cent copper and $10 gold per ton.

SILVER-LEAD.

Since silver and lead, as found in the Cordilleran region, are usually closely associated with one another, it has seemed best to combine the descriptions of the deposits of these two metals. The same deposits also have afforded a certain amount of zinc, the amount produced varying with market conditions. Almost all the silver and lead produced in the Cordilleran region comes from southern British Columbia, mainly from the southeastern part of the Province. In 1907 the total production of lead in British Columbia was 47,738,703 pounds, and above three-quarters of this amount came from the Fort Steele district, in East Kootenay. In the same year the amount of silver recovered in British Columbia was 2,745,448 ounces.

By far the largest single producer of lead is the St. Eugene mine, discovered in 1895 near Moyie. The ore bodies lie in a nearly vertical fissure zone, outcropping for a vertical distance of above 2,000 feet on the side of a steep hill. The country rock is a quartzite of Cambrian or pre-Cambrian age. The fissure zone consists of two main, roughly parallel, fissures, two to three hundred feet apart and connected by cross veins. The ore consists chiefly of argentiferous galena with some zinc blende and a little pyrite. During a considerable period of time the ore averaged about 18 per cent lead and carried about 6 ounces of silver. The gangue is usually country rock with some quartz.

The ore bodies are irregular in distribution and shape, but have a general lenticular habit. They lie along the courses of the main and cross veins, and more particularly at the junction of the two sets, where masses of ore up to 60 feet in width occur. In one instance solid ore continued along a drift for a length of 1,000 feet. In height some of the lense-like bodies reach 50 feet to 150 feet.

In the same district the North Star mine, near Kimberley, is of an unusual type. The country rock is an altered, feldspathic sandstone, and the contact of rock and ore bodies is generally sharp. The ore consists of nearly pure argentiferous galena associated with some lead carbonates. The ore bodies lie close to the surface, being merely covered by drift; in form they are basin-shaped, nearly flat-lying, and are of considerable size, one having measured 400 feet in length, 70 feet in width, and 50 feet in depth.

Many silver-lead deposits have been found in the region between Kootenay and Arrow lakes. The deposits occur in fissure veins having gangues of quartz, calcite, and siderite. The ores consist of argentiferous galena, blende, argentiferous tetrahedrite, copper, and iron pyrites, arsenopyrites, argentite, native silver, and gold. The pay ores are generally localized in chutes, and are often concentrated around inclusions of carbonaceous country rock or along the wall-rock, and sometimes in it. The larger ore bodies are generally situated at points of intersection of veins.

The Slocan Star, near Sandon, is a mine of the above class. The deposit occurs along a vein varying in width from 4 to 40 feet and cutting slates. The vein dips at moderately high angles, and the gangue is mainly of quartz, siderite, and calcite with a little barite. The ore is largely galena, with considerable zinc blende and a little tetrahedrite; all these carry silver, and picked specimens of tetrahedrite have been said to carry silver at the rate of several thousand ounces to the ton.

On the east shore of Kootenay lake, opposite Ainsworth, are examples of silver-lead deposits in limestone. The country rocks are various gneisses, quartzites, and crystalline limestones, apparently flat-lying at this locality. They have been classed with the Shuswap group. The ores occur replacing the limestone along certain beds or bands within a zone of shearing some 800 feet wide. The ores consist of pyrite, pyrrhotite, blende, and galena, forming bodies of considerable size, in which sometimes the iron sulphides, sometimes the lead and zinc minerals predominate. The ores are silver-bearing, and sometimes the zinc content is high.

Rich silver-bearing veins occur in the Yukon Territory, on the shores of Windy Arm, Lake Tagish. The veins occupy fissures usually lying in basic porphyrites. They generally are comparatively narrow, though sometimes they attain widths of 8 or 10 feet. They are fairly persistent along the strike, one having been traced for over 1,500 feet. The gangue is largely quartz, containing, besides native silver, a variety of silver-bearing minerals such as argentite, stephanite, and pyrargyrite, all of which are generally present. Pyrite and argentiferous galena always occur in the veins, generally accompanied by small quantities of zinc blende. Various copper minerals are also associated with the above minerals.

IRON.

Though large bodies of iron ore are known at various points in the Cordilleran region, they have, on the whole, been left unworked. Considerable deposits of iron ore in the form of vein-like bodies lying in quartzite have been described from near Kitchener, some twenty miles east of Kootenay lake. The deposits consist of very pure ores, largely hematite, with some magnetite, and vary in width from 5 to 20 feet. They lie parallel with one another in nearly vertical positions, and outcrop at intervals for several miles along a comparatively narrow zone.

A deposit at Cherry bluff, on the south shore of Kamloops lake, at one time produced a considerable amount of iron ore. The deposit consists of magnetite in a gangue of calcite, feldspar and epidote, occurring veinlike, with distinct walls and traversing a plutonic rock.

Considerable deposits of magnetite occur on Texada island and from them some 20,000 tons have been mined. The ore bodies vary in shape from rounded, irregular or lense-shaped masses, to long, vein-like bodies evidently deposited along a zone of shearing. The deposits occur along the contact of limestone with granite or porphyrites, or, apparently isolated, within any one of these three classes of rock. It is believed by some, that in all cases the ore bodies were formed as replacements of limestone, and where the deposits now appear entirely separated from any limestone that the limestone was originally present, and was either completely replaced by the ore or else the remaining portions swept away by erosion. At one locality, a series of lense-like bodies rather closely follows the winding contact of limestone and igneous rocks for a distance of about two miles. Some of the bodies are over 200 feet in length.

The ore is a coarse, crystalline magnetite, locally impure from impregnations of copper and iron sulphides. Some of the ores have carried as high as 3 per cent copper. Quartz, actinolite, calcite, epidote, and garnet are present in small amounts in parts of the ore bodies.

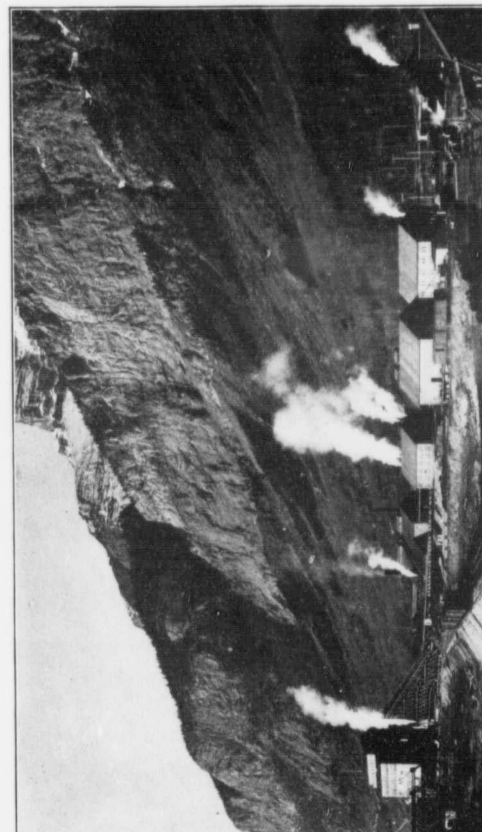
COAL.

The coal produced in the Cordilleran region is almost entirely bituminous, and by far the greater part is of Cretaceous age. Coals of Tertiary age are known at a number of localities, as in the Nicola valley and near Princeton. The Tertiary coals are lignites, and sometimes form thick seams, as in the case of the Princeton area, where an 18 foot seam outcrops on the banks of the Similkameen river. The total coal produced in 1907 was in the neighbourhood of 3,000,000 tons. Though Cretaceous coals occur in the Yukon, on some of the islands of the Queen Charlotte group, within the basin of the Skeena river, and elsewhere, the main development of coal mining has, as yet, taken place on Vancouver island, and within the Rocky mountains and the foothill districts to the east.

On Vancouver island, the coal seams occur in the upper part of the Cretaceous. Coal mining is concentrated in two areas on the east coast of the island, known as the Comox, and the Nanaimo coal fields. The Comox field has an estimated area of about 300 square miles. At one mine, within a vertical section of 122 feet, there are ten seams, with an aggregate thickness of about 29 feet, the thickest seam measuring 10 feet. In the Nanaimo field, two seams, one varying in thickness from 5 feet to 20 feet, and the other from 3 feet to 5 feet, are being mined. The coals are all bituminous.

In the Rocky mountains and the foothills, the Cretaceous coal measures occur as basins amongst the folded and faulted Palæozoic and Mesozoic strata. The basins, generally stretching northwestward and southeastward, and sometimes for very long distances, are known to occur at intervals from the International Boundary to the Athabaska river, a distance of over 200 miles. The coals within the Rocky mountains are bituminous varieties, in places passing into anthracite, as at the Bankhead and Anthracite mines in the Bow valley. Eastwards, in the foothills, as the plains are approached and the regions of disturbance left

PLATE LXXXI.



Bankhead colliery, Alberta.

behind, the lignite coals of the higher members of the Cretaceous are gradually encountered.

Within the mountains and the adjacent foothills, there are three coal horizons. The lowest occurs within the Kootenay formation belonging to the base of the Cretaceous, possibly the summit of the Jurassic. The seams of the Elk River and Crowsnest basins lie within this horizon. The next group of productive measures is the Belly river, situated towards the top of the upper Cretaceous column. The highest group of coal measures lies in the Edmonton of early Tertiary age.

Some of the major coal basins, commencing with the more southerly, are as follows. The southern Elk River basin, with an area of about 300 square miles, and containing the mines at

PLATE LXXXII.

Coke Ovens, Fernie, B.C.

Fernie and Michel. In this basin there are at least twenty-two workable coal seams, having an aggregate thickness of 216 feet, all lying within the Kootenay formation. The northern portion of the Elk River basin, separated from the southern division by a short gap, has approximately the same area and extends as a narrow band far to the north.

A short distance east of the Elk River basin lies a series of narrow basins known collectively as the Crowsnest basin, which, with certain breaks, extend far to the north to join the Cascade basin that runs north of the Bow river. The Crowsnest and Cascade basins lie in the Kootenay horizon, and in the south include the mines at Blairmore and Frank. In the southern basin twenty-one workable seams occur, with a total thickness of 125 feet of coal.

The Cascade basin, crossing the Bow river at Banff, contains the Bankhead mine, at present the only anthracite producing mine in Canada. In the vicinity of Bow river, the Kootenay measures of the basin contain ten to fourteen workable seams, with from 75 to 100 feet of coal. Northward are other basins. On the Red Deer river, the Kootenay measures hold at least fifteen workable coal seams. with a combined thickness of 114 feet. Other coal basins of Kootenay age lie still farther north, continuing at least as far as the Brazeau river and perhaps farther.

Within the foothills, to the east of the Rocky mountains proper, the Kootenay beds sometimes outcrop, as in the Moose Mountain area. The main basins there, however, lie in the Belly River, that outcrops over bands sometimes hundreds of miles long.

BUILDING AND ORNAMENTAL STONES, ETC.

Excellent building stones of various kinds are found throughout the Cordilleran region. Marble of a high quality is quarried near Lardo, also on the Pacific coast.

CHAPTER VIII.

THE GLACIAL PERIOD IN CANADA.

Preceding the glacial period, Canada, as a whole, had long been uplifted and subjected to erosion. The deep, submerged, seaward continuations of many of the larger drainage channels has been held to show that during parts of Tertiary times the continent had been elevated several thousand feet or more above the sea. Possibly, however, the formation of these, now drowned valleys, may have been due to other causes than the uplift of the continent as a whole.

Before the beginning of the glacial period the long continued Tertiary erosion had produced the main land features of the present day. But the crust of the earth, then as now, was subjected to differential movements, resulting in the warping of large areas. It was by movements such as these, guiding and controlling the ancient drainage, that the depressions now occupied by the Great lakes are believed to have formed.

During the glacial period nearly one-half of the North American continent was, at one time or another, buried in ice that virtually occupied the whole of the Canadian portion of the continental land, and, in the region of the great lakes, extended into the United States to about the 37th parallel, an area in all of above 4,000,000 square miles. The Arctic islands, however, during this period do not appear to have supported glaciers any larger or more important than the local ones at present occurring on portions of Baffin and Ellesmere islands. Nor was the Klondike region, in the Yukon Territory, glaciated, and the same is true of the larger part of Alaska, save about the mountains.

During the glacial period there appears to have been at least three great centres of glacial radiation—the Labradorean, on the Hudson Bay side of the centre of the Ungava peninsula; the Keewatin, occupying a corresponding position to the northwest of Hudson bay; and the Cordilleran, lying within the mountain system of the west. From these three centres, as indicated by the glacially transported material and the markings on the often polished and grooved rock surfaces, the ice sheets moved outwards in all directions, scouring from the surface of the country its disintegrated material, and wearing down the exposed rock surfaces. But, though the general movement was always outwards from the glacial centres, locally it was often guided by outstanding physical features, excepting, perhaps, during the periods of greatest ice development. Whether all these glacial sheets were contemporaneous is, perhaps, not definitely determined, but it at least is certain that they reached their maximum development at different times. Thus there is evidence to show that the Keewatin glacier once occupied territory afterwards covered by the Labradorean, and that the ice tongues from the Cordilleran had retreated from the plains before the Keewatin glacier reached the foothills.

The results of glacial action in Canada are everywhere shown by the presence of boulder clay, moraines, eskers, etc. These deposits, though frequently containing material drawn from far distant sources, are often largely of local composition. In the southeastern portion of Canada, where the relief of the country is low, and the energy of the glaciers was taxed with its load of debris, the evidence goes to show that the erosive power of the glacial sheets was largely confined to the removal and redistribution of the previously existing soil, and the outer, more weathered portions of the rock surfaces. In the mountainous districts of the west, on the other hand, the destructive action of the glacial ice appears to have been incomparably greater. There the presence of "hanging valleys" indicates that the ice sheets wore down many of the main valleys for depths of many hundreds of feet. In the more northerly portions of eastern Canada, where the energy of the ice sheets would be greater than in the south, erosion is also likely to have been important.

The glacial epoch did not consist of one general advance, followed by a simple retreat and disappearance of the ice sheet. Instead, there appears to have been a number of invasions separated by considerable intervals, and as many as six such invasions have been recognized. The evidence of these distinct invasions is furnished by the unconformable superposition of sheets of drift on one another, by the effects of weathering visible on the tops of different layers, and by the presence, between till-sheets, of

soil, sand, gravel, etc., containing plant remains. In some cases the plant remains of the interglacial deposits, such as those near Toronto, indicate that during the interval the climate of the region was milder than that of the present day, and this has led to the conclusion that during some of the interglacial intervals the ice sheet may have largely or completely disappeared.

Though the whole of eastern Canada seems to have been buried beneath ice sheets, it is not certain that the Labradorean glacier ever occupied the whole of the country east of the St. Lawrence. The evidence, indeed, seems to indicate that parts of eastern Quebec and the Maritime provinces were occupied by distinct glacial sheets extending from one or more local centres.

The results of the action of the ice of the glacial period in many ways profoundly modified the pre-existing drainage features. Great deposits of glacial debris in many instances filled up the older drainage courses, ponded back the waters, and caused the development of new water courses and the formation of lakes. In many districts a mature drainage system was partly or largely changed to a juvenile one, now expressed by lakes, rapids, and falls.

Preceding, or during the glacial epoch, there seems to have occurred a widespread, downward warping of the northern country of central and eastern Canada. The older, general southward slope of the land was changed to a northward one. Consequently, as the margin of the last ice sheet retreated northward, it acted as a dam on the northward sloping country, impounding the waters with the consequent temporary formation of large and small lakes, in which were sometimes formed thick, lacustrine deposits. Some of the glacial lakes were very extensive. Such a one was Lake Agassiz, occupying the low plain of Manitoba, east of the Manitoba escarpment and extending southward into the United States, with a maximum area in the neighbourhood of 100,000 square miles.

A long succession of glacial lakes formed in the Great Lakes region, at first draining southward, but gradually finding lower and lower outlets to the eastward along the northward retreating ice front. Finally the ice retreated so far as to allow of the advance of the sea up the St. Lawrence valley, at least as far as the foot of Lake Ontario, and up the Ottawa valley some distance beyond Ottawa. During the submergence beds were deposited containing marine shells, etc., and similar deposits have been found in the low country south of James bay, and in the Maritime provinces, all pointing to the once lower level of the land.

With the final disappearance of the continental ice sheet, a general upward movement of the north country was inaugurated, and now the marine beds, in places, are found at elevations of over 500 feet. The upward rise is also indicated by the tilted position of the older beaches and wave-cut terraces of the glacial lakes, once horizontal, but now rising to the north along increasing gradients. The eastern country thus appears, in general, to be re-assuming an earlier condition when the main drainage of Canada was southward.

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CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH.

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

PUBLICATIONS

OF

SPECIAL ECONOMIC INTEREST.

Since 1842, a large number of reports, monographs, bulletins, etc., descriptive of the mineral resources of Canada, have been published by the Geological Survey. Among these are bulletins describing the occurrence in various parts of the country of minerals of economic interest.

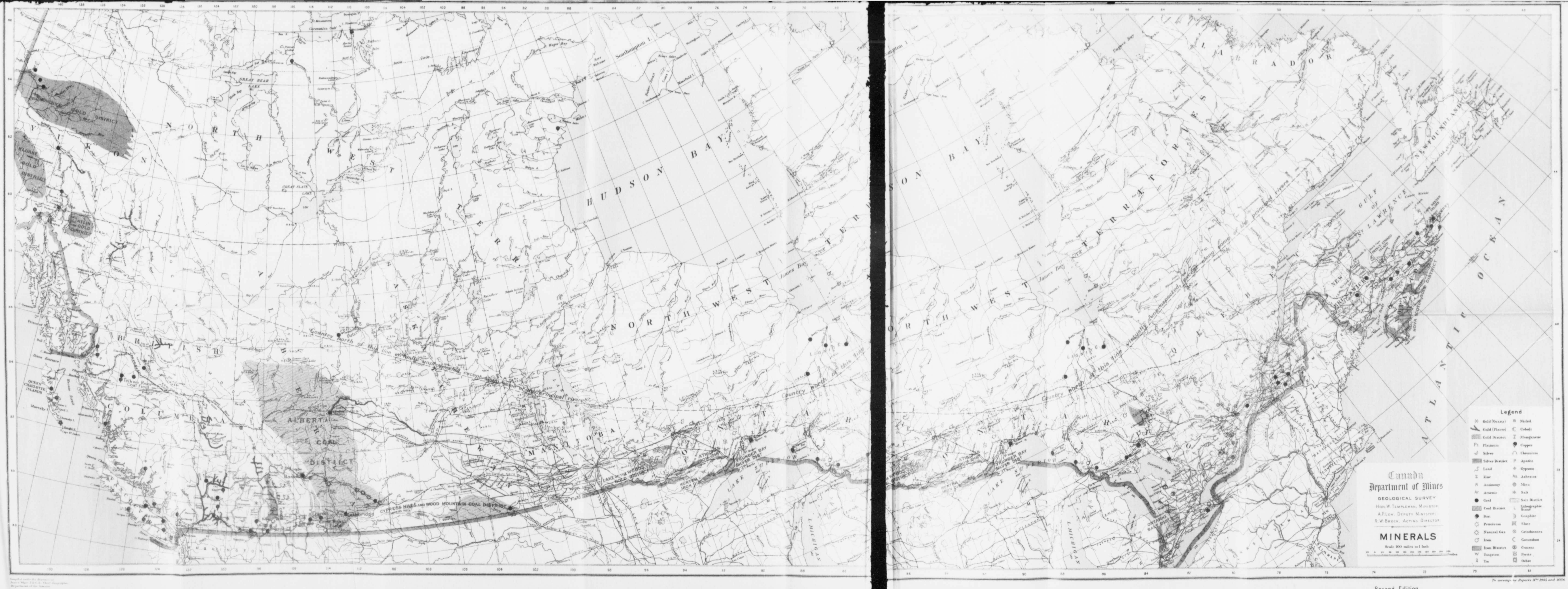
In addition to these special bulletins, comprehensive reports dealing with the general geology, mineralogy, palæontology, zoology, botany, ethnology, archæology, etc., of the respective Provinces, and of individual mining camps, have been issued: most of which are well illustrated, and accompanied by coloured maps.

A new Catalogue (pp. 181) of the Geological Survey publications is now ready for distribution; and this catalogue, together with individual maps, or reports, will be furnished free to *bona fide* Canadian inquirers, and to others at prices generally less than the cost of printing, upon application to the

DIRECTOR, GEOLOGICAL SURVEY,

DEPARTMENT OF MINES,

OTTAWA.


HUDSON BAY
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YUKON
BRITISH COLUMBIA
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QUEBEC
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NEWFOUNDLAND
GULF OF ST. LAWRENCE
ATLANTIC OCEAN
CYPRESS HILLS AND WOOD MOUNTAIN COAL DISTRICT
Canada
Department of Mines
GEOLOGICAL SURVEY
Hon. W. Templeman, Minister;
A.P. Low, Deputy Minister;
R.W. Brock, Acting Director.
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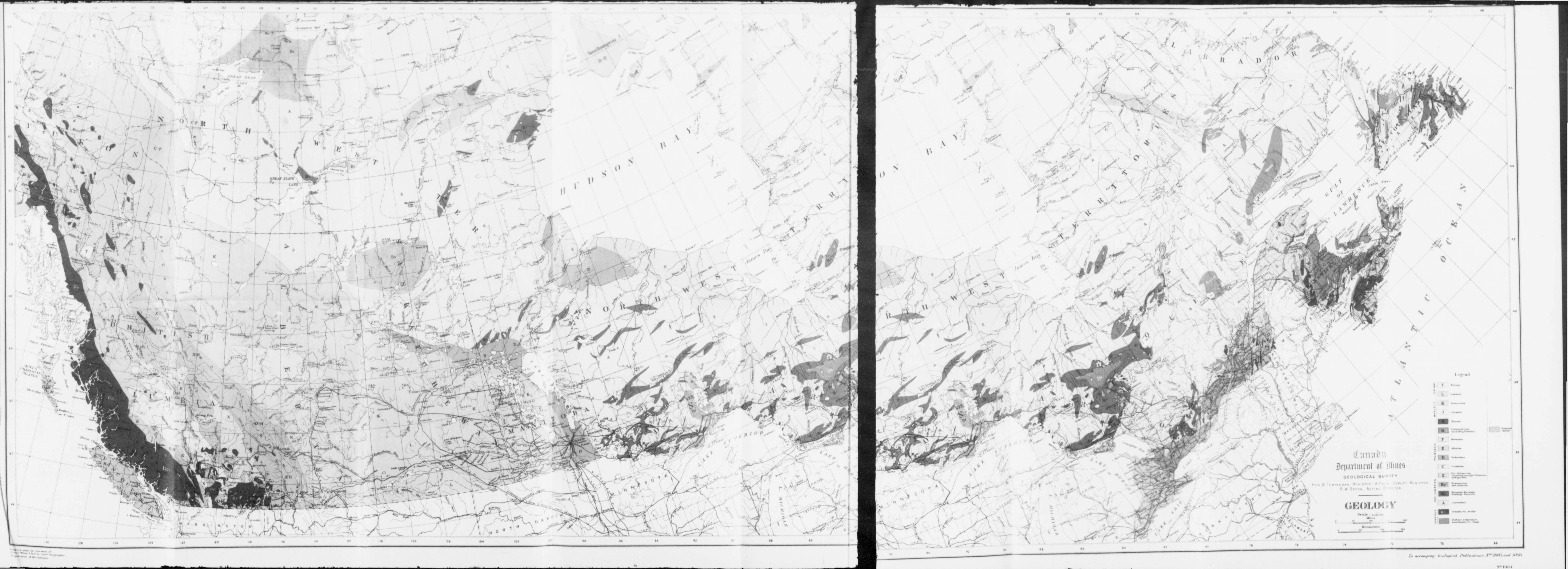
Apatite
Gypsum
Asbestos
Mica
Salt
Salt District
Lithographic Stone
Graphite
Slate
Grindstones
Corundum
Cement
Pyrite
Ochre
To accompany Reports Nos 1085 and 1086
Second Edition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R. W. BROCK, ACTING DIRECTOR.
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LAKE SUPERIOR
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ECONOMIC MINERALS

OF

CANADA

GEOLOGICAL SURVEY,
DEPARTMENT OF MINES
OTTAWA,
1909.

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH.

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

A DESCRIPTIVE SKETCH

OF THE

GEOLOGY, AND ECONOMIC MINERALS

OF

CANADA.

BY

G. A. YOUNG

INTRODUCTION

BY

R. W. BROCK
Director of Geological Survey.

OTTAWA
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1909

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A DESCRIPTIVE SKETCH

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GEOLOGY, AND ECONOMIC MINERALS

OF

CANADA.

PART I.

INTRODUCTION

BY

R. W. Brock.

The present booklet is intended to give a brief account of the general geological conditions in Canada, and of the minerals which, under recent development, have assumed the greatest economic importance.

Excellent sketches covering the subject have been written by Dr. George M. Dawson, late Director of the Geological Survey of Canada; but these are now out of print, and the increasing demand for this general information has rendered necessary a new publication such as this. The present review is largely based on these preceding ones.

In a brief and general statement concerning so wide a subject, and covering so vast a territory, much that is interesting and important must of necessity be passed without notice; and the broad generalizations cannot be expected to present with absolute fidelity the actual facts. What has been attempted is, to give merely a general idea of the conditions obtaining in the various geological provinces into which the Dominion of Canada is naturally subdivided, together with the more important minerals which are characteristic of, or which have been exploited in each.

GEOLOGICAL INVESTIGATIONS.

The geological investigation of Canada may be said to have commenced in 1843, with the organization of the Geological

Survey of Canada, under Sir William Logan. The classical work of Logan, and his little coterie of assistants, Murray, Hunt, Billings, &c., was summarized in the Geology of Canada published in 1863, which deals with the southern portions of the Provinces of Ontario and Quebec. Since this was written the work of the Geological Survey has gradually widened, until, as at present, it embraces the northern half of the continent of North America. Much of this work has been exploratory. The great field to be covered with a small force has prevented concentration of effort, and in no single district can it be claimed that the geological problems are completely solved. The natural difficulties of travel in the northland have rendered the progress of even reconnaissance work tedious, and a large part of Canada is still practically unexplored. Nevertheless, sufficient has been done to make known its main geological features; to roughly indicate the territories that will be found to be mineral bearing; to presage the character of its mineral resources in the different geological provinces, and to demonstrate that Canada is destined to become one of the great mining countries of the world.

The reader is referred to the geological map, and to the mineral map for indications of the distribution of the main rock formations of the country, and important occurrences of minerals.

It will be noted on the mineral map, that the greater part of Canada is as yet unprospected. Even the portions of the country represented as being within the prospected territory must not be considered as more than partially explored for minerals. To illustrate the condition with respect to this: six years ago the line representing prospected territory would probably have been placed considerably north of Lake Timiskaming, yet only a few miles west of a silver lead deposit on Lake Timiskaming—that had been known for a century and a half—lay the undiscovered silver veins of Cobalt, recently revealed by constructing a railway through them.

It will, therefore, be readily seen that, the amount of mineral bearing territory still awaiting the prospector is prodigious, the greatest, in fact, that now remains anywhere on the globe.

The mining industries of the country may be said to have only just begun. The reason for this tardiness in developing the mineral resources is probably to be found in Canada's wealth in farming lands. The first settlers, in order to provide food, were forced to become agriculturalists. As population increased, and fertile lands were to be had in plenty, fresh acres were brought under the plough. Naturally, Canada became an agricultural country, and it was the farming lands that were sought after, and that were developed by lines of transportation. The lack of transportation facilities in the mineral bearing areas, and the extent of country in proportion to its population were contributory factors.

In 1886 the mineral production of Canada did not reach $10,250,000 in value, and was only $2.23 per capita. In 1908 the production was over $87,000,000, or $12.57 per capita. Although mining is only in its infancy, it has become one of the leading industries of the country. The output of the mine is now greater than the combined output of forest and sea, and ranks next to agriculture.

The total production of minerals for the last twenty-three years amounts to $926,516,579: of which gold represents $267,700,000.

Though just entering the field, Canada already ranks well among the mineral producing countries. According to the review of the world's production in 1907, Canada ranked first in asbestos and nickel; third in chromite; fourth in silver; seventh in copper; eighth in gold, and tenth in coal. The nature of the product, and the relative importance of the various minerals, is shown in the statement of the annual production for 1908, prepared by Mr. J. McLeish of the Mines Branch, Department of Mines.

ANNUAL PRODUCTION OF MINERALS IN CANADA, 1908.

Product.		Quantity.	Value.
Metallic.			
Copper	Lbs.	64,361,636	$ 8,500,885
Gold			9,559,274
Pig iron from Canadian ore	Tons	99,420	1,664,302
Lead	Lbs.	45,725,886	1,920,487
Nickel	"	19,143,111	8,231,538
Cobalt	"	1,853,286	112,253
Silver	Ozs.	22,070,212	11,667,197
Total value, metallic			41,655,936
Non-Metallic.			
Arsenic	Tons	699	38,054
Asbestos	"	65,534	2,547,507
Asbestos and asbestos sand	"	25,239	25,829
Calcium carbide	"	6,864	417,150
Coal	"	10,904,466	25,567,235
Chromite	"	7,225	82,008
Corundum	"	1,039	100,389
Feldspar	"	7,877	21,099
Graphite	"	251	5,565
Grindstone	"	3,843	45,128
Gypsum	"	340,964	575,701
Limestone for flux in iron furnace	"	418,661	289,705
Magnesite	"	120	840
Mica	"		191,602
Mineral Pigments:—			
Barytes	"	4,091	18,265
Ochres	"	4,746	30,440
Mineral waters			109,391
Natural gas (h)			1,012,060
Petroleum (i)	Bls.	527,987	747,102
Phosphate (apatite)	Tons	1,596	14,794
Pyrites	"	47,336	224,824
Quartz	"	27,134	32,277
Salt	"	79,975	378,798
Talc	"	1,076	3,048
Tripolite	"	36	195
Total value, non-metallic			$32,479,006

STRUCTURAL MATERIAL AND CLAY PRODUCTS.

Product.		Quantity.	Value.
Cement, natural.	Bls.	1,044	$ 815
Cement, Portland.	"	2,665,289	3,709,063
Flagstones.	No.	4,000	3,600
Sand and gravel (exports).	Tons	298,954	161,387
Sewer pipe.			514,042
Clay products, stone, lime, etc. Estimated.			8,500,000
Total structural material products and clay products.			$12,888,907
All other non-metallic.			32,479,006
Total value non-metallic.			45,367,913
Total value metallic.			41,655,936
Estimated value of mineral not reported.			300,000
Total value 1908.			$87,323,849

The geographical distribution is shown by the production of the provinces.

MINERAL PRODUCTION OF BRITISH COLUMBIA, 1907.

Material.		Quantity.	Value.
Gold, placer.	Ozs.	41,450	$ 828,000
Gold, lobe.	"	196,179	4,055,020
Silver.	"	2,745,448	1,703,825
Lead.	Lbs.	47,738,703	2,291,458
Copper.	"	40,832,720	8,166,544
Coal.	Tons, 2,240 lbs.	1,800,067	6,300,235
Coke.	" "	222,913	1,337,478
Other materials.			1,200,000
			$25,882,560

MINERAL PRODUCTION OF ALBERTA, 1907.

Material.	Quantity.
Lignite coal.	639,355 tons
Bituminous coal.	939,295 "
Anthracite coal.	256,115 "
Coal used in coke production	112,887 "
Coke produced.	73,782 "
Briquettes produced.	49,585 "

MINERAL PRODUCTION OF ONTARIO, 1907.

Material.		Quantity.	Value.
Gold	Ozs.	3,810	$ 66,399
Silver	"	10,028,259	6,157,871
Cobalt	Tons.	739	92,751
Nickel	"	10,972	2,271,616
Copper	"	7,303	1,045,511
Iron ore		205,295	482,532
Pig iron		286,216	4,716,857
			$14,833,537
Less value Ontario iron ore (120,177 tons) smelted into pig iron			282,702
Net metallic production			$14,550,835

Non-Metallic.		Quantity.	Value.
Arsenic	Tons.	2,958	$ 40,104
Brick, common	No.	273,882,000	2,109,978
Tile drain	"	15,578,000	250,122
Brick, pressed	"	69,763,423	648,683
" paving	"	3,732,220	73,270
Building and crushed stone			675,000
Calcium carbide	Tons.	2,667	173,763
Cement, Portland	Bl.	1,853,692	2,777,478
" natural rock	"	7,239	5,097
Corundum	Tons.	2,683	242,608
Feldspar		12,328	30,375
Graphite	Tons.	2,000	20,000
Gypsum		10,186	19,652
Iron pyrites		15,755	51,842
Lime	Bu.	2,650,000	418,700
Mica	Tons.	456	82,929
Natural gas			746,499
Peat fuel	Tons.	200	1,040
Petroleum	Imp. gal.	27,621,851	1,049,631
Pottery			54,585
Quartz	Tons.	56,585	124,148
Salt	"	62,806	432,936
Sewer pipe			435,088
Talc	Tons.	1,870	5,010
Non-metallic production			$10,468,538
Add net metallic			14,550,835
Totals			$25,019,373

MINERAL PRODUCTION OF QUEBEC, 1907.

Product.		Quantity.	Value.
Bog iron ore	Tons of 2,000 lbs.	22,681	$ 80,231
Calcined ochre		2,300	29,430
Raw ochre		2,700	5,400
Chrome iron ore		6,407	63,130
Copper ore		29,574	160,455
Asbestos		61,985	2,455,919
Asbestic		29,193	27,293
Mica, trimmed		550,247	199,848
Mica, crude		150	24,030
Phosphate of lime		408	3,410
Prepared graphite		120	5,000
Magnesite		35	....
Slates	Squares	4,336	20,056
Flag stones	Sq. yds.	3,000	2,550
Cement	Bls.	....	640,000
Granite	Cub. yds.	51,873	560,236
Lime	Bu.	556,000	96,000
Bricks		94,000,000	525,000
Tiles and pottery		....	270,000
Limestones	Cub. yds.	97,710	223,580
			$5,391,568

MINERAL PRODUCTION OF NOVA SCOTIA.

(YEAR ENDING SEPT. 30, 1907.)

Material.		Quantity.
Coal	Gross tons.	5,730,660
Pig iron	Gross tons.	293,436
Coke made	Net tons.	493,102
Iron ore	Gross tons.	562,746[1]
Limestone	Net tons.	458,601
Gypsum	Gross tons.	332,345
Gold	Ozs.	15,006
Bricks		25,000,000
Building stones	Net tons.	63,861
Cement	Bls.	58,762
Antimony ore	Net tons.	1,403
Manganese ore	Gross tons.	495[2]
Copper ore	Net tons.	2,471
Drain pipe	Feet.	300,000
Grindstones	Net tons.	350
Copper	Lbs.	12,320
Moulding sand	Net tons.	190

[1] Including imported ore. N.S. ore 48,337 tons.

[2] Imported.

DISTRIBUTION OF THE CHIEF MINERALS.

Coal is abundant and is extensively worked in the eastern and western provinces. The more important mines are situated in Nova Scotia, British Columbia, and Alberta. New Brunswick produces small quantities of coal for local use, and lignites are mined to some extent in Saskatchewan. There is no available coal in Ontario and Quebec, but the abundant waterpowers that may be utilized for electrical energy, together with petroleum and natural gas in Ontario, to a considerable extent compensate for this deficiency.

Iron is found in most parts of Canada; but only in Nova Scotia, Ontario, and Quebec is it as yet of industrial importance, and here, only developed on a limited scale. Substantial progress is, however, being made, and notable expansion is to be expected.

Gold is worked in British Columbia, Yukon Territory, Ontario, Nova Scotia, and Quebec, and certain rivers in Alberta. In British Columbia the lode mines now furnish the principal production; but placers are still of importance. Ontario and Nova Scotia have only lode mining. Elsewhere, placer mining furnishes the gold.

Silver is to be credited to the rich silver ores of northern Ontario, and the silver-lead mines of British Columbia. The phenomenal development of the silver district of Cobalt and Montreal river has placed this region in the premier position among the silver camps of the world. An important addition to the output of silver is contributed by the gold-copper ores of British Columbia. A certain amount is also produced in the copper sulphur ores of Quebec.

Copper is furnished by British Columbia, Ontario, and Quebec—in the order named. The copper production of the former is rapidly expanding.

Lead is almost entirely derived from the mines of British Columbia, but it also occurs in the other provinces.

Zinc is widely distributed, but the production is as yet light, and mostly from the lead mines of British Columbia.

Nickel is one of the most important metallic products of Canada, but is largely confined to the mines of the Sudbury district in Ontario. A certain amount is produced in the Cobalt district, and prospects still farther north—resembling the Sudbury occurrences—are undergoing development.

Manganese, in the form of its oxides, is produced intermittently in Nova Scotia and New Brunswick.

Mercury has been furnished in small quantity by British Columbia.

Platinum occurs in some gold placer deposits in British Columbia, and also in the nickel-copper ores of Sudbury.

Tin and wolfram have recently been found in the gold veins of Nova Scotia. Wolfram also occurs in certain gold veins in British Columbia. Tin-bearing minerals have been found in certain pegmatites of eastern Ontario and Quebec.

Arsenic is obtained in connexion with gold ores in eastern Ontario, and in the silver ores of Cobalt.

Antimony is produced, to some extent, in Nova Scotia. It is being developed in New Brunswick, and at a few points in British Columbia.

Chromite is mined in Quebec.

Asbestos is the chief mining product of Quebec, and the deposits of this mineral in that Province are the most important in the world.

Graphite occurs in important deposits in eastern Ontario and Quebec; but the industry is not fully developed.

Gypsum is extensively mined in Nova Scotia, and New Brunswick. It is also mined in Ontario. It occurs in other provinces as well, and is beginning to attract attention in British Columbia.

Mica is an important product of Ontario and Quebec, where it occurs in shoots in veins. Some of the deposits are very large.

Phosphate of lime, or apatite, is still produced, generally as a by-product of the mica mines.

Corundum is extensively produced in eastern Ontario, from deposits which, as regards purity and magnitude, are unique.

Feldspar occurs in wonderful purity in eastern Ontario and Quebec, and is of considerable industrial importance.

Pyrites is now mined extensively in Ontario, and to some extent in Quebec.

Petroleum and natural gas are obtained in Ontario; Alberta is also producing a large quantity of gas, and will probably develop petroleum fields.

Salt of excellent quality is obtained in Ontario, and in quantities regulated only by the requirements of the market. New Brunswick and Manitoba also furnish a certain amount.

Magnesite occurs in Quebec, and hydromagnesite in British Columbia. Little has yet been done in the way of their development, but the indications are that in the near future they will be utilized.

Structural materials and clay products are found throughout the country and the production is rapidly growing.

In addition to the mineral products just enumerated, a great many others that are useful or valuable have been found, and these will become economically important as the mineral resources become more extensively developed.

LATENT POSSIBILITIES OF THE MINERAL INDUSTRY.

More interesting, however, than past production or present development are the latent possibilities of the mineral industry.

Although, as has been said, the greater part of Canada is unprospected, and much of it even unexplored, what is known of its geological structure enables forecasts as to its mineral wealth to be made. As will be seen from the following pages the country falls naturally into a number of geological provinces, characterized by certain peculiarities in the way of rocks, rock structure, and minerals. The general outlines of these provinces are known. Their southern portions, at least, both in Canada and in the United States, have been more or less developed, demonstrating their mineral possibilities, and it is fair to assume that in the northward unprospected extensions of these provinces, the mineral deposits will also, in some measure, be repeated. Any hesitation one might feel about applying this principle is removed when one compares the results already obtained in the frontier camps, with the corresponding stage in the development of the older mining districts of Canada and the United States, in the same geological province, and when one remembers the discoveries that have followed the opening up of each new section, and considers that geological explorers report the occurrences of the same minerals and the same geological conditions in the north that characterize that geological province in the south.

A brief summary of the characteristics of the main natural divisions of the country will at least suggest the possibilities of great expansion in the mineral development of the country.

APPALACHIAN REGION

The southeastern portion of Quebec, together with the Maritime provinces, form the northeastern extension of the Appalachian Mountain system. The Appalachian region is characterized by rock formations, ranging from pre-Cambrian to Carboniferous, that are typically disturbed and thrown into a succession of folds. In Canada, the Appalachian extension is found to possess many of the minerals which have placed some of the eastern states in the foremost rank of mineral and industrial districts of the world. Important deposits of coal, iron, and gold are mined in Nova Scotia. Of lesser importance, but still considerable, are the gypsum, stone and building material industries; manganese, antimony, tripolite and barite are also mined, and some attention has been paid to copper.

Pennsylvania, which is probably the best developed Appalachian state, now has an annual production of domestic minerals approximately equal to $9,340 per square mile of territory, or to $67 per capita.

Nova Scotia has an annual production of about $1,000 per square mile, or $46 per capita. Taking into consideration the more intensive production which follows increase of population and development, a geological comparison would appear to be fair, and Nova Scotia would seem to possess proportionately equal mineral resources with the most favoured Appalachian states. Its coal reserves have been estimated by Hon. R. Drummond to be 6,000,000,000 tons.

The mineral development of New Brunswick is backward. This is partly due to the covering of soil, and the forested areas which make discoveries difficult; so that very little of it has been prospected. The principal products at present are gypsum, lime, coal, building material, grindstones, clays, and mineral water. Iron, manganese, and albertite have been important: and iron promises to again become prominent. Antimony is being mined; copper, lead, silver, nickel, gold and other minerals have been found. Shales rich in oils and ammonium salts occur in large quantity, and seem likely to give rise to an important industry.

The southeastern portion of Quebec—also belonging to this area—may be said to be a high producer of economic minerals.

The main asbestos mines of the world are situated in this area; and important industries are carried on in chrome iron ore, copper, and pyrites. Iron ores, and gold, also occur.

LOWLANDS OF THE ST. LAWRENCE VALLEY.

The southern portion of Ontario and the valley of the St. Lawrence are very similar, geologically, to the State of New York: consisting mainly of flat-lying Palæozoic rocks; and the mineral products are the same: clay, cement and other building materials, petroleum, natural gas, salt, gypsum and other non-metallic products—extremely valuable, if less showy than the metallic minerals.

THE LAURENTIAN PLATEAU.

North of the valley of the St. Lawrence, from Newfoundland to beyond Lake of the Woods, and enclosing Hudson bay like a huge V, is an area of pre-Cambrian rocks, estimated to cover 2,000,000 square miles, or over one-half of Canada. Over the greater portion reconnaissance surveys only have been made, and the southern fringe of it alone may be said to be known, and of this fringe only a portion prospected. These rocks of the pre-Cambrian are remarkable for the variety of useful and valuable minerals they contain. Iron, copper, nickel, cobalt, silver, gold, platinum, lead, zinc, arsenic, pyrite, mica, apatite, graphite, feldspar, quartz, corundum, talc, actinolite, the rare earths, ornamental stones and gems, building materials, etc., are all found, and are, or have been, profitably mined. Most of the other materials, both common and rare, that are used in the arts, have been found. Diamonds have not been located; but from their discovery in glacial drift from this area, it is altogether probable that they occur.

A tongue of these pre-Cambrian rocks extends into New York State, which supports some large and varied mineral industries. Another extension crosses over from Canada into Michigan, Wisconsin, and Minnesota. In it are located the Michigan Copper mines, and the great Lake Superior iron ranges. Along the southern edge of the pre-Cambrian in Canada, there are known the gold ranges of the Lake of the Woods; the silver of Thunder bay; a succession of iron ranges extending from Minnesota for hundreds of miles to Quebec; copper rocks of Michipicoten and Bruce mines;

the Sudbury copper nickel deposits; the Montreal River and Cobalt silver areas; the corundum deposits of eastern Ontario; the magnetites of eastern Ontario and Quebec, and their large apatite-mica deposits, etc. It is quite true that few good merchantable iron deposits have been found in our extensive iron range formations; but in the Mesabi range—the richest in the world—only about two per cent is iron ore, so that immediate discovery in the little prospected areas in Canada is scarcely to be expected. To realize the unprospected nature of the country, it is only necessary to remember that the greatest asbestos deposits of the world were brought to notice by blasting the Quebec Central railway through them; that the greatest corundum deposits extending in a belt a hundred miles long, were found in a settled district by an officer of the Survey only twelve years ago; that the Sudbury nickel deposits were discovered by putting a railway through them; that Cobalt, now the premier silver camp, although only a few miles from one of the earliest routes of travel in the country, and only a few miles from a silver-lead deposit known a hundred and fifty years ago, was discovered less than six years ago, and then only by means of a railway cutting through a rich vein.

In trying to form an idea of the mineral possibilities of this great stretch of 2,000,000 square miles, we have a few facts on which to base an opinion. It is known from the explorations of the Geological Survey, that scattered over this area are patches of all the various formations that go to make up the pre-Cambrian; that almost all the minerals known to occur in the developed southern edge have been noted by explorers in the north; that in the known or partially known southern border, are found the greatest iron mines in the world: mines that have produced over 400,000,000 tons of iron ore, and are calculated to furnish at least 1,500,000,000 tons more; what may still be called the greatest copper camp: having produced about 4,500,000,000 pounds of copper and yet steadily increasing its production; also the greatest nickel mines in existance; and what promises to prove one of the greatest silver districts. In fact, in the known districts of Canada the pre-Cambrian appears to be as important from the mineral standpoint as in the highly developed districts in the United States. It seems to be safe, therefore, to assume that in the great northern areas, as yet unattacked by the pick of the prospector, are vast stores of minerals which will become available as the country is opened up.

THE INTERIOR PLAIN.

The greater portions of Manitoba and Saskatchewan, which lie outside of the pre-Cambrian, and the Province of Alberta, are pre-eminently agricultural, but in addition to furnishing an important market for the product of the mines, they will have a large output of non-metallic minerals. The Interior plain is underlain for the most part by sedimentary rocks, chiefly of Cretaceous age, and containing coal, building stones, clays, and cement materials. Natural gas over wide areas and under great pressure has been tapped, and there is every indication of a large oil field in the northern portion, at least, of Alberta, and some oil has been encountered in the southwest. The lower sandstones of the Cretaceous along the Athabaska river, when they come to the surface, are for miles saturated with bitumen. These tar sands will probably average 12 per cent in maltha or asphaltum. Mr. R. G. McConnell estimates that the tar sands seen by him occupy 1,000 square miles, which, with the thickness of 150 feet, would give 28·40 cubic miles of tar sands in sight; or about 6·5 cubic miles of bitumen; or, by weight, 4,700,000,000 tons of bitumen. The lignites of the eastern plains, useful for local purposes, become more highly bituminized as the mountains are approached. Mr. D. B. Dowling has estimated the available coal in the known fields of the northwest provinces as follows:—

Province.	Area of Coal Land	Anthracite.	Bituminous.	Lignite.
	In Square miles.	In Million Tons.	In Million Tons.	In Million Tons.
Manitoba	48	.....	.....	330
Saskatchewan	7,500	.....	.....	20,000
Alberta	19,582	400	44,530	60,002
Mackenzie district	200	.....	.....	500

Gold is found in a number of the rivers coming from the mountains. Clay ironstone occurs in many parts of the northwest, and will in time be utilized. Salt and gypsum also occur.

THE CORDILLERAN BELT.

The Cordilleran belt, in South America, in Mexico, and in the western states, is recognized as one of the greatest mining regions of the world: noted principally for its wealth in gold, silver, copper, and lead. The Cordilleras stand unparalleled in the world for the continuity, extent, and variety of their mineral resources. In Canada, and in Alaska, this belt maintains its reputation; although in both for the greater part unprospected.

In Canada this belt has a length of 1,300 and a width of 400 miles. It is pre-eminently a great mining region. Its rocks range from the oldest formations to the youngest; vulcanism and mountain building processes have repeatedly been active.

Although developed along the International Boundary Line on the south, and while some of the main streams have been prospected to some extent for placer gold, the greater part of the belt is as yet untouched. Probably not one-fifth may be said to have been prospected at all; not one-twentieth prospected in detail; and not one area, however small, completely tested.

Lode mining may be said to have commenced in British Columbia about fifteen years ago, the production previous to this date being largely in placer gold and coal. In 1893 the annual production of minerals in British Columbia had a value of about $3,500,000; it now runs about $25,000,000. The total production of British Columbia to the end of 1907 was approximately $300,000,000. The Yukon, which up to the present has produced practically only placer gold, is credited with over $125,000,000.

The Cordilleran belt in Canada is not only rich in gold, silver, copper, lead, and zinc, but has enormous resources of coal of excellent quality, varying from lignites to anthracite, which is conveniently distributed. Only the coal areas in the southern portion of the Province, and a few small areas on the Telkwa and Nass rivers, and on the Yukon, are at present known; but the estimated coal in the known fields is enormous, as shown in the following table prepared by Mr. D. B. Dowling:—

	Coal Areas. In Square miles.	Anthracite. In Million Tons.	Bituminous. In Million Tons.	Lignite. In Million Tons.
British Columbia	1,123	20	38,642	314
Yukon	400	32	32	850

Great unprospected areas are known to contain, in places, coal formations, and will, no doubt, when explored, add greatly to the above reserves. The coal production is not large as compared with the supply; but a large increase in production may be expected in the near future, as these are the best steaming and coking coals in the west, and railway facilities will be provided to supply the transcontinental railways, and the great smelters in the northern states.

The whole belt of the Cordilleras, from Mexico to Alaska, may be considered as forming one general geological province. The nature and mode of occurrence of the minerals are in general similar throughout. The great mineral wealth of Mexico and the western states has been amply demonstrated by mining. Only about one-fifth of Alaska has been explored, and lack of transportation facilities, and rigorous climatic conditions still handicap rapid development; but already it has a large production, showing that the Cordillera maintains throughout, its highly mineralized character.

Probably nowhere along the Cordilleran belt has the maximum production been reached. The value of the production of the non-metallic minerals, such as coal, oil, etc., is rapidly growing, as is also that of the baser metals, copper and iron; and most of the minerals used in commerce and the arts are being produced.

The prospective resources of the Cordilleran belt in Canada may, therefore, be considered enormous. Though mostly unprospected, it has already been proved to possess the greatest coal fields; one of the greatest copper mines; one of the greatest silver-lead mines; and two of the greatest placer camps in western America—a region noted for its extraordinary mineral wealth.

Upon the knowledge already gleaned concerning the economic deposits of the Dominion, by geological exploration, by prospecting, and by actual mining, it is safe to predict that the mineral industry will become a very great and valuable one. Its development will render essential a close study of the geology of the country. The geological field in Canada is as rich and inviting as the mining. Perhaps half the rock history of the world is written in the pre-Cambrian, and it is of this portion that most remains to be deciphered. Since the greatest spread of these old rocks occurs in Canada, much of this work will fall to Canadian geologists, and the careful solution of the problems presented will be as valuable to science as to the mining industry.

NOTE.—For detailed descriptions of the geology and mineral resources, etc., the reader should consult the publications of the Geological Survey, and the Mines Branch, Department of Mines, also the reports of the Bureau of Mines of the several provinces.

Folds in mountain, Mount Kidd, Selkirks, B.C.

PART II.

A DESCRIPTIVE SKETCH

OF THE

GEOLOGY, AND ECONOMIC MINERALS

OF

CANADA

BY

G. A. Young.

CHAPTER I.

Introductory.

The description of the geology of Canada set forth in the following pages is only a generalized view of the subject. No attempt has been made to enter into details; since such a mode of procedure would greatly increase the bulk of the volume, and probably result in the production of a work of interest to only a very limited number of readers. Unfortunately, the broadly descriptive method adopted frequently renders it necessary to condense into a few words the description of the complicated geology of many and wide regions. There is, perhaps, a tendency to make it appear as though the geological history of the greater part of Canada was now definitely known, when in truth, there is scarcely a district in which important geological problems do not still remain unsolved.

Palæontological subjects have been scarcely touched upon, since, under the plan adopted, little better could have been offered than comparatively uninteresting lists of fossils. In dealing with the occurrences of the various economic minerals in different districts, no endeavour has been made to mention or describe all of the deposits that are at present of economic importance, nor all such as may yet become of value. Instead, as far as possible, the aim has been to indicate the nature and mode of occurrence of the more characteristic mineral deposits of each region. It will be apparent that, in following this plan, more space has been devoted to certain classes of deposits or individual occurrences than their relative economic importance would otherwise demand. The inclusion, under the title of mineral deposits, of descriptions of peat bogs, etc., cannot, of course, be strictly justified.

In dealing with the geology, the plan followed has been largely that adopted by the late Dr. G. M. Dawson in his admirable outline of the physical geography and geology of Canada, prepared for the Handbook of Canada at the time of the Toronto meeting, in 1897, of the British Association for the Advancement of Science. The author also wishes to record his indebtedness to Mr. R. W. Brock, Director of the Geological Survey, and to Messrs. W. McInnes and R. A. A. Johnston for aid received and revisions suggested during the preparation of the work. In the case of the description of the ore deposits, many sentences have been transcribed almost word for word from articles by numerous writers. Since in the present work it has seemed best not to give references to the host of authorities consulted, the author may only here acknowledge in general terms his indebtedness to the various geologists and professional men who have contributed to the written record of Canadian geology.

Canada embraces the northern half of the continent of North America, with its adjacent islands, including those of the Arctic ocean between the 141st meridian and Greenland, but exclusive of Alaska in the extreme northwest, the island of Newfoundland, which still remains a separate British colony and holds jurisdiction over the Labrador coast, and the small islands of St. Pierre and Miquelon, retained by France. The total area of Canada is estimated at about 3,729,665 square miles. This area is somewhat larger than the United States (including Alaska) and not much less than all Europe.

The form of the North American continent may be described as that of an isosceles triangle, of which the narrower part, pointing south, constitutes Mexico; a wide central belt—the United States; while the broader base is the Dominion of Canada. The northern margin of the continental land lies approximately on the seventieth parallel of north latitude, but in the east the land area is continued far northward by the great islands of the Arctic archipelago, while south of these the continent is broken into by the large but shallow sea named Hudson bay, 800 miles from north to south, and some 600 miles in width.

Surrounding Hudson bay lies the Laurentian plateau, or Canadian Shield, a tract of land underlain by ancient, largely crystalline rocks, and, though relatively elevated, scarcely ever rising over 2,000 feet above the sea, except in the extreme northeast. Spreading widely in the Ungava peninsula, this upland runs with narrower dimensions round the southern extremity of Hudson bay, and thence continues northwestward to the Arctic ocean. Along the southern margin of the Laurentian plateau lies the great waterway, the river St. Lawrence, reaching to the very centre of the continent, and expanding there into the group of inland fresh-water seas generally spoken of as the Great lakes, while the Winnipeg system of lakes, with Athabaska, Great Slave, and Great Bear lakes, occupies a very similar position on the outer rim of the western extension of the plateau.

Following respectively the trend of the southeast and southwest sides of the Laurentian plateau, the two great mountain systems of the North American continent—the Appalachian in the east, and the Cordilleran in the west—converge to the south, embracing between them, to the south of the Great lakes, the central plain of the continent that, west of the Laurentian plateau, extends northward through Canada to the Arctic ocean. But in the east, in Canada, the Appalachians closely follow the border of the Canadian Shield, separated from it only by the valley of the St. Lawrence river. While the two mountain systems of the continent are, with respect to one another, symmetrically disposed, they are opposed in extent and character. The Cordilleran system of the west embraces a mountainous tract, of which large areas are elevated more than 5,000 feet above the sea, with peaks rising to heights of 10,000 feet and more. On the other hand, the mountains or hills of the Appalachian system, in Canada, seldom rise more than 2,000 feet above the sea, and over the greater part of the eastern provinces—New Brunswick, Nova Scotia, and Prince Edward Island—the land lies below the 1,000 ft. datum line.

A large portion of Canada is essentially a region of lakes and rivers, and no feature of the country is more important, whether historically or geographically, than the great length and volume of its principal watercourses, and the manner in which these interlocking streams penetrate almost every part of the area. In eastern Canada—in the Maritime provinces—the waterways, though of local importance, and including the St. John river, nearly 400 miles long, are relatively unnoteworthy; but elsewhere are river and lake systems almost unequalled in size and extent. The St. Lawrence river, with its numerous tributaries, amongst which may be mentioned the Ottawa, nearly 700 miles long, drains a basin lying largely in Canada, and having an estimated area of 530,000 square miles. The easterly flowing St. Lawrence, with the great system of lakes at its head, offers, above Montreal, by aid of the canals on the Ste. Marie, Niagara, and St. Lawrence rivers, a navigable route nearly 3,000 miles long, leading to the heart of the continent; while, eastward of Montreal to the Strait of Belle Isle, for almost 1,000 miles the estuary of the river and the Gulf of St. Lawrence form a route for the largest sea-going vessels.

Emptying into Hudson bay and strait are numerous rivers, draining an estimated area of 1,486,000 square miles. The height of land bounding the Hudson Bay basin runs southwesterly through the Ungava peninsula, and westerly through Quebec and Ontario to near the head of Lake Superior, whence, diverging southward into the United States and again entering Canada, it follows a general westerly course to the Rocky mountains, leaving in southern Saskatchewan and Alberta a narrow strip of territory whose waters find their way to the Gulf of Mexico. Continuing northward for some distance along the crest of the Rocky mountains, the divide then assumes a general northeasterly course, and, passing just north of Edmonton, runs to a point north of Hudson bay. Within this basin, in the west, is the Saskatchewan river, rising in the Rockies and flowing easterly to the Winnipeg system of lakes, beyond which it is continued by the Nelson, emptying into the southwest corner of Hudson bay, thus forming a river system 1,660 miles long. North of the Saskatchewan lies the Churchill river, that, with its tributaries, has a total length of about 1,300 miles. Besides these, many other rivers, often of no inconsiderable size, drain countless lakes, large and small, and flow from all sides into Hudson bay.

In western Canada, northwest of the Hudson Bay basin, and between it and the continental divide, lies a great region of about 1,290,000 square miles, draining northward to the Arctic ocean.

The greater part of this territory is drained by the Mackenzie and its tributaries, affording a river system with a maximum length of about 2,500 miles. West of the continental divide, within the Cordilleran region, lies the Pacific basin, with an area of about 387,300 square miles, drained by numerous rivers breaking transversely through the northerly trending mountain ranges. In the south, the Fraser, 695 miles long, and the Columbia—only partly in Canada—are the chief rivers. In the north, the Yukon—about 1,760 miles long—drains an area in Canada of about 145,000 square miles, and finds its way through Alaska to Bering sea.

Thus, with the exception of a relatively insignificant area of about 13,000 square miles, the whole of Canada lies on the northern slope of the continent, draining into the northern Atlantic, the Arctic, or Pacific oceans.

Canada is notable not only for the size and volume of its great river systems, but also for its almost countless and often large lakes, that occur more particularly within or along the borders of the Laurentian plateau. Lying along the boundary between Canada and the United States are the large bodies of fresh water known as the Great lakes, having a total area of over 95,000 square miles, of which Lake Superior, the largest, occupies about 31,800 square miles, and Lake Ontario, the smallest, 7,260 square miles. Westward, in Manitoba, Lakes Winnipeg and Winnipegosis have areas respectively of 9,460 square miles and 2,086 square miles. Farther to the northwest lies Lake Athabaska, with an area of 2,842 square miles; Great Slave lake, 10,719 square miles, and Great Bear lake, 11,820 square miles. Besides these there are many other lakes whose size would place them in the first class.

In this connexion it may be useful to state the height of a few of the larger lakes, each of which marks the lowest level of large tracts of adjacent land. The Great lakes, though they stand at four levels, in reality occupy only two distinct stages, separated by Niagara Falls. Below this cataract is Lake Ontario, 246 feet above the sea; above it, Lake Erie, 572 feet; Lake Huron and Lake Michigan, 581 feet; and Lake Superior, 602 feet. Farther to the west are: Lake of the Woods, 1,057 feet; Lake Winnipeg, 710 feet; Lakes Manitoba and Winnipegosis, 810 feet and 840 feet respectively; Athabaska lake, 620 feet; Great Slave lake, about 520 feet; and Great Bear lake, about 390 feet.

The great, central, U-shaped Laurentian plateau, with an area of over 2,000,000 square miles, is, both physiographically and geologically, a dominant feature of Canada. Composed mainly of very ancient rocks, largely of the nature of granites, and formed during the first geological era, it represents a portion of the pre-Cambrian land, that at one time doubtless extended far to the north, west, and south, possibly forming a continental mass resembling the present one in extent. During succeeding ages, seas alternately advanced over and retreated from the area of this continental land, and in them were deposited the sandstones, shales, limestones, etc., now almost entirely surrounding the Laurentian upland, and in places lying within it.

East and west, towards the borders of the continent, periods of mountain building, of volcanic activity, and of invasions of deep-seated igneous bodies alternated with the processes of sedimentation. But during all these times the central Canadian Shield, as well as its westward extension now hidden by the younger strata of the western plains, remained comparatively stable, unaffected by mountain building processes or by the invasion of igneous masses. Probably a very large portion of the Laurentian highlands was never covered by the successively invading seas, in which, on all sides, were laid down great volumes of sediments, in part, at least, derived from the erosion of the central uplands.

Except locally, or for comparatively short periods of time, eastern Canada, from the close of the second great geological era (the Palæozoic), appears to have remained elevated above the sea, undergoing erosion and unaffected by mountain building processes. But west of the Canadian Shield, during Mesozoic and later times, sedimentation, mountain building, and igneous activity continued until a recent date. Thus Canada might be divided into two portions—an eastern one of relatively low relief and fundamentally underlain only by Palæozoic or older strata, and a western division, in which sedimentation continued through Mesozoic and Cenozoic times, accompanied by, in the west, igneous activity and the operations of mountain building forces. For the further description of the geology and physical features of the country it is, however, more convenient to employ a sixfold division, as follows:—

(1.) *The Appalachian Region*, including the portion of Canada east of a line running from Lake Champlain to the neighbourhood of the city of Quebec and thence down the channel of the St. Lawrence.

(2.) *The St. Lawrence Lowlands*, including the plains bordering the St. Lawrence river above the city of Quebec and extending through southern Ontario to Lake Huron.

(3.) *The Laurentian Plateau Region*, including the great U-shaped upland surrounding Hudson bay.

(4.) *The Arctic Archipelago*, including the islands of the Arctic ocean north of Hudson bay.

(5.) *The Interior Continental Plain*, including the central belt of plains lying between the western margin of the Laurentian plateau and the Rocky mountains.

(6.) *The Cordilleran Region*, including the mountainous region of the western portion of the continent.

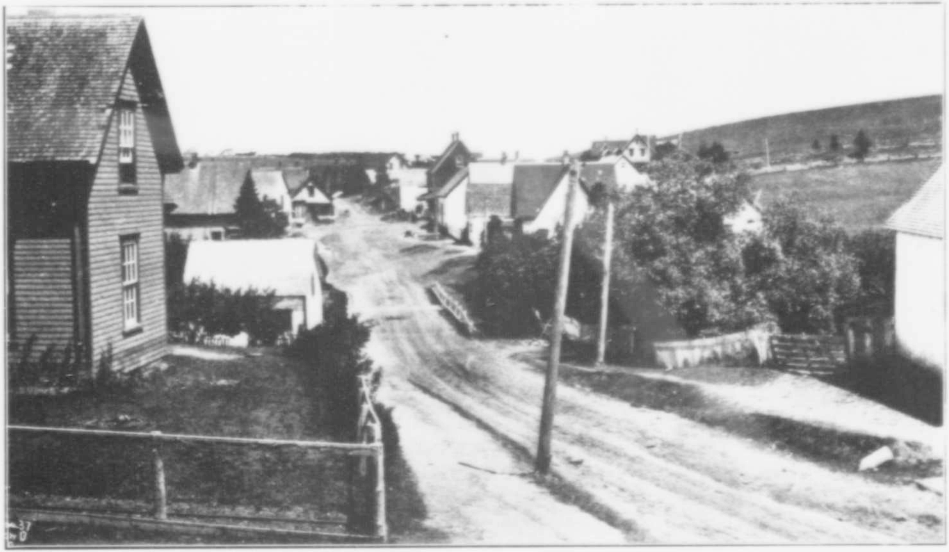
CHAPTER II.

THE APPALACHIAN REGION.

GEOLOGY.

The *Appalachian region* of Canada may be defined as including the territory lying east of a line running northeast from the foot of Lake Champlain on the Vermont border, to the city of Quebec and thence down the St. Lawrence valley, that is, it contains most of the Province of Quebec lying east of the St. Lawrence, together with the Maritime provinces of New Brunswick, Prince Edward Island, and Nova Scotia. The country is part of a mountainous belt, the Appalachian Mountain system, that, commencing not far from the Gulf of Mexico, continues northeastward through the eastern portion of the continent to the Gulf of St. Lawrence, beyond which it reappears in the island of Newfoundland. Throughout this belt the strata are frequently highly folded and faulted, and evidence of igneous activity is not wanting; while within it, in Canada as elsewhere, are many valuable mineral deposits, including the asbestos deposits of southeastern Quebec, the most noted in the world, the coal and gold fields of Nova Scotia, as well as bodies of iron, copper, and various other ores.

The Appalachian Mountain system, throughout its entire course of 1,700 miles within the limits of the continental land, preserves a general southwest and northeast trend. South of New York state it is represented by two parallel ridges, upon the eastern one of which many peaks rise above 6,000 feet. In northern New York, the New England States, and eastern Canada, the mountain system is less regular in structure. In Vermont occur the Green mountains, whose highest peak rises to 4,430 feet. Farther east, towards the southeastern angle of the Province of Quebec, lie the White mountains, with Mount Washington 6,291 feet high. Northern Maine, bordering the Province of Quebec on the east, is also mountainous, with one peak rising above 5,000 feet. In eastern Canada, the Appalachian system, regarded



Hunter River, Prince Edward Island: typical island village.

Farming scene, Prince Edward Island.

as a mountainous belt, is, strictly speaking, represented only by the elevated tracts of eastern Quebec and northern New Brunswick. Elsewhere, over the greater part of the Maritime provinces, the Appalachian character is mainly represented by the general trend of the major hills and of the large indentations of the sea, and by the general geological structure of the country as a whole.

In the Eastern townships of southeastern Quebec, the Green mountains of Vermont are continued northeastward by the Notre Dame mountains, that approach the St. Lawrence below Quebec, and from there, bordering the estuary of the river, continue with increasing altitudes into and through the Gaspé peninsula, where they are known as the Shickshocks. In the Eastern townships the Notre Dame mountains are represented by three rudely parallel ridges, that, passing eastward, have progressively higher average elevations, and finally, over considerable areas, rise above 2,000 feet, with Sutton mountain, in the westernmost range, attaining a height of nearly 3,000 feet.

Proceeding northeastward to a point opposite the city of Quebec, the Notre Dame mountains sink to lower and lower elevations, but beyond this they again increase in height, so that in the Gaspé peninsula they form an uplifted area with a general elevation of from 1,000 feet to 2,000 feet, with many peaks rising above 3,500 feet. Throughout the elevated tract of eastern Quebec the country is largely drained by tributaries of the St. Lawrence, flowing northwestward through defiles which they have trenched across the northeasterly trending ridges.

In the Maritime provinces the Appalachian system is represented by the broken, hilly district of the northwestern part of New Brunswick, where the general elevation over considerable tracts of country is above 1,000 feet, while a number of hills rise over 2,500 feet above the sea. A second relatively high tract in this Province borders the Bay of Fundy, and, though much broken in its westward portion, forms a considerable area of plateau-like country, with a general elevation of about 1,200 feet. Lying between the two hilly portions, a very large part of New Brunswick has a mean elevation of only a few hundred feet, and the same is true of Prince Edward Island. The higher land of the peninsula of Nova Scotia forms a central ridge seldom reaching 1,200 feet, though, in what may be regarded as its continuation, in the island of Cape Breton, some higher points attain an altitude of 1,500 feet.

Though the general course of the hills of the Maritime provinces parallels that of the Appalachians, the propriety of including the territory in the Appalachian region is better shown by the geological features such as the Appalachian folding, and by the pronounced northeasterly trend of the whole Province of Nova Scotia, the parallel, long indentation of the Bay of Fundy in the southeast, and that of Chaleur bay, with the valley at its head, in the northwest.

The Appalachian region, though essentially a broken, often rugged, hilly country, contains many fertile, cultivated districts. Amongst these may be mentioned the valleys of the Eastern townships of Quebec, the St. John River valley of New Brunswick, and in Nova Scotia the Annapolis-Cornwallis valley that parallels the Bay of Fundy, from which it is separated by the long ridge of North mountain. Much of the Appalachian region in Canada is, however, a forested country, traversed by swiftly flowing streams, and, in parts of Nova Scotia and New Brunswick, dotted with small lakes. Some of these are very picturesque, and in Cape Breton the salt, nearly land-locked, Bras d'Or lakes, with their often bold shores, are justly noted for their beauty.

Geologically the Appalachian region of Canada is characterized by a very complicated structure. The strata, chiefly of Palæozoic age, at various times and over large tracts, have been greatly disturbed, traversed by many faults, and now lie in highly inclined positions. During earlier Palæozoic times, embayments of the sea spread over the region in question, alternately expanding and contracting, while frequently these bodies of water seem to have taken the form of long, wide sounds, extending in a general southwesterly direction, sometimes to join the great interior seas that flooded the central portions of the continent. In these embayments were deposited great volumes of sediments, which, during intervals of emergence, were eroded, and folded and faulted during successive periods of activity of mountain building forces. Over considerable districts intrusive areas of igneous rocks occur, and the geological history is further complicated by the local presence of volcanic material.

As a result of the successive action of similar mountain building processes in the Appalachian region, there is now a pronounced general tendency for the different formations to occur in elongated bands, striking approximately northeast and southwest. In the

PLATE V.

Brook in Pictou County, N.S.

Eastern townships and Gaspé peninsula, along the central axes of folding and uplift, crystalline rocks of pre-Cambrian age are now exposed. Rocks of this ancient era occupy considerable areas within the two hilly regions of New Brunswick, and also in the northern and eastern portions of Cape Breton island.

Cambrian and Ordovician strata occupy much of southeastern Quebec, and continue northeastward into Gaspé, where they are accompanied by large volumes of Devonian and Silurian sediments. Silurian measures are widely displayed over northwestern New Brunswick, and appear, associated with Devonian, Ordovician and older strata, in the southern part of the Province. In Nova Scotia, Devonian and older beds occupy the main portion of the Province.

In the Canadian Appalachian region strata of Carboniferous and Permian age are confined almost entirely to the Maritime provinces, where they occupy all of Prince Edward Island, and, on the mainland, border the shores of the Gulf of St. Lawrence; while in southern New Brunswick they extend westerly almost completely across the Province. Triassic measures occur both in Nova Scotia and New Brunswick along the shores of the Bay of Fundy, but, with the exception of these beds, the Mesozoic system, as well as the Tertiary, is unrepresented in the Canadian Appalachian region.

The pre-Cambrian rocks of the Appalachian region are largely of igneous origin, often deformed and now schistose or gneissic. In the Eastern townships of Quebec, the rocks of the pre-Cambrian areas appear to be almost entirely volcanic rocks, chiefly basic varieties; no true sediments are definitely known to be included with them, though, by the action of later earth movements, they are now, in places, intricately associated with more or less altered Palæozoic strata. In the Gaspé peninsula the corresponding rocks include other forms, of the nature of granites, as well as acid volcanics and possibly sediments. The same is true of the regions in northern New Brunswick, while in southern New Brunswick and Cape Breton, besides large volumes of granitic and gneissic rocks, variously altered acid and basic volcanics are common, and there also occur masses of crystalline limestone, as well as schistose rocks of possibly sedimentary origin.

The comparatively limited, but widely separated areas of pre-Cambrian rocks, are the visible portions of the ancient pre-

Palæozoic continent upon which the later rocks, during periods of depression, were deposited. Though usually largely composed of igneous matter, the general character of the different assemblages varies rather widely from place to place, indicating the likelihood that the buried portions are also heterogeneous, perhaps in places including large amounts of sedimentary rocks. Possibly the great series of sediments known as the gold-bearing (or Meguma) series, which occupy a very large portion of the Nova Scotia peninsula, may represent such an ancient sedimentary series, though they have been generally regarded as of early Palæozoic age.

The gold-bearing series of Nova Scotia, together with great intrusive masses of later granites, occupies the whole Atlantic coast of the peninsula, extending in the southwest almost completely across it, and underlying, in all, an area of some six or seven thousand square miles. This series, consisting of a lower division comprised largely of quartzites, and of an upper one mainly of dark slates, has yielded a section of over 25,000 feet of sediments, thrown into a series of folds whose axes follow a general northeasterly course. Cutting the sediments are large, batholitic bodies of granite of a later age, possibly late Devonian. Along the axes of folding, within the lower quartzite division, is a widespread system of veins of quartz, often gold-bearing. The gold-bearing series has generally been regarded as of early Cambrian age, though, so far, without fossil evidence, and the entire dissimilarity of the measures as a whole to the undoubted Cambrian beds found elsewhere in the Maritime provinces, lends support to the alternate view that the formation of this great volume of sediments antedated the Palæozoic era.

Fossiliferous strata of Cambrian age are well developed at two points in the Maritime provinces—in Cape Breton and in the neighbourhood of St. John city. In these, often highly disturbed measures, which consist largely of shales, slates and sandstones, yielding total sections of over 3,000 feet, the whole Cambrian system is represented. In Quebec an almost continuous zone of Cambrian sediments extends from the extremity of Gaspé peninsula to the Vermont border. Within this belt, following a course nearly 600 miles long, the strata are usually intricately folded and faulted, and the volume of the beds, largely sandstones and slates, is very great, probably reaching a total thickness of above 5,000

Cape St. Mary, looking toward Yarmouth, Digby County, N.S.

Valley of the St. Mary River looking up from the post-road at foot of Cochranes belt and head of Stillwater, with the Crows Nest mine in the distance on the right, Guysborough County, N.S.

feet, representing various divisions of the Cambrian from the lowest to the highest.

The Cambrian beds of the Maritime provinces have yielded a rich and varied fauna, presenting close analogies to the types recovered from beds of similar age in northern Europe. On the other hand, the Cambrian measures of eastern Quebec hold a fauna unlike, in some respects, that of New Brunswick and Nova Scotia. Largely on the evidence thus afforded, considered in connexion with the distribution of the sediments, the Cambrian strata of Quebec are believed to have been deposited in a long sound extending from beyond Gaspé, through eastern Quebec, to the southern United States. This sound, it is believed, was separated from the eastern Cambrian sea, that reached at least from Massachusetts in the south, through New Brunswick and Nova Scotia, to Newfoundland in the north.

Both of the Cambrian seas appear to have continued to exist through very early Ordovician times, but during this period, as has often been the case throughout geological time, differential movements of the earth's surface progressively shifted the position of the coast lines. In the northeastern portion of the peninsula of Nova Scotia are considerable districts occupied by greatly disturbed formations, probably of Ordovician age, consisting of sediments accompanied by large volumes of igneous rocks, some of which may represent the products of contemporaneous volcanoes. In New Brunswick, Ordovician beds partly occupy the broken, hilly country stretching northeasterly through the Province to Chaleur bay. In this region, the beds of this system consist of shales and sandstones or their altered equivalents, often penetrated by large bodies of granite and other igneous rocks.

In northeastern Quebec, various divisions of the Ordovician, sometimes largely of calcareous measures, sometimes chiefly slates and sandstones, occur along the shores of the St. Lawrence and Chaleur bay, but the Ordovician system is best exemplified in the districts lying southward towards the Vermont border. There it is represented by considerable volumes of sediments of various kinds, all highly disturbed, but indicating by their relations constantly occurring changes in the extent of the land and sea areas.

Towards the close of the Ordovician period, the whole Appalachian region of eastern America was involved in a series of mountain building movements. During this interval much, if not most of the eastern portion of the continent was elevated above the sea, and the strata folded and eroded before subsiding beneath the Silurian seas that appear to have swept over much of the Maritime provinces and the peninsula of Gaspé, and that probably extended southwestward into southeastern Quebec. During Silurian times there also appears to have been at least one general, though temporary, retreat of the seas.

Throughout western and northwestern New Brunswick, and the Gaspé peninsula generally, large tracts are floored by great volumes of shales (often calcareous), sandstones, and limestones of Silurian age, now usually highly folded and faulted. With these beds occur many varieties of igneous rocks, some of which represent the products of contemporaneous volcanoes. In Nova Scotia, the Silurian strata are largely confined to the northeastern portion of the Province, and at one locality, on the shores of Northumberland strait, there is a nearly complete section of the whole system represented by about 3,000 feet of sediments. In other portions of the Province, igneous rocks, possibly in part of contemporaneous volcanic origin, are associated with the sedimentary beds.

Devonian strata are widely distributed over the Canadian Appalachian region; the earlier ones are often largely calcareous, and their fossils indicate true marine conditions of deposition; but large portions of the system consist mainly of shales and sandstones, often rich in the remains of land plants, and apparently, were laid down in lakes—fresh, brackish, or salt; or in estuaries, tidal flats, etc. True marine, calcareous beds occur locally at a few points in southeastern Quebec, indicating the former presence of once extensive seas, whose deposits have since been largely removed by erosion. Early Devonian beds of a similar nature also occur in Nova Scotia, while at the extremity of Gaspé peninsula these earlier marine beds are represented by about 2,000 feet of shales and calcareous strata. These are overlain by 7,000 feet or more of conglomerates, sandstones, and shales, abounding in plant remains, and even occasionally containing thin coal seams. Towards the head of Chaleur bay is a disturbed basin of such measures, famous for their contained fish remains. In southwestern New Brunswick great volumes of argillaceous and arenaceous strata occur, sometimes with an estimated thickness of about 7,500 feet; these have also been assigned to the Devonian.

The same conditions are duplicated in Nova Scotia, where at one place occur strata containing tuff-like beds indicative of contemporaneous volcanoes.

In late Devonian, and, perhaps, during a portion of early Carboniferous times, the Canadian Appalachian region was again subjected to widespread earth movements, by which much of the region was once more elevated, the strata folded and faulted, and the mountains further uplifted. At the same time deep-seated intrusions of granites and allied rocks took place over considerable areas throughout the region. These granitic bodies, intruding and altering the older strata, as well as the Devonian, are found in the Eastern townships, over large areas in New Brunswick, and throughout the Province of Nova Scotia, forming there the large bodies of granite penetrating the gold-bearing rocks of the Province. Perhaps the granitic and related igneous rocks forming the Cobequid hills, along the north side of Minas bay, were intruded during this interval. From this time onwards, until a comparatively recent geological date, nearly the whole of Quebec remained above the sea, but large portions of the Maritime provinces were, during the succeeding period, gradually depressed, and floored with immense volumes of sediments. The boundaries of the Carboniferous sediments, with the older formations in many places, still indicate the old, sinuous shore lines that followed along the base of the ancient uplands of Carboniferous time. This condition is strikingly shown in the western portions of Cape Breton, where the Carboniferous strata occur along the sea coast as a mere fringe, skirting hills of crystalline pre-Cambrian rocks, or penetrating them along the courses of old pre-Carboniferous bays and valleys.

The Carboniferous strata of the Maritime provinces, within which occur the prolific coal seams of Nova Scotia, are of immense volume. Near the Sydney coal fields, Cape Breton, there is a combined section of above 13,000 feet, and along the Nova Scotia shores of the Bay of Fundy, the famous Joggins section, including younger Permo-Carboniferous, or Permian strata, has a thickness of above 14,500 feet, in which over seventy coal seams are exposed. Throughout the region bordering the Strait of Northumberland the Carboniferous measures are succeeded by a great volume of Permian rocks that extend throughout Prince Edward Island.

The Carboniferous sediments in New Brunswick occupy about 10,000 square miles, forming an area, triangular in shape, bordering the eastern coast, and contracting inland between the two elevated districts of the Province. The Carboniferous and overlying measures extend eastward into Nova Scotia, occupying much of the country north of the Bay of Minas, and reaching into Cape Breton. These areas, as indicated by the presence of Carboniferous strata on the Magdalen islands, lying far north in the Gulf of St. Lawrence, appear to be but the outer margin of a larger area now submerged beneath the waters of the gulf. Over nearly the whole of New Brunswick, Prince Edward Island, and much of Nova Scotia, the measures still lie nearly flat, or with gentle undulations, though in certain districts the beds are tilted and traversed by dislocations of considerable magnitude.

Within the Carboniferous and the succeeding system, are horizons of unconformity, marking intervals of uplift, of the contraction of the basins, or of periods of expansion. The strata consist very largely of shales, sandstones, grits, and conglomerates, but at one widespread horizon occur beds of limestone, often accompanied by thick beds of gypsum. Younger than the true Carboniferous measures are huge volumes of sandy and shaly beds of Permian age, extensively developed along the shores of Northumberland strait, and throughout Prince Edward Island. Sometimes these Permian beds succeed the Carboniferous, with no very evident unconformity, but at times their basal portion is marked by hundreds of feet of conglomerate, in places overlapping older formations.

With the close of the Palæozoic era, almost the whole of the area of the Maritime provinces seems to have been permanently withdrawn from the sea. In early Mesozoic times, however, Triassic strata, largely red shales and sandstones, were locally deposited, and in Nova Scotia now occupy a narrow strip along the Bay of Fundy; they also appear on the New Brunswick side of the same body of water. These beds indicate only local submergence, and may be of the nature of estuarine or tidal-flat deposits. With them occur thick sheets of diabase (trap), which in Nova Scotia form a sheet overlying the Triassic sediments that extend almost continuously along the Bay of Fundy shore for nearly 250 miles.

PLATE VIII.

Willows in Park at Sydney, N.S.

The Triassic marks the close of the subaqueous history of the Canadian Appalachian region; the deposition of strata then ceased, and the cycle of erosion, inaugurated over a large part of the country in Carboniferous or earlier times, has continued to the present day. There are reasons for believing that this process of degradation was already far advanced in Cretaceous times, when portions of the Maritime provinces, in common with much of the coastal region of the United States, were probably reduced to the condition of a sloping plain. But the geological record of the Appalachian regions is largely a blank from the close of Palæozoic times onwards to the glacial period, the leading features of which will be discussed later in connexion with the glacial history of Canada as a whole.

ECONOMIC MINERALS.

The most important economic minerals of the Appalachian region in Canada are the asbestos of the Eastern townships of Quebec, and the coal of Nova Scotia. Approximately two-thirds of the total coal production of Canada is at present furnished by Nova Scotia, while the asbestos deposits of Quebec are particularly notable, since they are the largest bodies of this mineral now being worked in any country. Gold, copper, chromite, iron, barite, and gypsum are also mined, whilst deposits of various other minerals of economic value have been worked from time to time, or are now engaging attention.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE APPALACHIAN REGION.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold......	Free gold with pyrite, etc., in a gangue of quartz, with some calcite forming veins in the gold-bearing series of Cambrian or pre-Cambrian age.	Nova Scotia gold fields.
	Free gold with pyrite, etc., in a gangue of quartz forming veins in pre-Cambrian schists, etc....	Cape Breton.
	Alluvial gold in pre-glacial sands and gravels in ancient, largely buried river valleys..........	Gilbert River field, Que.
	See also under copper, antimony.............	Eastern townships, Que.
Copper-Gold-Sulphur....	Chalcopyrite with small amounts of chalcocite and bornite, in pyrite, replacing country rock and forming lenses in pre-Cambrian schistose porphyries and andesites........................	Eustis, Capelton and Suffield mines, Eastern townships, Que.
Copper....	Chalcopyrite, bornite and chalcocite forming irregular bodies in Ordovician sediments and near intrusive, basic dikes........................	Acton, Quebec.
	Chalcopyrite with a little pyrite in pyrrhotite, forming irregular bodies lying along the contact of Ordovician strata and intrusive diabase.....	Southeastern Quebec.
	Chalcopyrite, etc., in mineralized zones in pre-Cambrian felsites, etc........................	Coxheath, Cape Breton.
	Native copper in veins and along jointing planes in Triassic trap..............................	Minas basin, N.S.
Lead......	Galena in small veins and pockets in Carboniferous limestone..................................	Colchester co., N.S.
	Galena and sphalerite in veins cutting Silurian strata..	Gloucester co., N.B.

CHIEF MINERAL DEPOSITS—Continued.

Element or Mineral Sought	Character and Mode of Occurrence of Deposit.	Example.
Tin.......	Cassiterite in small quantities associated with various minerals containing lithium, boron, etc., in pegmatite cutting Devonian granite.......	Lunenburg co., N.S.
Chromium.	Chromite forming irregular pockets in serpentine of Ordovician or pre-Cambrian age...........	Eastern townships, Que.
Manganese.	Chiefly pyrolusite forming veins, pockets and large bodies in Carboniferous limestone............	Hants co., N.S., near Sussex, N.B.
Tungsten. .	Scheelite with mispickel in quartz veins cutting the gold-bearing series....................	Halifax co., N.S.
	Hübnerite in quartz veins cutting pre-Cambrian gneiss....	Inverness co., N.S.
Iron......	Hematite in fossil-bearing beds in Devonian and Silurian strata....	Torbrook, N.S.
	Hematite, high in manganese, forming beds in Silurian slates..........................	Woodstock, N.B.
	Siderite, limonite, etc., occurring within a zone of veins of ankerite, siderite, etc., cutting Devonian sediments near intrusive acid igneous bodies..........................	Londonderry, N.S.
	Magnetite in elongated bodies with local developments of pyrite, etc., lying in early Palæozoic or older altered sediments and volcanics.....	Gloucester co., N.B.
Sulphur. . .	*See* under copper-gold-sulphur...............	Eastern townships, Que.
Antimony .	Auriferous stibnite with pyrite, mispickel and galena, in a gangue of calcite, forming veins cutting the gold-bearing series...............	West Gore, N.S.
	Native antimony and stibnite in quartz veins cutting early Palæozoic sediments in the neighbourhood of intrusive bodies of granite and diabase..........................	Prince William, N.B.
Barium. . .	Barite forming pockets and irregular bodies in Palæozoic strata..................	Cumberland co., N.S.
	Barite in a gangue of calcite with some quartz and fluorite, forming veins cutting pre-Cambrian schists, etc..................	Cape Breton.
Asbestos . .	Complicated systems of narrow, gash veins of asbestos in small bodies of Ordovician and pre-Cambrian serpentine with which is associated granite, etc..................	Thetford, Black Lake, Que.
Coal......	Bituminous coal in Carboniferous strata.........	Sydney, and Inverness, Pictou and Cumberland cos., N.S.
Oil and sulphate of ammonia	In beds of highly impregnated shales of early Carboniferous age..................	Albert co., N.B; Hants, Pictou and Antigonish cos., N.S.
Gypsum. . .	In thick beds with anhydrite and associated with Carboniferous limestones..................	Hillsborough, N.B.; Windsor, etc., N.S.

GOLD.

The more prominent gold-bearing districts of the Canadian Appalachian region are two in number—the alluvial gold deposits of the Chaudiere river and its tributaries in southeastern Quebec, and the area occupied by the gold-bearing series of Nova Scotia. Gold has also been found in other portions of eastern Canada. Quartz veins carrying gold have been discovered, from time to time, in southeastern Quebec, while recently the mineral has been found in dikes of granite porphyry near Lake Megantic. Alluvial gold has been recovered from the tributaries of the Tobique river, in northwestern New Brunswick. Near Woodstock, in the same Province, a gold-bearing quartz vein has been opened. In Nova Scotia gold also occurs with the antimony deposits of West Gore, Hants county. At Gays river the lower Carboniferous conglomerate overlying the gold-bearing series contains gold, and has been worked on a small scale. In Cape Breton gold-bearing quartz veins have been discovered, and in some cases considerable development work has been carried out.

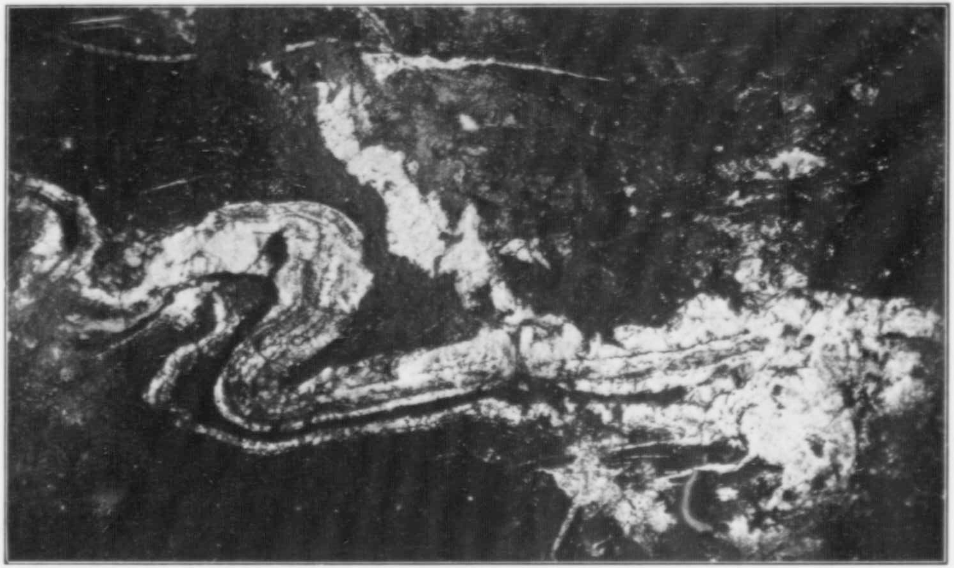
The gold-bearing districts within the gold-bearing series of Nova Scotia are of special interest because of their wide distribution, the regularity of their mode of occurrence, and the many points of similarity between them and the gold field of Bendigo, Australia. Gold was discovered in Nova Scotia in 1860, and mining operations then commenced. Two years after the discovery gold, valued at nearly $142,000, was recovered from the quartz veins, and since that time the annual production has, with the exception of one year, fluctuated between $200,000 and $628,000, nearly attaining the latter figure in 1902. In 1908, the production was probably not over $225,000.

The gold occurs in connexion with veins chiefly of quartz, but with some calcite. The veins commonly follow planes of stratification between beds or bands of slate lying within the thick group of quartzites that form the lower portion of the highly-folded gold-bearing series. The vein quartz is usually dark, ribboned, and dense. Pyrite and arsenopyrite occur in both the country rock and the veins, the pyrite being especially abundant in the slates and often lying along the planes of bedding. The distribution in the veins of these sulphides, with which the gold is doubtless associated in origin, is somewhat erratic; but,

Waverley Gold district looking west from Laidlaw Hill, N.S.

PLATE X.

Isaac Harbour, N.S.



Vein at Goldenville, N.S.

Valley of the Chaudière River, Beauce County, Que.

in general, pyrite is common and, when abundant, usually occurs along or near the borders of the veins. Pyrrhotite, chalcopyrite, and galena also occur, though but sparingly.

Gold occurs in the veins, in the slates, and, to a much less extent, in the quartzites. In the veins a large proportion of the gold within the zone of oxidation is free, occurring in the form of filaments, leaves and nuggets, or so fine as not to be visible. The precious metal is sometimes uniformly distributed through the veins, but usually is, to a varying extent, locally concentrated, and, commonly, the richer ground is situated towards the middle of the zones of quartz veins. The larger particles of gold are usually found at points of local enrichment at or near the junction of the main veins with branches.

The average yield of gold in some districts has been as high as 1½ ounces per ton, while in other districts, 100 ton lots or over have carried as high as 3½ ounces to the ton. More attention has of late been paid to the lower grades of ore that contain sulphides of iron and arsenic with gold. The total production from 1862 to 1906 averaged $8.97 per ton, while the ore mined in 1907 averaged about $4 per ton.

The gold-bearing series of Nova Scotia is a sedimentary group of rocks thrown into a system of nearly parallel folds following a general southwest and northeast direction. The beds are cut by numerous dikes, bosses, and batholites of granite, intruded after the folding of the sediments and later than the formation of the gold-bearing quartz veins. The sediments and the igneous rocks stretch along the whole length of the southeastern seaboard of the Province, occupying an area roughly estimated at 8,500 square miles, of which about two-fifths is underlain by the sedimentary beds.

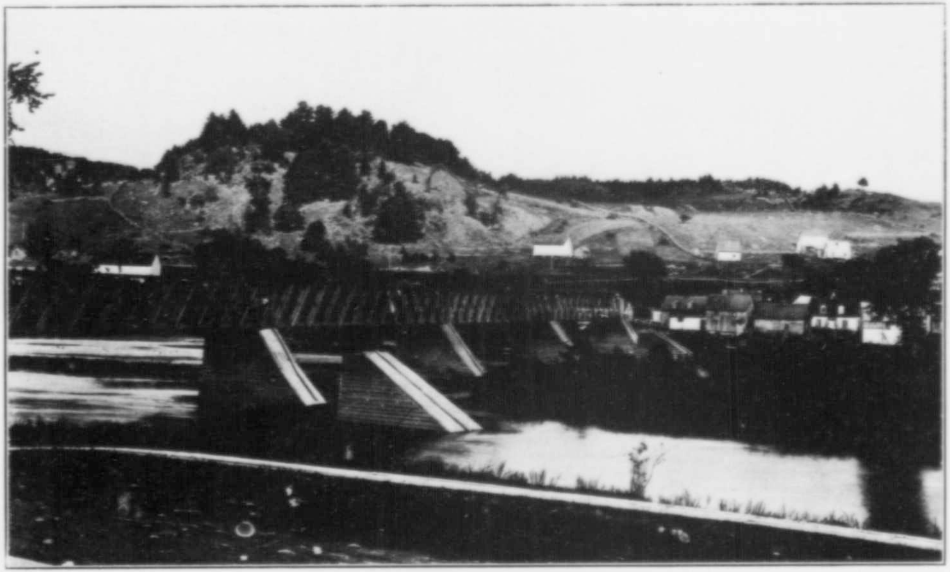
The gold-bearing series has generally been classed with the lower Cambrian, but may belong to the pre-Cambrian system. The series consists of two portions, of which the lower is formed very largely of quartzites, but with many interstratified beds and bands of slate; while the upper portion is almost entirely composed of dark slates. It has been estimated that the visible portion of the series is at least 25,000 feet thick, while its total thickness must be considerably greater, since neither the top nor the bottom of the series is exposed.

The auriferous quartz veins are almost entirely confined to the lower quartzite group. Most, if not all of the gold-bearing centres are situated at points of doming along the anticlinal axes of folding, and are scattered throughout the whole length of the area underlain by the gold-bearing series. Though mining operations have been conducted over only a small proportion of the known domes, yet nearly every dome is known, directly or indirectly, to be a point of occurrence of quartz veins, often gold-bearing. The number of these domes must be very large, for over considerable districts the average distance apart of the axes of the anticlinal folds is less than five miles, while the average distance between one dome and the next, along the same anticlinal axis, varies from ten to twenty-five miles. Though it is believed that most of the domes are centres of systems of quartz veins, it is not to be inferred that every point of doming will eventually prove to be a profitable gold-mining centre.

The auriferous quartz-veins are dominantly bedded veins formed along the planes of stratification of the slates, within, or more commonly, along the borders of bands of slate interbedded with the quartzites. Accompanying these are the so-called angulars—branches of the main, bedded veins, cutting irregularly across all structures and dying out at various distances from the parent mass.

Where the strata are closely folded and the opposing limbs of the anticlines make with one another angles of 45° or less, the veins are largely localized along the crowns of the arches, giving rise to a series of superimposed saddle reefs individually attaining thicknesses of fifteen to twenty feet or more, but rapidly thinning out along the legs of the folds. Where the folds are broader, the veins, as a rule, do not occur along the courses of the anticlinal axes, but at a variable distance to one side of them, and within a zone 200 feet to 1,000 feet wide, towards the centre of which the veins are generally thicker. These veins, situated along the legs of the folds, perhaps average from 4″ to 12″ in width, but are often larger.

The bedded veins frequently present a banded structure, and, together with the associated angulars, apparently formed during the slow folding of the gold-bearing series, when the operation of the mechanical forces would tend to cause the strata to open up at points of least vertical pressure. The veins, with the



St. François, Beauce, Que.

adjoining portions of the bands of slate in which they occur, are frequently plicated or corrugated. This plication appears to have been due to a flowage of the less resistant material of the argillaceous beds lying within the more rigid quartzites, towards the points of relief of pressure, situated, in the case of the sharper folds, along the anticlinal axes, but in the case of the broader folds to one side of the axes of folding.

Besides the above described veins, others occur cutting the planes of stratification at various angles. Many of these are auriferous and appear to be later in origin than the bedded veins, and to have formed after the folding of the strata.

The occurrence of alluvial gold in southeastern Quebec has long been known, the first recorded discovery having been made in 1824 at a point about fifty miles southeast of Quebec city, on the Gilbert river, a tributary of the Chaudière. In 1847 mining operations commenced, and since then have been intermittently continued.

Alluvial gold has been found and worked along the valley of the Chaudière, and many of its tributaries, from a point some distance below the mouth of the Gilbert river, eastward almost to the International Boundary. Alluvial gold has also been recovered from the valley of Ditton river, near the New Hampshire border, and along a narrow strip of country extending from Lake St. Francis southwestwards towards the Vermont border.

The total amount of gold recovered from these various areas has been estimated to be in the neighbourhood of $3,000,000, of which sum possibly one-half was obtained from a limited area of a few square miles in the valley of Gilbert river. Much of the gold was comparatively coarse, and from time to time various nuggets of considerable size were found, one being reported to weigh 52·5 ounces. Very small quantities of platinum and iridosmine were detected in some of the washings.

The main source of the gold has been the pre-glacial sands and gravels of the beds of older river systems, now largely concealed by deposits of boulder clay, as well as the sands, etc., of the present waterways that in many cases still occupy the valleys of the older streams. The auriferous gravels of the pre-glacial streams are in many places buried by seventy-five feet or more of glacial and recent deposits. The gold, while sometimes distributed with some degree of uniformity through the old river gravels, is more often locally concentrated, and the disintegrated portion of the underlying rock has often proved to be particularly rich. Gold has also been recovered from recent gravels that, during the natural processes of erosion, appear to have derived the metal from the pre-glacial deposits.

The source of the alluvial gold has not been definitely determined, but it has been shown that the alluvial deposits have generally been found in the neighbourhood of areas of pre-Cambrian volcanic rocks, or in positions where it would have been quite possible for the material to have been transported by streams from such areas. These volcanic rocks frequently carry copper ores, often with important amounts of gold, hence it seems not unlikely that the placer gold may have been derived from the pre-Cambrian volcanics in pre-glacial times, or, in some cases, in post-glacial times.

COPPER.

The presence of copper ores in the Eastern townships of Quebec was known as early as 1841, and by 1866 their occurrence at nearly five hundred localities had been recorded. The metal was extensively mined between the years 1859 and 1866, though during that period copper was the only element sought for, and the lower grade ores were discarded. With the decline in the price of copper that followed, mining operations almost ceased, until between 1875 and 1885, when several properties were reopened; and these, in some cases, have been continuously worked for a period of about thirty years, during which a depth approximately of 3,000 feet has been reached. During the second period of mining operations the sulphur and all the metallic constituents of the ores, except the iron, have been utilized. From 1899 to 1908 the amount of ore annually shipped has varied from 20,000 tons to 40,000 tons.

The main ores—those now being actively mined—consist chiefly of chalcopyrite, with small amounts of chalcocite and bornite, in pyrite. They occur in or closely associated with schistose porphyries and andesites of pre-Cambrian age that form part of a comparatively narrow, discontinuous zone of rocks of this system, extending from Lake Memphremagog northeast as far as Lake St. Francis. Similar deposits also occur to the east and west respectively, in the two remaining zones of pre-Cambrian rocks of this part of Quebec. Active mining is now virtually confined to the district southeast of Lennoxville, where the Eustis, Capelton, and Suffield mines are situated.

The ore deposits form much flattened lenses, lying in conformity with the foliation of the country rock and arranged *en échelon*. The individual lenses seldom exceed 20 or 30 feet in width, approximately 200 or 300 feet in length, with perhaps about the same dimension along the plane of dip. Smaller bodies are common. The walls of the ore bodies are usually ill-defined, the ore gradually disappearing, but sometimes one wall is more distinct than the other. The ores seem to have been associated in origin with the volcanic rocks with which they are now found, and to have been derived from the volcanics subsequent to the folding and shearing of these rocks, and deposited along zones of shearing where they have replaced the country rock.

It has been stated that, in a general way, the ores may be said to carry at the surface 4 per cent copper, 35 per cent sulphur, and $2 to $4 of gold per ton, while at greater depths they yield 3 per cent copper, 45 per cent sulphur, and 3 ounces of silver and a small amount of gold per ton. Apparently there is a surface zone of secondary enrichment, more marked in the case of the gold than in that of the copper.

A second class of copper deposits, consisting of chalcopyrite, bornite and chalcocite, occurs in irregular bodies in Ordovician sediments along a zone stretching northeast from Roxton for a distance of about one hundred miles. Practically all of many, and the greater part of most of the ore bodies lie in sedimentary rocks, generally limestone, and near intrusive dikes. At Acton a large amount of high grade copper ore, sometimes containing 30 per cent copper, was produced for several years.

A third class of copper deposits in southeastern Quebec, consists of chalcopyrite in pyrrhotite, with a little pyrite. These ores occur at various points along the contact of Ordovician strata and intrusive diabase, in the neighbourhood of the areas of pre-Cambrian rocks.

Ores of copper have been found at many places in Nova Scotia, and considerable development work has been done at a number of localities. At Cape d'Or, Cumberland county, native copper occurs in veins and along joints in the Triassic diabase; during

1907, over two tons of copper were produced. Chalcocite and malachite in nodules are found in sandstones, etc., over a wide area between Springhill and Pictou. Considerable work has been done in the chalcopyrite deposits found in pre-Cambrian felsites at Coxheath, near Sydney. Ores, chiefly of chalcopyrite, and carrying gold, have been worked in the Cheticamp district, Inverness county.

In New Brunswick various ores of copper occur at many points in the southern part of the Province, both with sedimentary and igneous rocks. Many attempts at mining have been made, but, so far, with little success.

LEAD.

Galena, usually finely disseminated or in veins and small pockets, occurs at various points in the lower Carboniferous limestones of Nova Scotia, more particularly in Colchester county. The mineral also occurs in veins in the pre-Cambrian rocks of Cape Breton. In New Brunswick veins of galena and sphalerite, with various other sulphides, cut the Silurian rocks along the coast of Chaleur bay; the lead sulphide also occurs at a number of other points in the Province, but in small quantities only. Galena has been found at various localities in the Eastern townships of Quebec, and, farther east, in Gaspé.

TIN.

Cassiterite, accompanied by various rare minerals containing lithium, fluorin, etc., occurs in small quantities, in pegmatitic bodies cutting granite, in the neighbourhood of New Ross, Lunenburg county, Nova Scotia.

CHROMIUM.

The existence of chromite in the serpentines of the Eastern townships of Quebec, and in Gaspé, has long been known. Mining operations, however, did not commence until 1894, though prior to that date several small shipments of the mineral had been made. So far mining has been almost entirely confined to the immediate neighbourhood of Black lake, Coleraine township, one of the centres of the asbestos industry. From 1894 to 1903 the annual production of ore averaged about 2,000 tons, but in 1906 the amount rose to over 9,000 tons, while the production for 1908 is estimated to have been 7,225 tons.

The deposits of chromite occur in pockets of irregular shape scattered through the serpentine bodies. The masses of ore usually appear to be altogether unconnected with one another, though not infrequently it happens that a series of pockets are found following one another, or in close proximity. Sometimes the ore bodies are of considerable size; the largest so far worked was about 80 feet long at the surface, had a variable thickness of from 5 feet to 50 feet, and had been followed to a depth of 340 feet, with an average angle of dip of about 60°. The content of chromic acid in the crude ore often averages above 40 per cent, and reaches, in the case of picked specimens, nearly 60 per cent. The ore bodies seem to represent differentiation products of the peridotite magma that gave rise to the enclosing rock, subsequently largely altered to serpentine. Though occurring in the immediate neighbourhood of the asbestos-bearing serpentine bodies, the chromite-bearing serpentines seldom contain any considerable amount of asbestos.

MANGANESE.

Ores of manganese have been found at many points throughout Nova Scotia, and comparatively small quantities have been mined at various times, it being estimated that, from 1876 to the present date, the total production has been less than 5,000 tons. The ores have been found in various formations, but most commonly occur in the lower Carboniferous limestones, as in Hants county at the Tennycape mine, where the ore consists chiefly of fibrous pyrolusite, with compact and granular pyrolusite, psilomelane and manganite. The ores of this district are very pure and are accordingly highly prized. In the upper part of the Carboniferous limestone the manganese minerals occur in seams and pockets, varying in quantity from a few pounds to a thousand tons or more; in the lower portion of the limestone the ores form seams and veins sometimes six inches wide.

In New Brunswick, ores of manganese, chiefly pyrolusite, and often very pure, occur in association with the lower Carboniferous limestone, and, at one time, were actively mined, especially in the neighbourhood of Sussex, where from one mine, at Mark-hamville, over 25,000 tons were produced prior to 1894, when operations ceased. From one pocket alone, 4,000 tons were taken. Bog ore, or wad, also occurs in New Brunswick, and one deposit a few miles northwest of Hillsboro, is, in places, 25 to 30 feet deep.

TUNGSTEN.

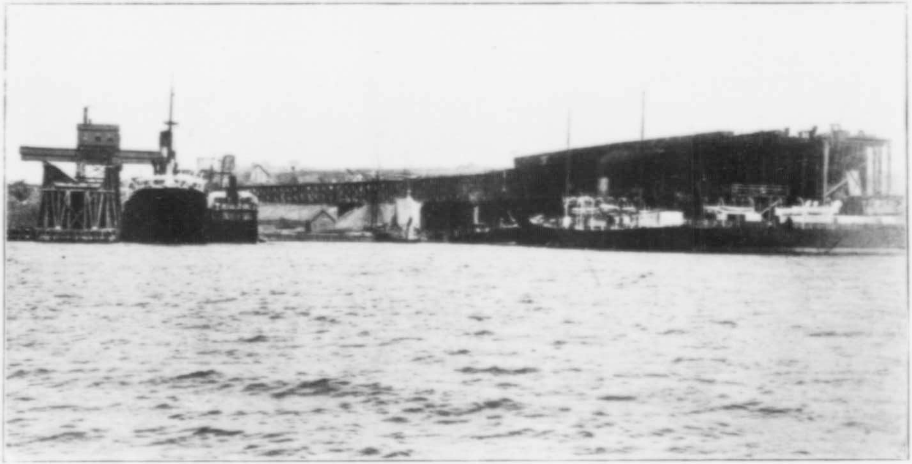
The tungsten-bearing mineral, scheelite, has been found at a number of localities in Halifax county, Nova Scotia. It occurs in quartz veins cutting the quartzites and slates of the gold-bearing series. The veins consist of quartz, mispickel and scheelite in varying proportions, while with these occur lithia mica, tourmaline, etc. Though the veins are of a regular bedded type like the auriferous quartz veins of the Province, they apparently do not carry gold, and are probably of different age and origin. Scheelite occurs also in the Malaga gold mining district, Halifax county; while at one locality in Inverness county from 300 to 500 pounds of hübnerite were recovered from a large detached mass of quartz lying at the outcrop of a lenticular vein of quartz cutting a gneissic or granitic rock of pre-Cambrian age. Scheelite has been found in Quebec, in Beauce county, in a quartz vein traversing pre-Cambrian rocks.

IRON.

Nova Scotia, though the seat of large iron and steel industries at Sydney, New Glasgow, Londonderry, and elsewhere, does not produce much iron ore, the amount in 1907 falling slightly under 90,000 tons. Deposits of iron ore of various kinds are widely distributed through the Province, but though numerous, are often small, and under present conditions, not of direct economic importance. Larger ore bodies occur near the Nictaux river in southwestern Nova Scotia, and near Londonderry on the south slope of the Cobequid hills.

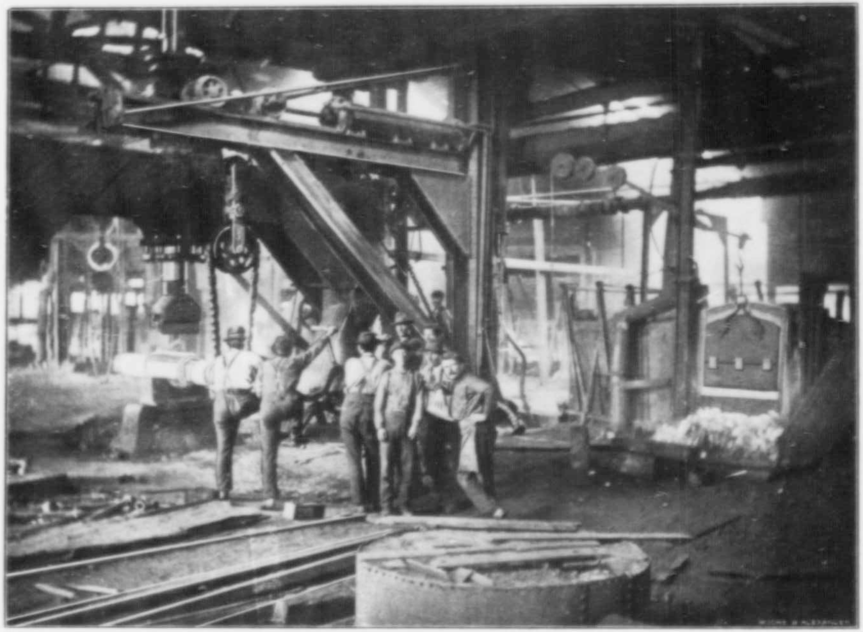
In the Nictaux-Torbrook district the ores are largely hematites occurring in fossil-bearing beds sometimes five or ten feet wide, and lying conformably within strata of upper Silurian and lower Devonian age. The ores were probably derived from the weathering of old land areas, by which iron from rocks, etc., passed into solution, was deposited as limonite, and afterwards changed to hematite and magnetite.

PLATE XIV.



Nova Scotia Steel and Coal Co's Piers, North Sydney, N.S.

Plate XV.



Forge Shop: Nova Scotia Steel and Coal Co.

The iron ores in the neighbourhood of Londonderry lie in Devonian slates and quartzites near the contact with the various acid intrusives, granites, granite porphyries, etc., forming the central portion of the Cobequid hills. The ores occur within a zone of fissuring, sometimes a hundred feet or more wide, that dips steeply and has been traced on the surface for a number of miles. The fissured zone is occupied by a complicated system of veins of ankerite, siderite, etc., often enclosing and surrounding large and small bodies of the country rock. Magnetite, hematite, and limonite are often very abundant, the relative amounts of the iron-bearing minerals varying widely from spot to spot.

In New Brunswick various ores of iron have been found at widely separated points, and in some cases have been worked at intervals for nearly fifty years. Low grade hematite ores with high contents of manganese occur at Jacksonville and elsewhere, near Woodstock in Carleton county. The beds are interstratified with slates of Silurian age, and vary in thickness from 1 to 15 feet. Recently, a large body of magnetite has been discovered on the Nipisiguit river, about twenty miles south of Bathurst. The ore body is exposed in places for a width of 30 or 40 feet, and outcrops over a length of nearly two miles. While the main body of the ore is nearly free of sulphides, iron pyrites is very abundant in the country rock forming the foot wall. The deposit occurs in schistose-quartz porphyry of early Palæozoic or pre-Cambrian age.

ANTIMONY.

Several veins of auriferous stibnite occur in the gold-bearing series at West Gore, Hants county, Nova Scotia. From the time of their discovery in 1880, until 1892, the deposit was worked solely as an antimony mine, and nearly 3,000 tons of ore were shipped. Though it is estimated that the ore carried two to three ounces of gold to the ton, the presence of the gold was long unsuspected. At present the annual shipments of ore average about 2,000 tons.

The ore occurs in nearly vertical veins, one of which has been traced at the surface for at least 1,200 feet, and followed downwards for over 500 feet. It consists of a gangue of slate, calcite and quartz, cut by a number of quartz stringers. Pyrite, mispickel and galena are abundant in places. The ore, sometimes solid stibnite, sometimes stibnite and quartz, varies in width from a few inches up to seven feet, and generally follows the hanging wall, which is always clear cut, while the foot-wall is irregular and indistinct. A varying quantity of gold is always present, and is highest where the proportion of stibnite is greatest. Except where a cross vein of quartz occurs, none of the gold is free, even in ore assaying as high as ten ounces of gold to the ton.

Native antimony and stibnite occur in New Brunswick, at Prince William, about twenty-five miles west of Fredericton. Mining has been conducted at this spot at various times since 1863. The antimony ore occurs in quartz veins cutting slates and quartzites in the neighbourhood of intrusive masses of granite and diabase. The native antimony is apparently largely or solely confined to the upper portions of the veins. Antimony minerals in considerable variety occur at South Ham, Quebec.

BARIUM.

Deposits of barites, widely distributed through north-eastern Nova Scotia: at Five Islands, Colchester county, and elsewhere, have been worked from time to time. But, in general, the deposits have proved to be pockety and difficult to work at a profit. Barite has been found under more favourable circumstances at Lake Ainslie and North Cheticamp, in Cape Breton, and since about 1890 the shipments of the mineral have averaged nearly 2,000 tons per annum.

At Lake Ainslie the barites, with some calcite and fluorite, forms a series of roughly parallel veins cutting pre-Cambrian felsites. The veins, though showing many irregularities in size, are comparatively persistent, one nearly vertical vein having a width of 7 to 14 feet for a depth of at least 250 feet, as shown on a hillside. In several instances the veins locally attained thicknesses of 20 feet. At North Cheticamp the barites veins, with a varying content of quartz, calcite, and fluorite, form a group of pinching and swelling veins running parallel with the curving planes of schistosity of the enclosing pre-Cambrian schists.

ASBESTOS.

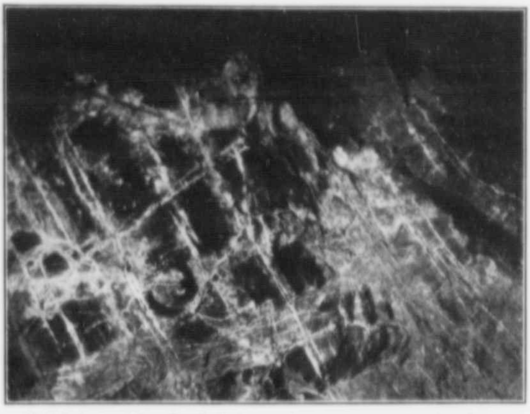
The mining of asbestos in the Eastern townships of Quebec commenced in 1876. In 1878 some fifty tons were taken out,

Veins of Asbestos at Thetford, Que., 1889.

PLATE XVII.

Bell Asbestos Mine, Thetford, Que.: view across Main Pit.

PLATE XVIII.



Bell Asbestos Mine, Thetford, Que.: view in cross-cut, showing large veins of Asbestos.

and since then the production has steadily increased, until, in 1908, it has reached over 65,000 tons of asbestos, and above 25,000 tons of asbestic (pulverized rock containing short fibres of asbestos).

The asbestos occurs in certain serpentine masses, usually of small area, that form part of a discontinuous belt of similar rocks reaching northeast from near the west side of Lake Memphremagog nearly to the Chaudière river, a distance of about 150 miles Most of the mines, however, are situated within a few miles of one another, in the vicinity of Black lake and Thetford. A second centre, East Broughton, lies to the northeast, about twenty-five miles away, while a third centre is at Danville, about forty-five miles to the southwest. The mines are worked as open pits, and one of them, at Black lake, is over 700 feet long by 200 feet broad, and in places 165 feet deep.

PLATE XIX.

Dominion Asbestos Co's Pit, Black Lake, Que.

The serpentine with which the asbestos is associated usually occurs in comparatively small bodies, and has been derived from the alteration of peridotites that, with possibly one exception, appear to be of Ordovician age, and lie between Ordovician sediments on the east, and slates and schists of pre-Cambrian or Cambrian age on the west. Associated with the serpentine are bodies of pyroxenite, hornblende granite, and diabase: the granite is thought to be nearly contemporaneous in age with the serpentine.

The asbestos is of the chrysotile variety, and occurs in gash veins varying in width from mere lines to sometimes 3″ across. The fibres of the mineral usually stand at right angles to the side walls of the veins, and sometimes extend completely across, but often there is, towards the centre, a film of chromite or magnetite.

The veins are exceedingly numerous, in one instance seventy veins were counted in a breadth of only two feet. Their courses often appear extremely irregular and their widths inconstant. The main veins, however, often show an approach to a rectangular arrangement, as though indicating original jointing planes in the rocks, but as the serpentine has been much shattered, there is also a series of minor veins, sometimes more or less parallel with one another. Partings also appear to have developed around the corners and edges of the larger blocks, giving rise to small, crescent-shaped veins.

The asbestos veins are invariably accompanied on both sides by bands of pure serpentine that grade into less altered peridotite. It has been shown that the proportion between the width of the asbestos vein and the combined breadth of the two accompanying bands of pure serpentine is fairly constant, about as 1:5·6. From the preceding statements it has been concluded that the serpentinization of the walls of the asbestos veins preceded the formation of the asbestos, and further, that the asbestos veins represent replacements of the serpentine on either side of fracture lines. Microscopic examination shows the asbestos fibres to grow at right angles outward from both sides of such fractures.

COAL.

Coal is the most important product of the mines of the Appalachian region. With the exception of thin and unimportant seams in the Devonian rocks of Gaspé, its occurrence is confined to New Brunswick and Nova Scotia, and the latter Province is by far the chief producer, yielding, in 1908, nearly two-thirds of the total amount of coal mined in Canada. The coal is all bituminous, of good quality, well adapted to the production of coke and gas, and also good steam coal. In the eastern provinces it has been mined for 200 years or more, though it was not until the close of the first third of the last century that the amount produced became notable. The total annual production first reached a million long tons in the year 1880, in 1900 it had increased to above 3,000,000 tons, and in 1908 had reached nearly 6,000,000 tons. Of the total production in 1908, almost the whole was mined in Nova Scotia, less than one per cent being raised in New Brunswick. The coal districts are five in number and are as follows, the accompanying figures indicating, approximately, the percentage of the total amount mined in each field: Sydney coal field, 71·9 per cent; Inverness county, 6·0 per cent; Pictou county, 12·7 per cent; and Cumberland county, 8·8 per cent; all in Nova Scotia; and Grand Lake in New Brunswick, 0·6 per cent.

The Sydney coal fields extend for thirty-two miles along the sea coast of the northeastern extremity of Cape Breton island. The coal measures have been estimated to underlie a land area of about fifty-seven square miles, as well as a large area, in which mining operations are conducted, underlying the sea. The strata are almost free from faults of any size and have gentle dips. Conformably underlying the productive measures occurs the Millstone-grit, a group of sandstones and shales having a thickness of about 4,000 feet; beneath these lie the sandstones, shales, and limestones of the Carboniferous limestone formation, and below these the basal conglomerates, etc., outcropping to the southward and overlapping pre-Cambrian rocks. The total thickness of the measures beneath the productive coal measures is estimated to be about 8,500 feet.

Since they are cut off by the sea, only a portion of the productive coal measures, in all about 1,800 feet, is exposed. The gently dipping strata are traversed by three anticlines, so that the coal seams lie in four basins—Cow Bay, Glace Bay, Sydney Harbour, and Bras d'Or basins. The strata are largely of shales and sandstones, and contain in all from forty to fifty feet of coal. The total number of seams is twenty-four, and of these, six are 3 feet or upwards in thickness. The similarity and persistence of the seams over the whole area is very remarkable. In a few instances they are split by the gradual thickening of their clay partings; and, sometimes, seams that are of workable thickness and good quality at one place, become unavailable at no great distance.

The coal fields of Inverness county include a series of narrow areas extending for over fifty miles along the western shore of Cape Breton island. The areas of the productive measures form part of the eastern rim of a basin, the greater part of which has been removed by erosion. The productive measures on their easterly side are underlain by the Millstone-grit and the various formations of the lower Carboniferous, in their turn resting on pre-Cambrian rocks. At various localities seams from 2 to 12 feet in thickness occur, usually with rather low angles of dip.

Besides the above mentioned two coal producing districts, coal also occurs on Cape Breton island, in Richmond county, where seams up to 8 feet in thickness, and one of 11 feet—but of poor quality—have been described.

On the mainland of Nova Scotia, the Pictou coal field has an area of about twenty-five square miles. Though the field is small, the coal seams are often of great size, one being 38 feet in thickness. The geological structure of the district is very intricate, faults, often of considerable magnitude, are numerous, and the productive measures are almost completely girdled by faults.

The Pictou field may be conveniently divided into three districts, namely, the central, western, and eastern. In the central or Albion district, four seams have been worked, one 38 feet thick, a second varying in thickness from 22 feet to 38 feet, a third 10 feet to 13 feet thick, and a fourth 13 feet to 20 feet thick. The beds dip at angles of 10° to 30°, are overlain by 1,000 feet of shales, and are conformably underlain by the Millstone-grit. The western or Westville district is separated from the central division by a fault with a throw estimated at 1,600 feet to 2,000 feet. Three seams of the western district are believed to be equivalents of seams in the central district. In the eastern or Vale district, the strata lie in a synclinal basin with a number of coal seams—of which two have been extensively worked—outcropping along the southern side of the basin.

In Cumberland county there are two productive areas: one, situated on the coast, may be called the Joggins area, while the other is at Springhill, about fifteen miles east of the first. In the Joggins area the coal seams occur along one side of a very broad synclinal basin of Carboniferous measures that, towards the centre of the basin, are overlapped by Permian beds. In the remarkable section of strata exposed along the coast of Chignecto

Coal Mine Point, South Joggins, N.S.

Dominion No. 2 Colliery, Glace Bay, N.S.: Phalen and Harbour Seams.

PLATE XXII.

Mine at Stellarton, N.S. Old Ford Shaft.

Carboniferous rocks east of Coal Mine Point, Joggins, N.S.

bay over seventy coal seams outcrop. Several seams are 5 to 6 feet thick, while one measures 9′-6″; but with 2′-6″ of shale partings. In the Springhill basin the geological structure is less simple and the strata dip more steeply than in the Joggins area, the seams being worked along slopes of 30°. In the Springhill district eight seams varying in thickness from 2′-4″ to 13′-0″, have been recognized.

In New Brunswick, though Carboniferous measures occupy an area of upwards of 10,000 square miles, the productive measures seem to be localized in a comparatively small area about Grand lake, some seventy miles north of St. John. Outside of this area coal seams have been found at a number of points in the northeast part of the Province, where seams 6″ to 10″ wide are known to occur.

Coal mining has been carried on for many years in the Grand Lake district, where in the nearly flat, gently undulating measures, occur two seams, one of 20″ to 24″, and the second from 6″ to 10″ thick. Sometimes the two seams approach so closely as to be worked as one, the parting being reduced to 6″ of shale. In places the nearly flat seams lie so close to the surface that they are worked by open pits, and nowhere over the one hundred square miles or so occupied by the coal basin, does it seem probable that the coal seams, at present worked, lie more than 60 feet beneath the surface, nor does it seem very probable that the relatively thin measures contain workable seams at any greater depth.

OIL SHALE.

In New Brunswick the Albert oil-bearing shales of very early Carboniferous age are exposed at intervals for about fifty miles, from near Dorchester westward to a point south of Norton. The Albert shales are usually highly inclined, much faulted and folded, and in thickness they often reach over 1,000 feet. At many points in the shale belt occur beds or bands of shales, dark brownish or dark grey in colour, that are very rich in bituminous matter. At least five such bands, varying in thickness from one to five feet or more, have been recognized. When retorted, these richer shales have been found to yield from 30 to 80 gallons of crude oil, and from 65 to 112 pounds of sulphate of ammonia per ton. The dense, crude oils, when further treated, yield lubricating oils,

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burning oils, and paraffin wax, while by-products, such as naphtha, benzole, aniline, etc., may be produced.

Many years ago, in the Albert shales, at Albert mines in the vicinity of Hillsborough, a large, vein-like body of albertite was found. This vein of nearly pure bituminous matter was mined during a period of twenty years, and yielded in all over 200,000 tons. The vein was worked to a depth of about 1,300 feet, and for a length of about half a mile.

Oil-bearing shales of Carboniferous age also occur at various points in Nova Scotia, as in Hants, Pictou, and Antigonish counties. In Cape Breton somewhat similar dark shales are found at Lake Ainslie and McAdam lake; oil shales are also found in Gaspé.

In Scotland very similar shales, no richer in oil and sulphate of ammonia, have been profitably mined, retorted and distilled for many years.

At some of the localities, both in New Brunswick and Nova Scotia, attempts have been made by means of borings to obtain oil from the shales, but so far without proved profitable results.

A considerable amount of boring for oil has been done in Gaspé, but without commercial success.

GYPSUM.

Beds of gypsum are associated with the lower Carboniferous limestones in New Brunswick and Nova Scotia, more particularly over the territory around the head of the Bay of Fundy, and extending, in Nova Scotia, eastwards around the Bay of Minas, and northeastwards into Cape Breton. The gypsum is mined at a number of points, more notably at Hillsborough in New Brunswick, near Amherst, at Windsor and other places in Hants county, and in Victoria county. In 1907 the two provinces produced nearly 450,000 tons.

The gypsum deposits are often very extensive, forming beds 200 feet or more thick. The mineral is of various colours, often snow-white. With it occurs anhydrite, sometimes in alternating beds, while at other times the two minerals are more irregularly associated.

BUILDING AND ORNAMENTAL STONES.

The bodies of granite, in many cases apparently of Devonian age, found in many districts in the Appalachian region, have been quarried at a number of points. In the Eastern townships of Quebec, near Staynerville and Stanstead, the granite is largely quarried for paving blocks, also for ornamental purposes. In New Brunswick a number of granite quarries have been opened near St. George, and the rock is also quarried at several localities in Nova Scotia.

In the Eastern townships marble for ornamental purposes is extensively worked near Stanbridge and elsewhere. Roofing slate is obtained from near Kingsbury. In New Brunswick and Nova Scotia, the various sandstones of the Carboniferous and Permian have furnished excellent stone for structural purposes, also for grindstones.

MISCELLANEOUS.

Clays and shales suitable for industrial purposes occur, but have not been extensively utilized. Infusorial earth occurs in New Brunswick and Nova Scotia. Moulding sand is produced to a limited extent.

CHAPTER III.

THE ST. LAWRENCE LOWLANDS.

GEOLOGY.

The *St. Lawrence lowlands*, floored with nearly horizontal Palæozoic strata, and bounded on the north by the southern edge of the Laurentian plateau, represent in Canada the northeastern extension of the great plain-like area of the interior of the continent. Commencing near the city of Quebec, the lowlands stretch southwesterly on both sides of the St. Lawrence, with slightly diverging boundaries, until, at Montreal, the level country is approximately 120 miles wide. Beyond Montreal, the northern boundary pursues a westerly course up the Ottawa valley to a point about fifty miles beyond Ottawa city, where a ridge of broken country—a low spur of the Laurentian highlands—projects southerly, crossing the St. Lawrence between Brockville and Kingston to join the elevated Adirondack region of northern New York. Near Kingston, at the foot of Lake Ontario, the lowlands again commence and occupy the portion of the Ontario peninsula lying between Lakes Huron, Erie, and Ontario, and bounded on the north by a nearly straight east and west line from Kingston to the foot of Georgian bay, Lake Huron.

The region thus outlined, with a length of about 600 miles and an area of more than 35,000 square miles, nearly all fertile farming land, is divisible into three portions, each a sloping, plain-like region, usually mantled with heavy deposits of glacial drift, etc., that largely hide the underlying, nearly horizontal sediments. Though essentially a farming region, the portion of the country lying between Lakes Huron and Erie supports valuable petroleum, gas and salt industries.

The most easterly of the three divisions of the St. Lawrence lowlands comprises the portion lying east of the spur of crystalline rocks crossing the St. Lawrence below Kingston. Its northern boundary is, in general, marked by an abrupt rise of the Laurentian

Western end of Canadian Fall, Niagara Falls, before curtailment of 415 feet.

hills, while on the eastern side lies the hilly, semi-mountainous Appalachian tract. Within this roughly triangular area, the land nowhere rises more than 500 feet above the sea, and, below Montreal, the districts immediately bordering the St. Lawrence have a general elevation of less than 100 feet, and, save in the case of a few isolated, abruptly rising hills of igneous origin, the lowlands on either side of the river never rise to 300 feet above sea level.

The second division of the St. Lawrence lowlands fronts on Lake Ontario, forming a plain-like area that at first usually rises rather abruptly from the lake (itself 246 feet above the sea), and then stretches inland with gradually increasing heights, sometimes reaching 850 feet above the sea. This area, comparatively narrow in the east, is bounded on the north by a marked escarpment, with a drop along its northerly facing slope of between 50 and 100 feet. Westward the district is limited by the Niagara escarpment, which runs in a northwesterly direction from the Niagara peninsula through the Indian peninsula separating Lake Huron and Georgian bay, and is continued westerly into Michigan by the northward facing cliffs of the Manitoulin islands.

The Niagara escarpment, the natural dividing line between the two western divisions of the St. Lawrence lowlands, presents a general abrupt rise of 250 to 300 feet. In the Niagara peninsula this amount represents the total rise of the country to the level of the third and westernmost division of the lowlands, but farther northwest the escarpment, though still a distinct feature, is only part of a narrow strip of rapidly rising ground, whose summit reaches in places an elevation of 1,700 feet, nearly a thousand feet above the low, flat-lying country stretching easterly from its foot towards Lake Ontario. The third division, lying between Lake Huron and Lake Erie, and bounded on the east by the Niagara escarpment, has, in the northwest, as already implied, a maximum elevation of 1,700 feet or more, from which point the surface slopes towards the level of the lakes on either side, the waters of Lake Huron standing at 581 feet, and those of Lake Erie at 572 feet above the sea.

The St. Lawrence lowlands are underlain by gently dipping beds of sandstone, shale, and limestone of Palæozoic age (Ordovician, Silurian, and Devonian), appearing to succeed one another without a break. Over certain areas they lie in low, very broad, dome-like folds, and at times they are traversed by faults of considerable magnitude, but, compared with the highly flexed and faulted measures of the Appalachians in the east, they may be said to be undisturbed. This sharp contrast in the general attitude of the beds of the two districts which, in Quebec, directly border one another, is also accompanied by differences in the character of the rocks, and in the fossils embedded in them. The materials composing the two sets of rocks appear to have been laid down under different conditions, and perhaps in separate basins.

In southeastern Quebec, the low, level country bordering the St. Lawrence, and underlain by nearly horizontal stratified rocks, extends eastward into the districts occupied by the highly disturbed measures of the Appalachian region. No marked changes in the physical aspect of the country are apparent in passing from one region to the other, but on approaching from the west the boundary between the two provinces, the effects of disturbances in the underlying rocks gradually appear, and finally they are found sharply folded. The boundary between these two distinct geological provinces runs northeast from the foot of Lake Champlain to the city of Quebec, and is marked by the St. Lawrence and Champlain fault, along which, and accompanying lines of dislocation, were relieved the stresses and strains due to the action of the mountain building forces that, in the east, folded, plicated, and faulted the strata, and, at times, thrust great blocks up and over westerly lying beds. The measures lying on the eastward shelving extension of the crystalline rocks of the Laurentides largely escaped these disturbing forces through the yielding of the strata along the northeasterly trending lines of weakness.

The Palæozoic strata of the eastern division of the St. Lawrence lowlands, in eastern Ontario and Quebec, are almost altogether of Ordovician age. In the districts about the junction of the Ottawa and St. Lawrence rivers, large areas are floored with a sandstone termed the Potsdam, that appears to represent the upper Cambrian of New York state. The Potsdam sandstone is brought to light along the eroded summit of a low, broad dome, and appears to be the oldest rock of the lowlands. A lithologically similar rock occurs at intervals along the northern border of the Palæozoic measures, where they overlap the crystalline rocks of the Laurentide hills. But these lower sandstones are not all of the same age, for, in some cases at least, they mark shore deposits laid down during successive intervals as the Ordovician seas gradually crept up over the land. Above the Potsdam occurs an arenaceous, dolomitic limestone known as the Beekmantown, or, as it was originally called, Calciferous. On the Beekmantown lies a group of shales and sandstones overlain by limestones, known as the Chazy. Above the Chazy occurs the Trenton group, usually composed of limestones and shales, and sometimes divided into three members, Lowville or Birdseye, Black River, and Trenton. Overlying the Trenton is the Utica formation, largely of dark bituminous shales, and these are followed by the dark grey shales, sandstones, and limestones of the Hudson River or Lorraine.

In the Province of Quebec the various divisions of the Ordovician, in a general way, occur in bands of successively younger formations roughly paralleling the edges of the area of ancient crystalline rocks on the north; the oldest members occur to the north and the youngest generally border the St. Lawrence and Champlain fault. In the triangular area lying between the Ottawa and St. Lawrence rivers the disposition of the various members is more basin-like, the younger beds occurring towards the centre of the area. All the divisions appear to succeed one another conformably, though it is quite possible that there may be important breaks masked by this general appearance of conformity. The total volume of rocks composing the Ordovician system is very great; in the neighbourhood of the city of Montreal there are 4,350 feet of strata from the base of the Potsdam to the highest members of the Lorraine there exposed. But the thicknesses of the different members of the system, as well as the characters of the different formations, vary locally.

Although the Ordovician strata occupy almost the whole of the district at present under discussion, there are also areas containing remnants of younger formations. A few, small, isolated basins in the Ottawa district, and in Quebec east of the St. Lawrence, contain considerable volumes of red shales, etc., thought to be of early Silurian age. In places these beds rest unconformably upon the underlying measures, showing, probably, that prior to their deposition the district had been elevated and the strata slightly deformed. Also, near Montreal there are certain limited deposits containing fossils of early Devonian age. These younger members thus furnish evidence that the lower plains were once covered by many hundreds of feet of strata, since almost entirely removed by erosion. This conclusion is strengthened by the phenomena exhibited by the isolated eminences of the Monteregian hills.

The Monteregian hills are eight in number, and six of them, including Mount Royal at Montreal—the most westerly of the group—lie in an approximately east and west line at distances of about ten miles apart. They form eminences circular or oval in outline, only a few square miles in area, and rising abruptly 600 to 1,200 feet above the surrounding level country. The flanks of the hills are formed of sediments variously altered and hardened, while the central portions, the cores, are composed of igneous rocks of alkali types, including different alkali syenites, nepheline syenite, essexite, etc. The igneous portions appear to represent laccoliths, or conduits, that may have led to the old land surface. The character of these igneous hills is such as to indicate that at the time of their formation there probably was an additional thickness of strata over the surrounding country of not less than 2,000 feet, all of which has since been removed. This conclusion is strengthened by the occurrence of fragments of Devonian rocks in dikes from the igneous pipes.

In the second division of the St. Lawrence lowlands, that borders Lake Ontario, and is bounded in the west by the Niagara escarpment, Ordovician measures are again widely exposed. The oldest are generally of Lowville (Birdseye) age, resting on the pre-Cambrian rocks of the north; they dip gently under and are succeeded towards the south by successively higher divisions of the Ordovician, until, in the neighbourhood of Toronto, the highest members of this system disappear beneath the Silurian that occupies the rest of the country, forms the outcropping beds of the Niagara escarpment, and extends farther west over the sloping plain of the western portion of the Ontario peninsula.

The bounding line between the Ordovician and Silurian crosses Lake Ontario from New York state, and runs nearly north from Toronto to the foot of Georgian bay. On the Manitoulin islands the Ordovician measures appear from under the Silurian along the northerly facing cliffs. What is usually considered the lowest division of the Silurian, the Medina, consists of variously coloured sandstones and shales, over a thousand feet thick in the

Niagara peninsula, but towards Georgian bay decreasing to a tenth of this volume. The Medina, possibly in part of Ordovician age, is succeeded by the Clinton, represented in Ontario usually by less than fifty feet of sandstones and shales. Overlying these are the beds of the Niagara group, chiefly limestones, some 200 feet thick in the Niagara district, but double that amount at Cabots head, at the extremity of Indian peninsula.

To the more resistant Niagara limestones is due the formation of the Niagara escarpment, bounding the third division of the St. Lawrence lowlands. The succeeding Silurian formations spread over a considerable part of the Ontario peninsula between Lakes Huron and Erie, where the strata still occur in northward trending bands of varying width. The Niagara limestones are overlain by the limestones and dolomites of the Guelph, represented along the Niagara river by a few feet only, but increasing northward to 100 feet and more. Above the Guelph is the Salina group, 200 to 300 feet thick, and composed of beds of gypsum, salt, dolomite, and dark shales, measures evidently deposited in a slowly evaporating sea. Overlying the Salina is a group of beds, sometimes measuring 40 feet or more in thickness, and composed of dolomites, etc., which, in Ontario, represent the highest Silurian present and apparently indicate a return to marine conditions of deposition.

The lowest beds of the Devonian system are wanting in the Ontario region, which, during the opening epochs of this period, appears to have been uplifted and slightly eroded. The lowest Devonian of Ontario is, in places, represented by the light coloured Oriskany sandstone, seldom more than twenty-five feet thick, while in other places the succeeding Devonian division rests directly on the Silurian measures. The Onondaga consists largely of limestones, often 150 to 200 feet thick. It occupies a narrow strip along the foot of Lake Erie, expanding in the Ontario peninsula into a wide band. The dark shales of the Hamilton succeed the Onondaga, and are, in places, overlain by still younger Devonian strata. West of the band of Hamilton measures, lower divisions of the Devonian again appear at the surface as the result of a low fold, and on the Detroit river Silurian strata appear.

The various ancient seas and embayments in which the Palæozoic strata of the St. Lawrence lowlands were deposited, were not limited to the continuous areas now underlain by the stratified beds of this era. In Ontario, beyond the northern boundary of these beds, occur outliers of similar strata, resting on and surrounded by pre-Cambrian crystalline rocks. These outliers are evidently erosion remnants of a once more extensive covering, which, in the Ottawa valley, seems to have extended as far as Lake Nipissing. An outlier of Niagara limestone also occurs far up the Ottawa valley, at the head of Lake Timiskaming, deposited in a Silurian sea coming either from the south, or, possibly, from the north.

In the east also, the Palæozoic beds once occupied a wider territory. Trenton and Utica beds occur on the shores of Lake St. John, 100 miles west of the St. Lawrence, at the head of the Saguenay river. At intervals along the north shore of the St. Lawrence river and gulf, Ordovician beds occur, while towards the Strait of Belle Isle, Cambrian beds repose on the pre-Cambrian. The large island of Anticosti, in the Gulf of St. Lawrence, is composed of Ordovician and Silurian strata dipping gently southwards.

ECONOMIC MINERALS.

Underlain by slightly disturbed Palæozoic measures, the geological history of the St. Lawrence lowlands has not been favourable to the development of metallic minerals. Southwestern Ontario is, however, the principal seat in Canada of the petroleum and salt industries, while throughout the whole region the brick, tile, and cement industries are becoming increasingly important.

TABULAR DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE ST. LAWRENCE LOWLANDS.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Oil.......	Occurs in natural reservoirs usually at the horizon of the Onondaga (Corniferous) in the gently undulating, nearly horizontal Palæozoic measures of southwestern Ontario....................	Petrolia, Tilbury, Leamington, etc., Ont.
Natural Gas.....	Occurs in natural reservoirs in the Guelph, Clinton, Medina, and Trenton formations in the gently undulating, nearly horizontal Palæozoic measures of southwestern Ontario...........	Welland, Haldimand, Essex cos., Ont.
Salt.......	In beds of rock salt (or as brine) in the Salina formation in the gently undulating, nearly horizontal, Palæozoic measures of southwestern Ontario..................................	Windsor, Sarnia, Wingham, etc., Ontario.
Gypsum...	In beds in the Salina formation in the gently undulating, nearly horizontal, Palæozoic measures of southwestern Ontario................	

OIL AND NATURAL GAS.

The principal oil fields of Canada are situated in the peninsula of southwestern Ontario, between Lake Huron and Lake Erie. The first oil was found in Lambton county in 1862, though it is recorded that Manitoulin island was the site of the first oil discovery in Canada. Until quite recently, the Lambton County fields, in which there have been about 11,000 producing wells, were by far the largest producers, but in 1907, the new Tilbury district, in Kent county, contributed about forty-four per cent of the total production, which for that year reached 27,621,851 gallons of crude oil.

Besides the two oil centres of Petrolia and Oil Springs in Lambton county, and the Tilbury district in Kent county, other important districts are: Bothwell and Coatsworth in Kent, Dutton in Elgin, Leamington in Essex, and Moore in Lambton. The oil districts are all situated within an area underlain by Devonian strata, usually on an anticlinal axis, and the petroleum is largely obtained from horizons in the Onondaga (Corniferous) at varying depths in the different localities. At Petrolia the oil-bearing horizon is usually between 450 feet and 480 feet beneath the surface; at Bothwell it is at about 600 feet. Oil has, in places, been obtained sparingly from the Trenton; while the Leamington oil "pool" was found in the Guelph at a depth of 1,075 feet.

When first drilled, the natural pressure often drives the crude oil to the surface, and sometimes produces gushers, such as one well in Raleigh township, Kent, that for a time yielded 1,000 barrels a day. After the flowing period, the oil has to be pumped to the surface. While some of the smaller districts become exhausted in a few years, in some cases the pool being only a few hundred feet wide and perhaps a quarter of a mile long, others have continued to furnish oil for a long period. The Lambton field, discovered over forty years ago, is remarkable in this respect, and though the average yield per well is small, the district still continues to produce a large amount of oil and some wells have been active producers for forty years. One group of 100 wells at Petrolia, for instance, produces about 150 barrels per month. In the Bothwell field, shortly after its discovery, a group of ninety wells furnished, on an average, about 1,250 barrels per month.

Natural gas is produced and used in large quantities in south-western Ontario. Although found almost everywhere associated with the petroleum, the yield in many of the oil districts is comparatively small; while in Haldimand and Welland counties a large supply appears to be available. In these counties the gas horizons are in the Clinton, Medina, and Trenton. In Welland county, one group of fourteen wells, drilled to depths of about 3,000 feet, regularly produces over 30,000,000 cubic feet of gas per day. In Essex county a single well driven 1,020 feet to a horizon in the

Guelph yielded gas at the rate of 10,000,000 cubic feet per day. The importance of the natural gas industry is shown by the marked increase of late years in the annual value of the output, that in 1903 was valued at less than $200,000, but had reached a little over $745,000 in 1907.

PEAT.

Large peat bogs occur at a number of points in Ontario and elsewhere in Canada, but not all of the bogs are suitable for the production of fuel, and, ultimately, it seems more than probable that, with the help of artificial fertilizers, many will be turned to agricultural purposes.

SALT.

At present Ontario is the only province producing salt, and the amount for 1908 reached nearly 80,000 tons, while during the last period of five years the annual production averaged about 64,000 tons. The discovery of the salt deposits was accidentally made in 1865 near Goderich during the sinking of a bore-hole in search of oil. Since then the salt deposits have been found to occupy a buried basin along the shores of Lake Huron, underlying an area of over 2,500 square miles in Essex, Lambton, Middlesex, Huron, and Bruce counties. The salt occurs in the Salina formation of upper Silurian age, in which the beds of the mineral sometimes reach a thickness of 250 feet, though then, generally with partings of shale. One well, in Lambton county, penetrated a total thickness of 705 feet of salt in 805 feet of strata, between depths of 1,210 and 2,015 feet beneath the surface.

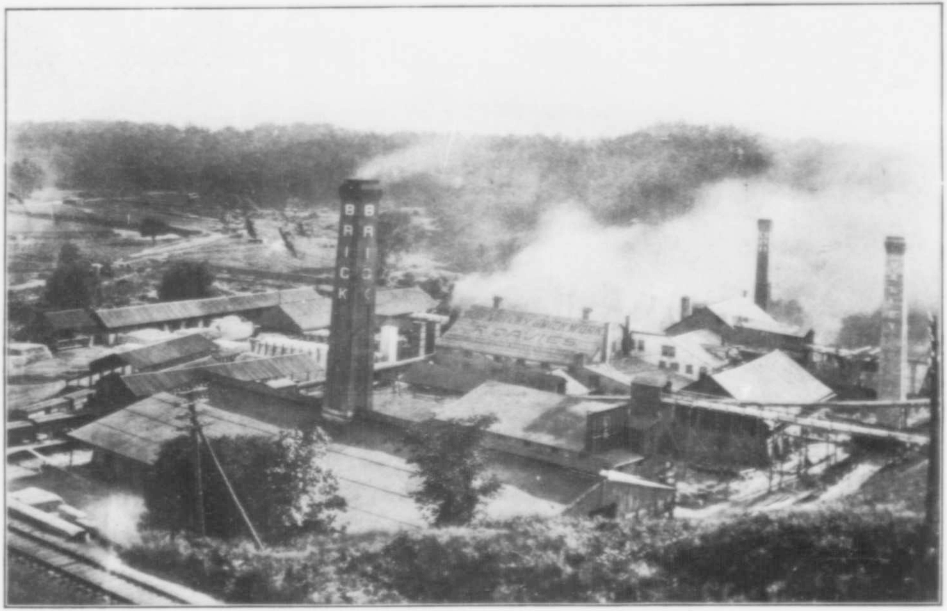
The salt beds have generally been found in wells ranging in depth between 970 feet and 1,650 feet. The salt is recovered either by forcing fresh water down the wells or by taking advantage of natural flows of underground water, and pumping the resulting brines to the surface to be evaporated. Some of the main salt-producing centres are Sarnia, Windsor, Goderich, Wingham, and Sandwich.

GYPSUM.

Gypsum occurs in western Ontario in the salt-bearing Salina formation of upper Silurian age. The outcrops of the Salina, after running parallel with Lake Ontario in New York state, enter Canada at the Niagara river, where the formation is estimated to have a thickness of between 200 feet and 300 feet. The group there consists of dolomites and soft crumbling shales, with lense-like bodies of gypsum, that, interstratified with the beds of dolomite, sometimes are a quarter of a mile in length. The gypsum beds are worked along the outcrop of the formation over its general northwesterly course from Niagara river to Lake Huron. The Salina evidently formed during a time of excessive evaporation of the sea, when the deposits of salt, gypsum, etc., were precipitated.

BUILDING AND ORNAMENTAL STONES, ETC.

The widespread clays of glacial and post-glacial age that often completely hide the underlying rocks over considerable areas of the St. Lawrence lowlands have furnished the material for numerous brick and tile industries both in Ontario and Quebec. Advantage has also been taken, for the same purpose, of the shales in various of the lower Palæozoic formations. The raw materials for the manufacture of Portland cement are abundantly displayed in the region, and support a number of large industries. Some of these utilize marls—deposits of calcium carbonate in lakes scattered over the uneven surface of the post-glacial deposits, and the clay beds of these deposits, while others use Palæozoic limestone. These limestones of several of the formations, and more especially of the Trenton group, are also extensively quarried both for building stones and for the production of lime. At several points the limestones are also used in the making of calcium carbide, while the dolomites are used in the manufacture of pulp.



Don Valley Brick Works, Toronto, Ont.

PLATE XXVI.

International Portland Cement Works, Hull, Que.

CHAPTER IV.

THE LAURENTIAN PLATEAU.

GEOLOGY.

The *Laurentian Plateau* region, surrounding Hudson bay with a U-shaped form, has an area of over 2,000,000 square miles. Limited in the east by the North Atlantic and by the gulf and estuary of the St. Lawrence as far as the city of Quebec, its southern boundary there passes inland and up the Ottawa river to beyond the city of Ottawa, then turns abruptly to the south and crosses the International Boundary at Brockville. Farther west, at the foot of Lake Ontario, it crosses back into Canada and follows a nearly due east and west line to the foot of Georgian bay, from which point the two upper Great lakes form the bounding line. West of Lake Superior the Laurentian Plateau region extends south into the United States. In southeastern Manitoba the boundary again enters Canada, and from there passes along a general northwesterly course through Lake Winnipeg, Great Slave lake, and Great Bear lake, to the shores of the Arctic ocean.

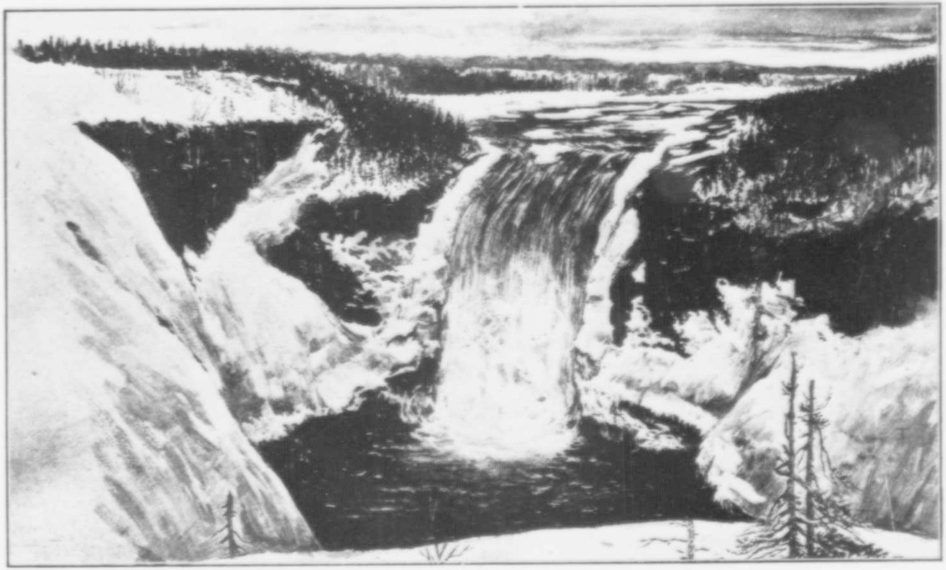
This great region is, for the most part, characterized by its uniform physical features. Considered by districts, the Laurentian plateau is composed of gently sloping regions whose even surfaces, save sometimes for the valleys of the larger rivers, are broken only by low hills rising a few hundred feet or less above the general level. Except in the northeast, along the Labrador coast, the land is generally comparatively low, seldom rising 2,000 feet above the sea. The more extensive elevated stretches of country within the plateau region all lie towards its outer margin, away from Hudson bay. Save towards the headwaters of the Ottawa river in the east, and over the wide depression bordering and extending north of Lake Winnipeg in the west, the higher lands form an elevated belt usually hundreds of miles wide, stretching from the North Atlantic in the east, around the foot of Hudson bay almost to the Arctic in the northwest, with a general elevation always above 1,000 feet, and over large tracts in the Ungava peninsula, approaching 2,000 feet. From this outer, elevated margin the country on all sides slopes inwards towards Hudson bay, surrounding which there is a nearly continuous belt of territory, often 125 miles wide, over which the land never reaches a height of 500 feet above sea level.

The highest land of the Laurentian Plateau region lies along the Labrador coast towards the eastern entrance of Hudson strait, where mountain peaks attain heights of about 6,000 feet. Southward along the coast, the general elevation decreases, but everywhere the shores are high and penetrated by deep inlets, with precipitous sides rising five hundred to several thousand feet above the sea. Along the Gulf of St. Lawrence shore the land is generally bold, rising inland rapidly to heights of 1,000 feet or move, though penetrated by long, narrow valleys occupied by the main waterways.

The abrupt rise of the southern boundary is also a notable feature along its course from Quebec inland up the Ottawa valley. It is repeated along the Lake Superior shores, where for miles bold hills and cliffs rise to heights of 300 to 1,500 feet above the lake. In the west, however, the characteristic sudden uprise at the outer boundary, so prominent in the east, largely disappears, or is replaced by a slight drop from the overlapping sediments to the level of the Laurentian plateau.

The Laurentian plateau is in detail characterized by countless lakes, both large and small, muskegs, and numerous branching streams and rivers that occupy the valleys between the hummocky hills. The territory in the east, south of the latitude of the foot of James bay, is densely wooded, while in the west, the heavily timbered country extends even farther north. Beyond this, to the north, the forest growth gradually decreases, and on the shores of Hudson bay, at about north latitude 59°, the barren lands commence and stretch away to the Arctic ocean. Essentially a forest region in the south, the Laurentian plateau also contains wide areas, the clay belts, that eventually should prove valuable for agricultural purposes.

Noted for its timber resources, the Laurentian plateau, where best known, is no less important from the standpoint of mineral wealth. Along the southern margin occur the noted copper and nickel ores of Sudbury, and to the north of these lie the Cobalt



Hamilton Falls, Labrador.

Rapid, Larch River, Ungava.

Port Burwell, at eastern entrance to Hudson Strait.

silver deposits. In eastern Ontario, and the adjoining portion of Quebec, are numerous and important deposits of graphite and mica. All through the region occur iron deposits, some now being mined, and many in the near future destined to become commercially important. Besides these, many other ores, both metallic and non-metallic, are known, although the country cannot in any sense be said to have been closely prospected. Nor do these mineralized belts seem to be confined to the southern part of the country, but everywhere through the Laurentian Plateau region the general conditions appear to be similar, and it is certain that many deposits of economic value yet remain to be discovered.

The Laurentian Plateau region, save for a zone of Palæozoic rocks bordering the southwestern side of Hudson and James bays, and a few relatively small outliers of the same system occurring elsewhere, is altogether underlain by rocks older than those of the Cambrian period. Collectively these ancient rocks will be referred to as the pre-Cambrian. The vast territory over which they now outcrop is but a portion of the ancient continent of Laurentia that, prior to Cambrian times, it is believed, occupied much of the present area of the North American continent. Rocks in many respects similar to those composing the Laurentian plateau extend far beyond its borders beneath the surrounding sediments deposited in Cambrian and later basins.

The various assemblages of rocks underlying the Laurentian plateau, by their relations and distribution, testify to a long and complicated history in pre-Cambrian times. They show that, at intervals and over wide regions, assemblages of rocks were formed, afterwards subjected to great earth movements, penetrated by vast bodies of deep-seated igneous rocks, then profoundly eroded, and finally depressed, to be again covered by another set of beds volcanic and sedimentary. This great cycle was, in some instances, repeated one or more times, but the extent of the Laurentian Plateau region is too great, and the knowledge of it as yet too elementary, to allow of a definite correlation of the details of its geological history as a whole.

The region is chiefly occupied by large and small bodies of igneous rocks, which at the time of their formation were deeply buried, but now, because of subsequent erosion, are partly exposed. These igneous rocks are often typically granitic in appearance, but, perhaps, more commonly show gneissic structures. Though of widely different relative ages, penetrating one another and later assemblages of pre-Cambrian rocks, yet over the wide expanse of the Laurentian plateau they preserve a general resemblance. By their nature they show they were not the first rocks to occupy the region, and often they may be seen cutting younger strata. Yet, from their wide distribution and the often vast dimensions of the individual masses, it is evident that these essentially granitic rocks form the foundation, as it were, of the whole Laurentian Plateau region, and now, if they do not appear at the surface, are either covered by a comparatively thin mantle of younger rocks, or else underlie, with intrusive relations, older formations.

Throughout the pre-Cambrian region occur other rocks, forming areas sometimes to be measured in yards, sometimes in scores of miles. These have been penetrated by the granites and gneisses, and are, therefore, the oldest rocks of their respective districts. Usually they are highly altered, but often they may still be determined to have been of the nature of sediments and volcanic rocks that formed on or near the earth's surface. The assemblages of these older, usually much altered rocks, vary in general character from district to district, are doubtless of various relative ages and, in some districts, may represent groups of strata that in other places still remain comparatively unaltered and unpenetrated by igneous bodies. Within the pre-Cambrian region also occur, sometimes over wide areas, assemblages of sedimentary beds that are at times scarcely more altered than recently consolidated measures. These younger pre-Cambrian strata frequently may be seen to overlie and to have been partly formed from older, sedimentary and volcanic rocks and the granitic rocks intruding them.

The general history of pre-Cambrian times within Canadian territory has, perhaps, been most clearly determined in the part of the Laurentian plateau lying within the Province of Ontario, and the adjacent portions of Quebec. In northern Ontario, near Cobalt, and in the districts about Lakes Timiskaming and Timagami, occurs a widely distributed group of rocks known as the Keewatin. These rocks, the oldest in the region, are invaded by large bodies of granite. The Keewatin strata are largely of volcanic origin, but with them, though but sparingly, also occur

High Falls of the Rivière du Lièvre, Que., at low water.

Looking north up the Rivière du Lièvre from Emerald, Que. Mine buildings in foreground.

rocks seemingly of sedimentary origin, such as banded quartzose beds often rich in iron, the Iron formation. The Keewatin, as a whole, is highly altered, its members are frequently in a schistose condition (greenstone schists) and apparently closely folded. Once, doubtless, forming a continuous, wide-spread, nearly horizontal series of rocks, the beds now occupy isolated, relatively narrow bands or areas, underlain and penetrated on all sides by granites and allied rocks.

The Keewatin strata, at the time of their folding, probably rose into mountain masses, while, at about the same time, vast bodies of granitic rocks intruded them from below. Later, as shown by the horizontal, overlying beds of younger conglomerate still occupying parts of the district, the complex assemblage was subjected to intense erosion and much of the Keewatin entirely removed; the once deeply buried granite masses were partly exposed, and the whole region reduced to a gently undulating country, much like that of the present time. The beginning of this great erosion period marked the close of what appears to have been the first pre-Cambrian era of which there is definite knowledge.

Towards the close of the first prolonged erosion interval, the Timagami district appears to have been depressed, and a widespread group of sedimentary rocks deposited, covering the Keewatin and the granites. This sedimentary group, the lower Huronian, still occupies much of the country. It consists of thick beds of conglomerate overlain by and passing upwards into slates, above which sometimes occurs a quartzite or arkose member possibly belonging to a second division, the middle Huronian. With the sediments are associated widely extending, often thick, sheet-like bodies of diabase, of later date, that sometimes cut the sedimentary beds, but more often rest on top of them. The Huronian series, though affected by faults and comparatively gentle folds, is, on the whole, flat-lying, and beneath its basal members may be traced the old, gently undulating, pre-Huronian land surface of Keewatin rocks and intrusive granites.

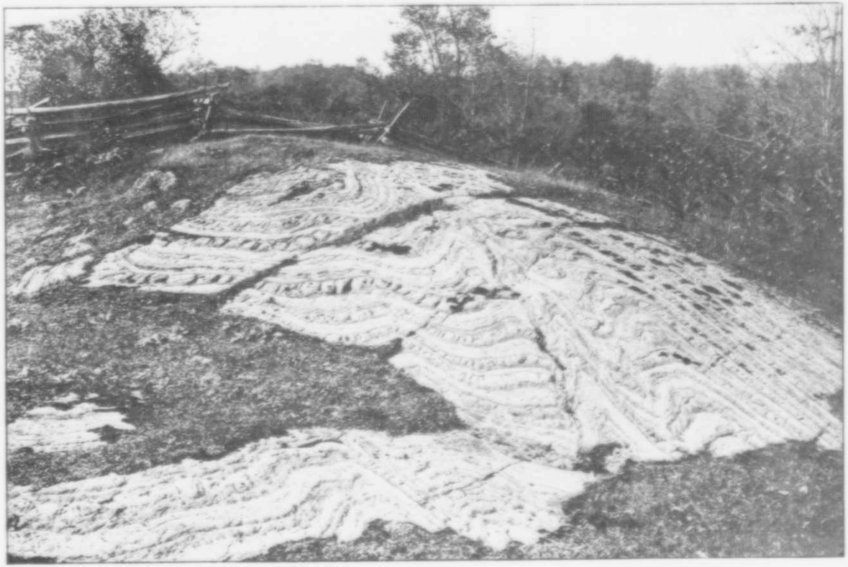
The conditions obtaining in the Timagami district seem, in part, to be duplicated through much of northern Ontario, and throughout the Laurentian plateau occur rocks like those of the Keewatin, sometimes occupying large areas and exhibiting many varieties of volcanic rocks in varying degrees of deformation.

Often the areas form gigantic meshworks enclosing, or partly enclosing areas of intrusive granites or gneissic rocks occupying many square miles of country. At times the Keewatin rocks are greatly changed, and sometimes form wide zones of gneissic or schistose varieties intermingled and interbanded with the granitic intrusives. But though the condition of the Keewatin and its relations to the granitic intrusions is, broadly speaking, everywhere alike, the same is not true of the widely distributed Huronian.

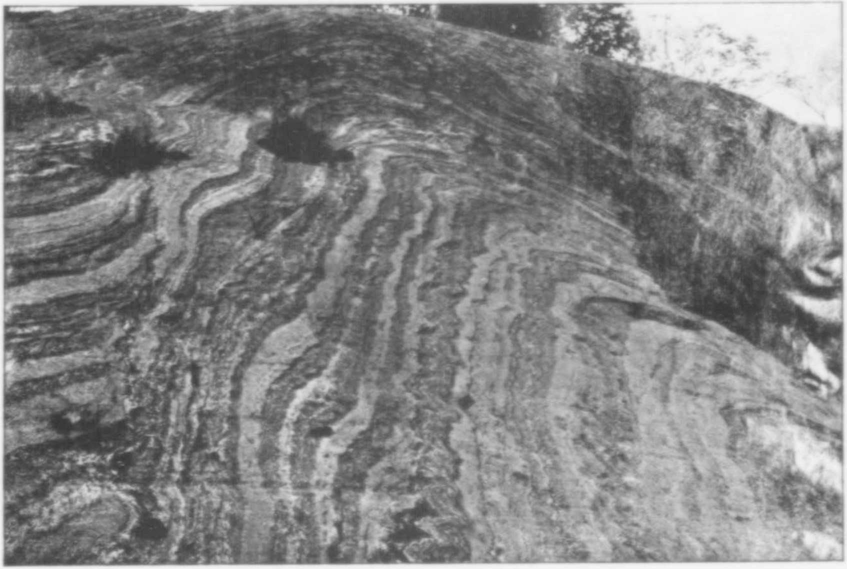
Strata similar to the but slightly disturbed lower Huronian of the Timagami district, and younger than the associated Keewatin, are found to the south and west, as, for instance, near Sudbury and in the Michipicoten district. In these districts the Huronian beds are found to be much disturbed, in places schistose and cut by granites, though not all of the granites of these districts are post-Huronian. Farther west, to the north of Lake Superior, the lower Huronian is as highly disturbed, and as much altered as the intricately associated Keewatin which has furnished detrital material to the Huronian, and both series appear to be cut by the same granitic bodies. In these western districts the Huronian and Keewatin appear to have been conjointly folded, elevated into mountainous areas, and penetrated by immense granitic masses. Subsequently the complex was deeply eroded and planed down to a gently undulating surface. This erosion period marks the close of the second recognized pre-Cambrian era.

After the second great erosion interval, portions of the ancient continent were again depressed, and, as exemplified near Port Arthur, heavy deposits of sediments, largely dark slate, sometimes with a horizon containing iron ore formation, were formed. This series, known as the upper Huronian or Animikie, occupies a large district in Canada, west of the head of Lake Superior. It overlies the older complex of Keewatin, Huronian, and intrusive granitic rocks with a marked unconformity. The upper Huronian beds are virtually unaltered and lie in what appear to be a series of fault blocks, forming ridges with southerly sloping tops and steep northern faces. As in the case of the lower Huronian, extensive, often very thick sills and sheets of intrusive diabase are associated with the Animikie.

After the deposition of the upper Huronian beds in the Lake Superior region, the land was once again elevated, the strata



Contorted Gneiss near ferry landing, Alfred township, Prescott Co., Ont.



Contorted Gneiss near ferry landing, Alfred township, Prescott Co., Ont.

Plate XXXIV.

The Narrows, Lake Timiskaming.

Notch or gorge near mouth of Montreal river, Lake Timiskaming.

subjected to earth movements, and eroded; but the deforming effects of these forces were slight when compared with the earlier deformation of the lower Huronian and Keewatin. After this third marked period of uplift and erosion the Keweenawan series was formed. This series consists of a sedimentary portion of red sandstones and conglomerates, calcareous shales, and dolomites, well exposed on the Lake Superior shore east of Port Arthur and about Lake Nipigon, and of a volcanic portion exhibited on Michipicoten island as an assemblage, many hundreds of feet thick, of tuffs and volcanic flows.

The Keweenawan is classed by some as of early Cambrian age, perhaps representing desert conditions, but for present purposes it is most conveniently regarded as late pre-Cambrian, the last of the sedimentary groups of that age. Associated with the Keweenawan beds about Lake Superior are immense sheets and sills of diabase, ranging in thickness up to perhaps 1,000 feet. These igneous rocks are distinctly younger than the Keweenawan, in places occurring in sills, or, more prominently displayed, as immense sheets overlying the whole sedimentary group and sometimes extending beyond, over the older rocks.

The account of the more striking features of pre-Cambrian history in Ontario may be supplemented by the discussion of other lines of evidence, but the deductions drawn from these are less certain. The lower Huronian measures already described, are paralleled along the north shore of Lake Huron by a somewhat similar assemblage containing a considerable volume of limestone. These beds are overlain unconformably, but not strikingly so, by a second group of somewhat similar measures, known as the middle Huronian. Possibly the middle Huronian beds were deposited during a portion of the erosion interval that, elsewhere, separated lower and upper Huronian times.

Along the Hudson Bay shores of the Ungava peninsula, also in the central portions, and again towards the Atlantic side of this territory, occur extensive areas occupied by a considerable thickness of sandstones, slates, dolomites, and siliceous iron ore beds. These measures, though faulted and tilted, are otherwise little changed from their original state, and, with some degree of definiteness, may be correlated with the upper Huronian of the Lake Superior region. To the north, along Hudson strait, are areas of apparently once similar beds, but now much disturbed, altered, and penetrated by bodies of granite. It is not impossible that the period of deep-seated igneous intrusions and deformation of these upper Huronian beds of Hudson strait was contemporaneous with the interval of uplift, and comparatively slight deformation and erosion separating the upper Huronian and Keweenawan periods in the Lake Superior district.

In eastern Ontario, and over a very extensive region reaching northeastward through Quebec, occurs a group of rocks whose relations with the various members of the pre-Cambrian system in the districts about Lake Superior are still uncertain. These rocks, first described from the district in the Province of Quebec bordering on the lower Ottawa river, and named the Grenville group, comprise large volumes of crystalline limestone associated with quartzites and various types of gneisses believed to have had a sedimentary origin. The measures are tightly folded, and are penetrated by great bodies of granite and gneiss. Traced westwards, the members of the Grenville group seem to occur in a less altered state, and in eastern Ontario have been thought to be represented by the Hastings series, though possibly the eastern Ontario assemblage of rocks includes more than the original Grenville. The relations of these Grenville-Hastings rocks with the Keewatin and Huronian rocks farther west has not yet been established. They may include the Keewatin, a portion of the Huronian, or some series not yet recognized in the Lake Superior region.

Other areas throughout the Laurentian Plateau region are underlain by strata whose definite correlation is still impossible. In the Ungava peninsula there are areas of gneisses and schist resembling sometimes the Keewatin, sometimes the Grenville, while in some instances they may represent greatly altered Huronian beds. Near Sudbury, Ontario, occurs a great volume of sediments and tuffs, overlying and cut by the intrusive nickel-bearing eruptive. These stratified beds, so far as is known, are not exactly paralleled by any other pre-Cambrian series, though they have been correlated with the upper Huronian. Northwest of Lake Superior, large areas are occupied by peculiar, uniform quartzose biotite gneisses, sometimes appearing to underlie and be older than the Keewatin, at other times appearing to be its equivalent.

Fly River, three miles from mouth.

Plate XXXVII.

Hills on Montreal River, two miles above Wapus River, Ont.

Plate XXXVIII.

Contorted gneiss at Fullerton, Hudson Bay.

The Nastapoka group, the probable equivalent of the upper Huronian in the Ungava peninsula, has already been mentioned. Similar measures outcrop over a limited area projecting through the Palæozoic beds just south of Hudson bay. Nearly identical rocks occur over large areas about Great Bear and Great Slave lakes. A large district bordering the southern shores of Lake Athabaska is underlain by sandstones supposed to be the equivalents of the Keweenawan. Farther to the northeast are considerable volumes of acid and other volcanic rocks, probably also of Keweenawan age. Possibly in the district extending from Great Bear lake to the mouth of the Coppermine river, on the Arctic ocean, both the upper Huronian and the Keweenawan are represented.

Although sedimentary and volcanic rocks are so widely distributed over the Laurentian plateau, yet their volume, as a whole, is much less than that of the associated plutonics, which, though not the oldest rocks, everywhere form the foundation on which the others rest. Frequently these bodies are typical granites, syenites, etc., but often they are composed of, or insensibly merge into gneisses, whose structures in many cases appear to be original. In other cases the gneissic structure is indisputably the result of pressure and the resulting crushing. These granitic rocks show an infinite number of varieties, ranging from very acid to very basic forms. Pegmatite dikes are an almost constant feature. The ages of the rocks must vary widely, though over large areas they often all seem to be approximately of one period, post-Keewatin, post-Huronian, etc., as the case may be. In eastern Ontario a considerable area is characterized by the presence of batholitic bodies of nepheline syenite, alkali syenites, and related rocks. Over the whole eastern portion of the Laurentian highlands, from the Great lakes to the Labrador coast, occur bodies of anorthosite, sometimes 10,000 square miles in extent.

ECONOMIC MINERALS.

Though only a very small part—the southern border only—of the Laurentian plateau may truly be said to have been prospected, the region has already proved to be one rich in mineral wealth. In Ontario, along the outer margin of the great pre-Cambrian region, many and varied deposits of economic importance have been discovered, though even this relatively limited area has been only imperfectly prospected. Within its bounds occur the noted nickel-copper mines of Sudbury, which now outrival in their production of nickel the New Caledonia deposits. Within 100 miles of Sudbury lies the Cobalt district, containing one of the richest and most easily worked silver camps in the world. In many districts are deposits of iron ore, often low grade, but doubtless soon to become commercially important. Ores of gold, copper, lead, sulphur, and arsenic are worked, while the mica, graphite, and many other mining industries are important.

The mineral wealth of the better known southern part of the Laurentian plateau is virtually confined to those districts in which are found members of the various Huronian, Keewatin, and Hastings-Grenville formations, though the mineral deposits not infrequently lie in igneous rocks, and often seem to have been connected in origin with the intrusion of plutonic bodies. Thus, the silver ore occurs in or near diabase intrusions, and many ores occur in the older rocks along the contact of an intrusive granitic rock. In the better known southern part of the vast pre-Cambrian area the formations with which the mineral deposits are associated collectively occupy very large areas, as, for instance, in the case of an irregular zone that stretches northeast from Lake Huron to Lake Mistassini, a distance of 600 miles. West of Lake Superior to the Manitoba boundary is another noted region of such rocks, while eastern Ontario and the adjoining portions of Quebec form a third.

In the northern, virtually unprospected and by far the larger portion of the Laurentian plateau, the same general geological conditions seem to hold as in the case of the better known south-

Atikameg River, Keewatin.

PLATE XI.

Wanapitei River below Welcome Lake.

ern part. Though in the north the plutonic rocks seem to bulk far greater than in the south, it is highly probable that, with advancing knowledge of the country, the older formations will be found to occupy large areas, and, reasoning by analogy, many of these areas should prove to be rich in mineral wealth.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold, Arsenic.....	Free gold and auriferous mispickel occur in quartz veins cutting schists and basic igneous rocks of the Hastings-Grenville series, usually near granitic intrusions....................	Deloro, Ont.
Gold......	Free gold and auriferous pyrite with pyrrhotite in quartz veins and stringers cutting altered gabbro of the Hastings-Grenville series..........	Belmont, Ont.
	Free gold with pyrite and chalcopyrite in quartz veins in Keewatin schists, etc................	Larder lake, Shakespeare mine near Webbwood, western Ontario.
Platinum..	In the mineral sperrylite in the nickel-copper deposits of Sudbury. *See* under nickel.....	Sudbury, Ont.
Copper....	Native in Keweenawan diabase, Lake Superior shores, also in diabase about Coppermine river, northwest of Hudson bay..................	
	Chalcopyrite, with, towards the surface, bornite in veins of quartz with some calcite, cutting Huronian sediments and post-Huronian diabase	Bruce Mines, Ontario.
	Bornite, chalcocite, chalcopyrite, pyrite, etc., in impregnated zones in schistose diorite, garnetiferous gneiss, etc..........................	Parry Sound, Ont.
	Chalcopyrite. *See* under nickel.............	Sudbury, Ont.
Silver.....	Native silver and argentite in veins of calcite and barite with varying amounts of quartz and fluorite, traversing Animikie sediments and post-Animikie diabase....................	Silver Islet, L. Superior.
	Native silver with argentite, smaltite, cobaltite, niccolite, native bismuth, etc., in narrow veins of calcite lying chiefly in Huronian sediments and post-Huronian diabase................	Cobalt, Ont.
	Native silver and argentite with hematite and various sulphides in aplite dikes cutting post-Huronian diabase..........................	South Lorrain, James township, etc.,Ont.
Lead......	Galena in calcite veins traversing mica schists of the Hastings-Grenville series.	Hastings co., Ont.
Zinc......	Zinc blende and galena in irregular bodies in crystalline limestone of the Hastings-Grenville series	Frontenac co., Ont.
	Zinc blende with iron and copper sulphide forming irregular, lenticular bodies in Keewatin schists.	Rossport, Ont.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

(Continued)

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Nickel-copper.....	Pentlandite, chalcopyrite and pyrrhotite, in very large irregular deposits situated at the edge of a norite body intruding pre-Cambrian sediments and igneous rocks	Sudbury, Ont.
	Niccolite, etc., occurring in the silver-bearing veins of cobalt. *See* under silver..................	Cobalt, Ont.
Iron......	Bog ore deposits, still under formation..........	Three Rivers, Que.
	Magnetite and, to a lesser extent, hematite interbanded with variously coloured quartz, forms long bands associated with Keewatin schists often cut by granites, etc..................	Lake Nipigon, Lake Timagami, Ont.
	Bands of magnetite, locally impregnated with sulphide, lie in Keewatin schists............	Atikokan range, Ont.
	Irregular bodies of magnetite with hornblende and epidote in a formation of magnetite and siliceous material, lie in Keewatin schists.......	Moose mountain, Ont.
	Concretionary-like hematite and limonite with large, sharply defined bodies of iron pyrite in a sandy state, forming a large body associated with banded siliceous rocks containing magnetite, iron carbonate and pyrite, and surrounded by Keewatin schists..........................	Helen iron mine, Ont.
	Irregular, often large masses of magnetite with varying amounts of pyrite, lying along the contact of crystalline limestone (Hastings-Grenville series) and intrusive granites, etc., or within bodies of basic igneous rocks................	Hastings co., Ont.
	Large and small, irregular bodies of titaniferous magnetite associated with bodies of anorthosite.	Quebec.
	Iron sands derived from the titaniferous magnetites of the anorthosite bodies.............	Lower St. Lawrence.
	Bodies of hematite and limonite in beds of cherty iron carbonate belonging to the Animikie sedimentary series............................	Loon lake, Ont.
	Seams and layers of magnetite and hematite interbanded with layers of variously coloured quartz forming part of the Nastapoka sedimentary group..................................	East shore of Hudson bay.
Sulphur...	Large elongated lenses of pyrite and quartz in Keewatin schists..........................	Near Missinaibi, Ont.
	Pyrite associated with iron ore. *See* under iron.	Helen iron mine, Ont.
Arsenic...	Auriferous mispickel accompanied by pyrite and chalcopyrite and forming large and small bodies in Keewatin schists, in gneisses, etc., of Hastings-Grenville series......................	Net lake, near Lake Timagami.
	Deposits of mispickel. *See* under gold-arsenic..	Deloro, Ont.
	Smaltite, etc., in silver veins. *See* under silver..	Cobalt, Ont.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE LAURENTIAN PLATEAU REGION.

(Continued)

Element or Mineral Sought.	Character and Mode of Occurrence of Deposit.	Example.
Cobalt....	Cobaltite, etc., in silver veins. *See* under silver.	Cobalt, Ont.
Mica......	Muscovite in pegmatite dikes..................	Buckingham district, Que.
	Phlogopite, commonly accompanied by apatite, in veins of calcite, pyroxene, etc., cutting rocks of the Hastings-Grenville series................	Eastern Ontario.
Graphite..	In plates disseminated through bands of gneiss, quartzite, etc., of Hastings-Grenville series, usually near intrusive granites. Graphite in veins in granitic rocks, or in irregular deposits in crystalline limestone......................	Buckingham district, Que.
Corundum.	Richly disseminated in various alkali syenites, anorthosite, etc., cutting members of the Hastings-Grenville series......................	Renfrew co., Ont.
Apatite...	Associated with phlogopite. *See* under mica....	
Feldspar..	Coarse pegmatite dikes cutting pre-Cambrian gneisses, etc............................	Frontenac co., Ont.
Talc......	In serpentines associated with Hastings-Grenville series....................................	Hastings co., Ont.

PRECIOUS AND SEMI-PRECIOUS STONES.

Though it can scarcely be said that there is, as yet, any established source of precious or semi-precious stones in the Laurentian Plateau region, yet many beautiful minerals have been found in various localities. There is even a possibility that diamonds may eventually be discovered somewhere in the northern region, for in the glacial drift of Wisconsin, small diamonds up to a few carats in size have been found, and it has been contended that these have been transported by ice during the glacial period from some point in the Laurentian region in the neighbourhood of Hudson bay.

Admirable specimens of the feldspar labradorite have been recovered from the anorthosite masses on the east coast of Labrador. The mineral shows a brilliant play of colours and has been used in jewellery. Labradorite showing many of the qualities of the mineral of the original locality, has been found at various points in a number of the large anorthosite bodies occurring all the way from Wisconsin to Hudson strait.

The pegmatite dikes so common throughout the Laurentian plateau often hold splendidly developed crystals of various minerals, such as tourmaline, idocrase, apatite, zircon, etc. Many such localities are known in the districts bordering the lower Ottawa, also in eastern Ontario, and, doubtless, these crystals eventually will be found in many other districts. Garnets of gem quality have been recovered from Charlevoix county, Quebec. Blue sodalite from the nepheline syenites of eastern Ontario is used as an ornamental stone, as is also perthite and other varieties of feldspar.

GOLD.

The known occurrences of gold within the Laurentian plateau are almost entirely confined to the southern border of the region in Ontario. There is, however, every reason to believe that eventually, as prospecting progresses, the mineral will be found throughout the pre-Cambrian region. Amongst the various gold-bearing districts of Ontario may be mentioned the eastern Ontario region in Hastings and neighbouring counties, Larder lake, Parry Sound, Wanapitei lake, the district north of Lake Huron, Michipicoten, Shebandowan lake, Sturgeon lake, and Lake of the Woods.

Though gold has been found and worked at many points in Ontario, from the Lake of the Woods on the west to the Hastings district in the east, a distance of roughly 650 miles, yet in spite of often highly promising showings no permanent gold industry has yet been established. First discovered in 1866, in Hastings county, the annual production of gold rose to a maximum in 1899, when 27,594 ounces were recovered, but in 1907 the amount was only 3,810 ounces.

In eastern Ontario the auriferous deposits appear to be confined to a belt of varying width and about seventy miles long, extending through Peterborough, Hastings, Addington, Frontenac, and into Lanark county. This region is occupied by crystalline limestones, various types of schists, and bodies of dark basic rocks, all commonly grouped as the Hastings-Grenville series, and cut by bodies of granite. The gold deposits occur in the older rocks, generally near granite intrusions and along lines of fissures containing quartz veins or lenses, and, commonly, with abundantly associated mispickel, sometimes mined for arsenic.

The Deloro mine, near the village of that name, in Hastings county, is situated on an area of schists, sometimes dolomitic, and quartzites cut by granitic dikes and surrounding a central mass of intrusive granite. The ore occurs in a series of quartz veins lying parallel to the foliation of the schist, and also cutting the granite dikes. The veins consist of a series of lenses lying along fissures and connected by cracks. The quartz veins sometimes carry considerable dolomite, mispickel, lesser amounts of iron pyrites, at times chalcopyrite or fluorite, and free gold. One vein that may be considered a typical example is 7 to 10 feet wide, and dips at an angle of 30°. It consists largely of quartz, with mispickel and some dolomite. The mispickel is sometimes coarsely crystalline, with gold adhering to the faces, but more commonly is fine and compact, and the associated gold invisible. The mine is worked both for arsenic and gold; assays of the ore have yielded $30 of gold to the ton, while several analyses of the mispickel showed that it carried gold at the rate of from $300 to $3,000 per ton.

At another locality in the eastern region, at the Star of the East mine, in Frontenac county, two veins, about twenty yards apart, lie in crystalline limestone. Each vein consists of isolated but nearly touching lenticular masses of quartz, 6″ to 24″ wide, and lying towards the centre of an altered zone 8 to 10 feet wide. With the auriferous quartz occurs pyrite, magnetite, calcite, a little galena, etc.

At the Belmont mine, in the county of Peterborough, a series of gold-bearing veins lie in a body of gabbro cut by a large number of ramifying granitic dikes, varying in width from merely a thread to several inches. In the neighbourhood of the gold-bearing quartz veins, the gabbro, sometimes over a zone fifty feet wide, has been altered to a chlorite schist carrying introduced quartz, calcite, and feldspar.

The gold occurs in a free state in lenses of quartz lying along fissures towards the centre of the zone of chlorite schist. The precious metal is also found in numerous quartz stringers in the schist, and in the iron pyrites with which the rock is impregnated. The larger ore bodies occur at the intersections of two or more fissures. Mispickel, though so characteristic of the eastern gold belt in general, is not present. Galena and chalcopyrite occur, but apparently only towards the surface. Pyrrhotite is present and carries gold, but not so abundantly as the pyrite, for while one specimen of pyrrhotite carried only $13 of gold to the ton, an assay of a mixed specimen of pyrite and quartz yielded gold at the rate of from five to six ounces per ton.

In the Larder Lake district, some distance northeast of Lake Timiskaming, many specimens of quartz carrying visible gold have been found. The best showings seem localized in a band of schistose rock, possibly representing an altered impure dolomite or limestone. This band, cut by pegmatite and porphyry dikes, is seamed with quartz stringers, sometimes with gold values, and carrying pyrite, chalcopyrite, and a few specks of galena. The quartz stringers are usually only a few inches wide. One vein carrying free gold, and several feet wide, yielded gold at the rate of about $8 per ton in a mill test of 1,600 pounds of ore.

Gold discoveries have also been made farther north, on the shores of Lake Abitibi. On an island in lower Abitibi lake there has been found, cutting a diabase, a vein of auriferous quartz varying from a few inches to four feet in width. The quartz carries free gold, frequently visible, iron pyrites, a little copper pyrites, and some zinc blende.

Along the Quebec side of upper Abitibi lake, the Keewatin schists are cut by a number of fine-grained, acid dikes, varying in width from a few inches to fifteen feet or more. The dikes have been shattered, and the resulting cracks, mostly pursuing transverse courses, filled with quartz. The dikes are impregnated with iron pyrites, apparently gold-bearing.

The only auriferous alluvial deposits in Ontario that have attracted any considerable amount of attention are those of the Vermilion river, not far from Sudbury. The auriferous gravels there apparently lie at the surface, and the small amount of gold in them is in a very fine state, though increasing in coarseness when traced northwards.

Prospects and partially developed gold mines occur in the district immediately north of Lake Huron, and at various points on the Lake Superior shore. The Shakespeare mine, one of the few mines at present producing gold, is situated near Webbwood, not far from Lake Huron. The ore is iron pyrites and chalcopyrite, carrying free gold, in quartz. In the Michipicoten district, in certain areas, the Keewatin schists are cut by swarms of veins and stringers of quartz, sometimes carrying free gold in visible quantities, but often quite barren.

In western Ontario, over a wide area extending westward from near the head of Lake Superior to Lake of the Woods, and northward from the International Boundary to Sturgeon lake, are many gold prospects and mines. Some of the mines have been extensively worked, and amongst these the St. Anthony, seventy-five miles north of Ignace, and the Laurentian, some twenty miles south of Wabigoon, together with the Shakespeare mine of the Lake Huron district, were the chief producers in 1907, in Ontario.

The mines of western Ontario embrace a number of classes, but are all situated in Keewatin rocks or in intrusive granites and gneisses. At one locality, a band of fine grained gneiss, half a mile wide and several miles long, contains pyrite, rather sparingly disseminated, and is auriferous throughout, the amount of gold varying from a mere trace to 50 cents a ton. In other localities granitic or gneissic rocks are, along shattered zones, sometimes several hundred feet wide, seamed with gold-bearing quartz veins.

Development work in the Sultana mine, about seven miles north of Kenora, and at present unworked, reached a depth of 600 feet. The deposit consists of a series of large lenses of quartz, sometimes twenty feet or more thick, lying in gneiss. The lenses are surrounded by biotite schist, itself sometimes auriferous. The quartz carries free gold, sometimes visible, and entirely apart from the iron pyrites also present.

Other types of deposits consist of parallel quartz veins in Keewatin schists impregnated with pyrite. In a number of instances fine-grained, acid dikes, traversed by quartz fissures, have proved to contain gold. The granites and gneisses of the region are sometimes traversed by clean-cut quartz veins carrying free gold.

Throughout the region the gold, or a high percentage of it, is generally free milling, and with it iron pyrites always occurs. Pyrrhotite is commonly present, though it seldom carries gold. Copper pyrites is nearly universal, and in some cases its presence is associated with the occurrence of high gold values. Galena occurs sparingly at very many points. Zinc blende, when present, always seems to be associated with the richest gold ore.

Native copper is comparatively common, and native silver has been found. Bismuthinite is abundant in one vein; mispickel is but rarely found. One vein in Moss township carried some sylvanite, and another vein, in the Lake of the Woods district, contained hessite.

PLATINUM.

Native platinum has been reported to occur in gold-bearing quartz veins in the Lake of the Woods district. In the Sudbury nickel-copper ores, platinum is present in the mineral sperrylite, that apparently is largely, if not solely, associated with the chalcopyrite. In 1906 the value of the platinum, with palladium and associated elements, recovered from the Sudbury ores, amounted to $5,652.

COPPER.

Most of the copper won in the Laurentian plateau comes from the nickel-copper mines of Sudbury, that are described under the heading of nickel. In 1907 these mines produced slightly over 14,000,000 pounds of copper, while the production of the other working mines of the region amounted to about 300 tons. The latter mines are situated in the district bordering the north shore of Lake Huron.

Outside of Ontario important deposits of sulphide copper ores have so far been found at only a comparatively few localities in the Laurentian region. Native copper has been described by explorers as occurring on the Coppermine river, flowing into the Arctic west of Hudson bay. The copper-bearing rocks of this northern region perhaps correspond to the Keweenawan of the Lake Superior district.

In Ontario, the occurrence of copper ores at different localities about the shores of Lake Superior was known from a very early date, about 1767. Native copper has been found in the diabases, probably of Keweenawan age, on the Lake Superior shores not far north of Sault Ste. Marie.

Copper ores are widely displayed through the district bordering the north shore of Lake Huron, and at Bruce mines mining commenced as early as 1846. The Bruce and Wellington mines in this neighbourhood produced, during the period from 1858 to 1878, over 8,000 tons of copper, but are now idle. These mines are situated, in each case, on a pair of closely parallel veins cutting uralitic diabase that is intrusive in the sedimentary rocks of this, the original Huronian area. The veins, with widths varying from a few feet to twenty feet or more, have been traced for a length of over a mile and a half. They consist of a gangue of quartz, in places with much dolomite, carrying copper sulphides, chiefly chalcopyrite, but with much bornite, especially towards the surface. A number of other copper-bearing veins of somewhat similar composition, and often of considerable dimensions, have been found at many points in the district north of Lake Huron, sometimes cutting diabase, sometimes cutting sedimentary beds. Chalcocite occurs on the Mississagi river.

In the Parry Sound district a number of discoveries of copper ore have been made. At a point about two miles east of Parry Sound a schistose diorite is more or less charged with bornite, chalcocite, and chalcopyrite, over a zone about 1,000 feet long and 250 feet to 400 feet wide. In places the ore is associated with stringers of quartz, but in general it occurs in bunches or pockets through the impregnated rock. At another locality in the same district, about eight miles south of Parry Sound, a garnetiferous gneiss is impregnated with copper and iron sulphides, over a band about 1,000 feet long and 30 to 75 feet wide.

SILVER.

The known occurrences of silver ores in the Laurentian plateau are almost entirely confined to Ontario. As early as 1846 veins carrying this metal were found on the shores of Lake Superior, in the district about Port Arthur, but at that time, copper, rather than silver, was the metal sought, and it was not until 1866 that silver began to be actively prospected for. From this time onwards, until 1903, the Port Arthur district produced silver, but in the latter year the production had dwindled to 16,688 ounces, and the last mine closed down. In the same year, 1903, the silver-bearing veins of Cobalt, lying about 100 miles northeast of Sudbury, were found, and in 1904 over 200,000 ounces of silver were recovered, while in 1907 the production had risen to slightly over 6,000,000 ounces, extracted from 14,788 tons of ore. This camp, at the same time, controls the world's market for cobalt.

The silver mines of the district in the neighbourhood of Port Arthur, while no longer actively worked, were at one time the centres of much activity. The ore-bearing veins, in general, occupy distinct lines of faulting or fissuring in the sedimentary Animikie beds, and cross the associated dikes and sills of diabase. The gangue of the veins is largely calcite or dolomite, and barite, with a varying amount of quartz. The relative proportions of these minerals vary widely, and sometimes much fluorite is present. The veins fluctuate in width, more especially in the sedimentary rocks, where they often pinch out or seem to disappear, though, when searched for, they are generally found to continue downwards.

Through the gangue occur various sulphides, zinc blende, galena, iron and copper pyrites, with silver both as argentite and in a native state. These minerals are usually irregularly distributed; sometimes they are very plentiful along streaks, or in bunches, while long stretches of vein matter are often free from them.

The most famous silver mine of the Lake Superior region was known as the Silver Islet, and was found on an island, some 90 feet square, lying near Thunder cape. The ore-bearing veins of carbonates and quartz traversed a large dike of diabase, cutting it along a fault plane. Only where the vein traversed the diabase did it carry silver; elsewhere, besides gangue material, it bore only sparingly disseminated galena. The Silver Islet vein varied in width from one foot to twenty feet or more, and held various compounds of nickel and copper, arsenical and antimonial ores of silver, as well as the more ordinary minerals of the other veins of the district. The distribution of the native silver and silver minerals was irregular; sometimes they formed large masses, and in one instance, such a body was over five feet wide and sixty feet, or more, deep. When the mine was abandoned in 1884, work had been carried on to a depth of 1,160 feet, and it is estimated that $3,250,000 of silver had been extracted.

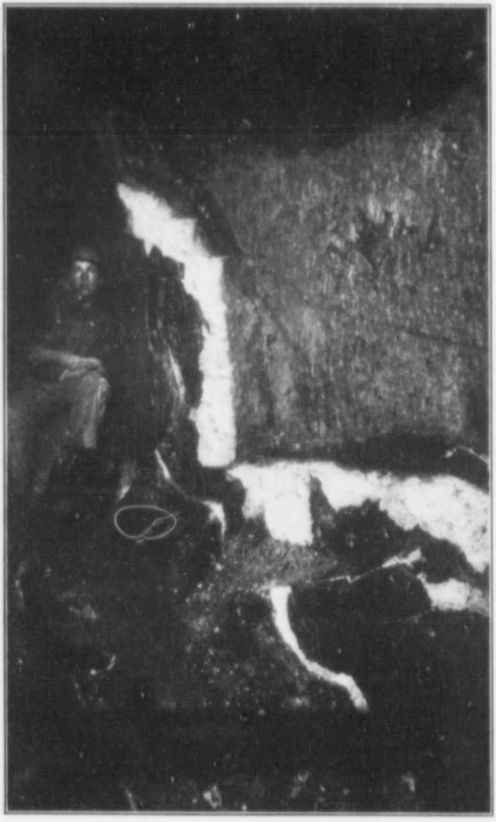
The phenomenal silver district of Cobalt was discovered in 1903, during the progress of railway construction. Most of the veins lie in slightly inclined, lower Huronian greywackes or slates, and conglomerates, but they also occur in the sill-like bodies of intrusive diabase, and at times in nearby Keewatin schists. The veins generally occupy clean-cut, nearly vertical fissures, but

PLATE XLI.

Larose Mine, Cobalt, Ont.

PLATE XLII.

Vein in Larose Mine, Cobalt, Ont.



Vein No. 7, Kerr Lake Mine, Cobalt, Ont.

their courses are often quite irregular, the veins splitting, coalescing, or dividing into a series of stringers confined to a narrow zone. The gangue is largely of calcite carrying native silver, argentite, and other silver compounds: smaltite, niccolite, cobaltite, native bismuth, etc. The native silver occurs in a variety of forms, sometimes in large flakes or sheets a foot or more in diameter. In places the silver is intricately mixed with the various mineral compounds of cobalt, nickel, and arsenic. In some cases the veins are almost void of silver, and are mined for their cobalt contents alone. The veins are sometimes quite long, as in the case of the main vein of the La Rose mine, which has been traced for more than 1,000 feet; usually they are quite narrow, a vein one foot wide being relatively quite gigantic. From one vein on the Trethewey, in an open-cut about 50 feet long and 25 feet deep, ore to the approximate value of $200,000 was extracted from a vein never more than 8″ wide.

Besides the original Cobalt district, other silver-bearing camps have been found in South Lorrain and at a number of points in the region to the westward, as in James township, at Bloom lake, and Gowganda lake. In some of these localities, besides the more ordinary calcite veins, others of a different character have been discovered. These are of the nature of aplite dikes, often containing much calcite, and carrying, besides silver and various arsenides and sulphides, considerable quantities of galena and hematite.

LEAD.

Veins carrying galena and other sulphides occur on the north shore of Lake Superior, where, at one time, they were worked. Within recent years mining has been conducted on certain lead properties in eastern Ontario, in the belt of Hastings-Grenville rocks. In the case of one of these mines—the Hollandia mine, near Bannockburn, Hastings county—the country rock is a fine-grained mica schist. The lead occurs in a nearly vertical fissure with well-defined walls, and traceable for over 1,000 feet. Where worked the vein varies in thickness between two feet and seven feet; but in places is filled with country rock or divides into numerous veinlets. It consists of calcite carrying galena in particles ranging in size from minute grains to others more than a foot in diameter. Some marcasite and siderite is present, and occasional grains of zinc blende, pyrite, etc.

ZINC.

Zinc blende, usually accompanied by galena, occurs in workable deposits at a number of points in Quebec and Ontario. The Olden or Richardson mine, in Frontenac county, has been worked in recent years. The ore consists of a mixture of zinc blende and argentiferous galena. The deposit is irregular, and occurs in a band of crystalline limestone of the Hastings-Grenville group. Some work has been done on zinc deposits at Calumet.

Zinc blende has been mined at several points in the neighbourhood of Rossport, on the north shore of Lake Superior. At the Zenith mine the ore consists of irregular bodies of sphalerite with associated copper and iron pyrites, lying in greenstones. At one point a surface of solid ore 20 feet × 15 feet was exposed. The ore apparently occurs in irregular, lenticular bodies, varying in size and lying along the strike of the foliation of the enclosing rock, presumably belonging to the Keewatin.

NICKEL.

Though nickel occurs with the silver ores of the Cobalt district, the mines, as a rule, are not paid for the nickel contents of the ores. The greater part of the production of the metal in Canada is derived from the Sudbury nickel-copper ores. In 1907 the amount of Sudbury ore smelted was 359,076 tons, containing 10,602 tons of nickel and 7,003 tons of copper, while considerable amounts of gold, platinum, and palladium were also recovered.

The Sudbury deposits were first noticed in 1856, but did not attract attention until 1883, during the period of construction of the Canadian Pacific railway, and a year later a railway cutting was made through the small hill on which the Murray mine was afterwards located. During the first few years the deposits were exploited for their copper contents alone, and not until 1886 was the presence of nickel determined and the true value of the ores made known. The Sudbury mines, and those of New Caledonia, now practically supply the whole of the nickel produced in the world.

The Sudbury ore deposits, consisting largely of pyrrhotite and chalcopyrite, form part of the edge of a great eruptive sheet of norite grading into micropegmatite, and having a length of

Creighton Mine, Canadian Copper Co., Sudbury district, Ont.: the largest Nickel Copper Mine in the world.

PLATE XLV.

Main Pit, Creighton Mine, Sudbury district, Ont.

Roast Yard, Canadian Copper Co's Smelter, Copper Cliff, Ont.

thirty-six miles, with a breadth of sixteen miles. This large igneous body, with an estimated thickness of a mile and a quarter, rests in a synclinal basin on upturned Huronian and Keewatin strata, penetrated by granitic, gneissic, and basic igneous bodies. The central part of the norite-micropegmatite body is covered by an open, synclinal basin of stratified rocks, agglomerates, tuffs, shales, and sandstones, so that the ore-bearing norite outcrops as an irregular, oval band, varying in width from a little over half a mile to slightly more than four miles.

Around the inner margin of the ore-bearing, igneous rock, that is, along the upper portion of the sheet-like body, the rock is of an acid type, micropegmatite. Passing outwards, the micropegmatite is found to gradually change to norite, while about the outer margin, at the lower part of the body, occur the ore bodies. There is a complete, though sometimes rather quick gradation from norite to ore, so that in places the rock might be termed a pyrrhotite norite. While there seems to be very little doubt that the ore bodies are primarily of igneous origin, directly derived by some process of segregation from the norite body, there is also evidence, at various places, of the former action of a more or less active process of redistribution and concentration of the metallic minerals.

The ore bodies occur only at the outer margin and in offsets of the eruptive body, and for miles along the edge there is no important break in the rusty band marking the presence of sulphides. The presence of the gossan does not, however, always indicate the presence of ore deposits of workable size, for, in general, the ore bodies are confined to parts along the edge where the norite projects outwards, either bay-like, or as a narrow, sometimes discontinuous, offset or dike.

The ore bodies in places reach an enormous size; the Creighton ore body, for instance, situated on a bay-like projection, forms a mass that, towards the surface, measured roughly 150 feet by 200 feet, and was proved by drilling to extend for at least 400 feet beneath the surface. The deposits are usually sharply defined against the outer edge, except where faulting, etc., may have taken place, but on the inner side they gradually change to norite.

The second class of deposits, those formed along offshoots from the main norite mass, may be exemplified by the body of the

Copper Cliff mine. In this mine an ore body, irregularly oval in cross-section, has been followed downwards for over 1,000 feet, with an average width of 50 feet to 90 feet, and a length of 75 feet to 200 feet.

The ores consist of pyrrhotite and chalcopyrite, and though the copper sulphide is almost invariably present, and usually in considerable amounts, the pyrrhotite decidedly predominates. The two sulphides, as a rule, are commingled in spots, bunches, or threads, and sometimes the iron sulphide is comparatively free from chalcopyrite. The nickel of the ores is mainly, if not solely, contained in the mineral pentlandite, that is usually very finely and evenly distributed. Pyrite is also present, and much of it is nickeliferous. A varying amount of gangue, usually of the mineral constituents of the norites, is always present.

IRON.

The occurrence of iron ores in the Laurentian region has long been known. The bog iron ores in the neighbourhood of Three Rivers, on the lower St. Lawrence, in part situated in the Laurentian region, in part on the plains of the St. Lawrence lowlands, were reported on as early as 1681. The smelting of these ores commenced in 1733, and has continued until the present day, about 11,000 tons of ore being mined and smelted in 1908. Some of these bog ore deposits, as in the case of that at Lac à la Tortue, grow so rapidly that they form a practically continuous supply of ore.

In Ontario, the earliest efforts at mining and smelting of iron ores seems to have been in 1800, in Leeds county. Later, in 1820, an attempt was made at Marmora, Hastings county, to treat the iron ores of that district, and from that time onwards the smelting and mining of the ores of Hastings and the more easterly counties of eastern Ontario, has been intermittently pursued. The first successful furnace was at Normandale, which smelted the bog ores of Norfolk county, and for a time supplied the Ontario Great Lakes trade. In later years, modern blast furnace plants have been erected at a number of points through the Province of Ontario, while iron ores have been discovered in districts scattered over the whole of the pre-Cambrian area of the Province. The amount of Ontario ore—and none save the bog ores are now produced elsewhere in the Laurentian plateau—raised and shipped in 1907, amounted to 205,295 tons, of which three-quarters was derived from the Helen mine, Michipicoten district.

The iron ores of the Laurentian plateau occur at a number of horizons, but the deposits have been found chiefly in the better known part of the region contained in the Province of Ontario. Iron ores are widely displayed in the Keewatin, and are present at many points in the districts underlain by the Hastings-Grenville group of eastern Ontario, and the adjoining districts of Quebec. The Animikie, or upper Huronian, of the Port Arthur district, contains iron ores, and the same is true of the Nastapoka formation, the probable equivalent of the Animikie in the Ungava peninsula. Titaniferous iron ores also occur associated with the anorthosite masses of Quebec, and probably these bodies are the source of the immense quantities of titaniferous iron sands found along the lower St. Lawrence and the rivers tributary to it on the north.

The great iron ore deposits of the Lake Superior iron district, south of the lake, occur in the iron ore formation at points where the iron has become concentrated by secondary action into large masses of comparatively pure ore, sometimes exposed on the surface, sometimes only revealed below the banded jaspilite by drilling. The iron ore formation occurs in the Keewatin, lower and upper Huronian, in these great ranges.

Bodies of iron ore have been discovered in the widespread Keewatin, west, north, and east of Lake Superior. An especially characteristic type is that of the jaspilites as found about Lake Nipigon, and farther east in the district about Lake Timagami. These deposits, frequently spoken of as the Iron formation, form narrow bands often several miles long, lying in and surrounded by various schists and greenstones penetrated by granitic and igneous bodies. The Iron formation is highly siliceous, often banded grey, brown, and dark from the presence of magnetite, and, to a lesser extent, hematite. At times streaks, lines or wider bands are largely of iron ore. The deposits such as these have generally been regarded as having had a sedimentary origin.

Another type of iron ore occurring in the Keewatin in Ontario is represented in the Atikokan range, about 128 miles west of Port Arthur. At this locality, enclosed in a belt of chlorite schists, are three nearly vertical bands of magnetite, respectively 40 feet, 10 feet, and 16 feet wide. The bands lie parallel with one another within a breadth of less than 250 feet. Considerable iron pyrites occurs with the magnetite, enough to necessitate the roasting of the ore.

The Iron formation of the Moose Mountainr ange, about twenty-five miles north of Sudbury, is also closely associated with various types of Keewatin schists, and is, in places, cut by granites. The Iron formation consists of magnetite ores usually interbanded with siliceous material, including cherts and phases resembling greywacke. The richer ore occurs in irregular bodies, often of considerable size and comparatively free from quartz, though frequently containing hornblende and epidote; while in places complete gradations exist between masses of magnetite and of hornblende. The Atikokan and Moose Mountain ores have been referred to the pegmatite type, and are supposed to have been brought to or near the surface in magmas and extruded from them much as in the case of pegmatite dikes. The banded material probably belongs to the so-called iron ore formation.

The deposit of the Helen mine in the Michipicoten district, the largest iron ore deposit worked in Ontario, has been described as having had an aqueous origin, possibly being of the nature of a chemical precipitate. A large amount of iron pyrites is associated with the ore.

The ore body lies towards one end of a strip of the Helen iron formation, about one and three-quarters mile long by a thousand feet wide. The band is surrounded by Keewatin schists, rising in hills on all sides but one. The Iron formation, supposed to be lying in a closely folded syncline, consists on one side of a banded siliceous rock containing siderite and magnetite, and on the other, of impure siliceous siderite containing pyrite in small crystals, grains, and masses.

The ore body lies in or on the band of impure carbonate, and consists chiefly of hematite and limonite in a porous concretionary-like state, and much pyrites usually segregated in distinct, sharply-defined bodies. At first the iron sulphide occurred in isolated, irregular masses of all sizes, up to some containing several hundred tons or more of pyrite in a finely granular state, mixed with quartz and behaving like unconsolidated sand. But as the workings have deepened, the iron pyrites, always occurring in the same state, has been found to greatly increase in volume, so that of a horizontal section of the body about one-half is iron sulphide.

Throughout eastern Ontario and adjoining portions of Quebec, in the districts in which the Hastings-Grenville series occurs, are numerous deposits of magnetite. Many of these have been worked for years, and some are being mined at the present time. The deposits, though usually irregular in shape and distribution, are often of considerable size. In one instance, at the Mayo mine, Hastings county, the ore has been worked from an open pit 1,100 feet long by 220 feet broad, while a drill hole was sunk 140 feet without passing out of ore.

In many cases the ore bodies lie along the contact of crystalline limestone and granitic or other igneous bodies. At times considerable pyrite is present, necessitating the cobbing of the ore. The general conclusion is that the ores are of contact metamorphic origin. Other iron ore deposits of the Hastings-Grenville districts lie within bodies of basic igneous rocks, are characteristically irregular in their occurrence, and doubtless are of direct igneous origin. Somewhat related in type are the masses of highly titaniferous magnetites so often associated with the various anorthosite bodies occurring throughout the eastern part of the Laurentian plateau. In size these titaniferous ore bodies vary widely, sometimes reaching large dimensions.

The gently dipping beds of the Animikie, in the Port Arthur region, sometimes contain iron ores probably of sedimentary origin. At Loon lake, about twenty-six miles east of Port Arthur, the formation contains two iron-bearing horizons separated by a zone of dark slates. The upper of the iron horizons is 200 feet to 250 feet thick, and is composed of cherty iron carbonate. A common phase of this horizon is a banded rock composed of alternating layers of iron oxide or partly altered carbonates, and cherts of various shades and colour. The lower iron horizon, between 50 feet and 60 feet thick, is distinguished from the upper by the presence of small granules embedded in carbonate material or in a greenish or dark greyish matrix. In places the rock is replaced by hematite and limonite, thus giving rise to ore bodies.

The Nastapoka group, found along the east coast of Hudson bay, is composed of usually gently dipping beds of sedimentary rocks several thousands of feet thick. Towards the middle of the series, and exposed at many points, are siliceous, iron-bearing beds; the upper of these beds, in places, hold ankerite or various carbonates, while the lower ones are banded and composed of layers of red and grey quartz impregnated with and alternating with seams and layers of magnetite and hematite. Bodies of low grade ores, resembling these and associated with similar strata, occur towards the centre of the Ungava peninsula, and perhaps west of Hudson bay, about Great Bear and Great Slave lakes.

SULPHUR.

The mining of iron pyrites for the production of sulphuric acid is becoming an industry of increasing importance in Ontario. During 1907, over 15,000 tons of pyrites were raised from various deposits in eastern Ontario, at the Helen iron mine, at James lake in the district of Nipissing, and from several deposits in western Ontario.

In eastern Ontario the sulphides generally occur in lense-like bodies, often in schists or gneisses, or within basic igneous bodies, or along their contacts with older strata. The occurrence of the iron pyrites at the Helen mine has already been referred to under the heading of iron. Near Missinaibi, large deposits, perhaps the largest known in Ontario, lie in Keewatin schists. The bodies consist of pyrite, often with considerable quartz, and in shape are generally elongated, with widths varying from a few feet to 250 feet. A number of pyrite deposits of notable size occur in the Keewatin rocks of western Ontario, and there, as elsewhere in the Province, often occur in the neighbourhood of iron ore deposits.

ARSENIC.

In 1907, in Ontario, 348½ tons of arsenic were produced, mostly from the ores of the Cobalt district, but some also from the mispickel ores of the Deloro mine in eastern Ontario, already described under the heading of gold. Mispickel deposits occur at a number of points in eastern Ontario, and elsewhere in the Province, as at the Big Dan mine on Net lake, near Lake Timagami. At this place, the mispickel is gold-bearing, and is accompanied by pyrite and chalcopyrite. The ore occurs in nearly solid bodies, distributed through Keewatin schists over a zone perhaps a third of a mile long, and varying in width up to a hundred yards.

COBALT.

Cobalt is obtained from the Cobalt silver ores; but figures for the amount of the element recovered are not available. The mines receive but little compensation for the metal, except when sorted to bring the cobalt content up to a certain grade, and, indeed, the actual cobalt contents of the ores produced in 1907 was much above the world's annual consumption.

MICA.

The known workable deposits of mica in the Laurentian plateau are largely confined to three districts in eastern Ontario, and the neighbouring portions of Quebec. In Quebec, one considerable district lies north of the Ottawa river, along the lower portions of the Lièvre and Gatineau rivers. The remaining two districts are situated in Ontario, one about the lower Rideau lakes south and west of Perth, and the other extending from Sydenham to the vicinity of Sharbot lake. In 1907 the amount of mica produced was about 775 tons.

Of the two varieties of mica that have been mined, muscovite and phlogopite, the latter is the one now chiefly produced. The muscovite variety occurs entirely in pegmatite dikes, such as the 50 foot one at the Villeneuve mine twenty miles north of Buckingham, on the lower Ottawa. The mica often occurs in large masses, and one crystal from the above mine weighed 281 pounds and measured across the face 30″ × 22″. Another noted locality for muscovite was the Maisonneuve mine, in Berthier county. In these pegmatite deposits the mica sometimes occurs in isolated crystals, or sometimes in accumulations near the walls of the dikes cutting the gneisses, etc., of the Grenville series and the associated igneous bodies.

The phlogopite mica, commonly accompanied by apatite, lies in vein-like bodies lying parallel to the plane of foliation of the surrounding gneissic rocks, or cutting these planes transversely. Pyroxene and calcite form the gangue. The veins sometimes exhibit a banded or zonal structure, with bands of nearly pure pyroxene, frequently accompanied by mica or apatite. Sometimes the calcite gangue, with varying amounts of the other minerals, occupies nearly the whole vein, or may occur towards the central part, or at one side. The phlogopite frequently forms large aggregates or crystals, at times occurring in pockets, or following the contact of the vein, or lying in or next a zone of calcite. The crystals of mica and apatite sometimes attain colossal dimensions. In the mine near Sydenham crystals of mica up to 9 feet in diameter have been found. The country rock adjoining the vein is often pyroxenized, forming the so-called pyroxenite rock characteristic of many of the occurrences.

GRAPHITE.

Mining for graphite in Canada commenced in 1847, near Grenville, and has since been pursued with a varying degree of success. In 1907, the production of graphite in Canada was all from districts occupied by the Hastings-Grenville series in eastern Ontario and adjoining portions of Quebec, and amounted to about 580 tons, while the production for 1908 was probably less than half this amount.

The most important graphite-bearing districts lie in the counties of Labelle, Argenteuil, and Ottawa, in Quebec; and in Ontario in the counties of Lanark, Leeds, Frontenac, and Addington. All these districts are situated within the region of the Hastings-Grenville series. The graphite deposits are largely confined to the bodies of crystalline limestone and associated quartzites and gneisses, the latter being often rusty weathering, sillimanite gneisses. Graphite deposits have also been found within bodies of the various types of igneous rocks that are so common throughout the region. In many cases it has been noticed that the graphite deposits are richer in the neighbourhood of such intrusive bodies.

The graphite occurs in three general ways, of which the first to be mentioned is, from an economic standpoint, the most important. The mineral frequently occurs in small, scaly particles disseminated through bands or beds of gneiss, quartzite, etc. In such cases, the graphite is often largely confined to particular bands, layers or veins, varying in thickness from 1 foot to 30 feet or more, and these bands alternate with others containing comparatively little of the mineral. Such bands or layers of graphite-bearing rock, frequently carry ten to fifteen per cent of the mineral, while the amount sometimes rises to thirty or forty per cent, and the rock may appear quite black.

In the case of the second class of deposits, the graphite occurs in a fibrous or laminated form, filling veins that commonly are confined to igneous rocks or occur in their immediate vicinity. These veins are usually narrow, irregular, and discontinuous, and vary in thickness from a mere thread to eighteen inches or more.

In the graphite deposits of the third class, the mineral forms numerous but scattered, irregular, vein-like or lenticular masses of small size, usually lying in crystalline limestone. Sometimes the graphite occurs in small, spheroidal masses with a radiating structure, lying in limestone. It has also been found as a constituent of pegmatites cutting the Grenville.

LIGNITE AND GYPSUM.

Thin seams of lignite are found along some of the northern rivers, and beds of gypsum occur in the Devonian area lying within the Palæozoic basin south of Hudson and James bays.

CORUNDUM.

Corundum was discovered in 1896, and since that time has been shown to occur at intervals over a belt about seventy-five miles long stretching through Haliburton, Hastings, and Renfrew counties, as well as in several isolated areas in the same region. The mineral is, in general, associated with various types of alkali syenites, nepheline syenites, corundum syenites, anorthosites, etc., that occur both in large and small bodies cutting members of the Hastings-Grenville series.

Corundum is now mined at several places, and in 1907, 2,683 tons were produced. The Craig mine, in Renfrew county, is one of the chief producers. At this locality, the corundum occurs in a foliated, nepheline syenite. The mineral is scattered through layers varying in thickness from a few inches to more than twenty feet, with intervening barren bands. The corundum is irregularly distributed through the individual ore-bearing bands, in crystals of all sizes up to sixty pounds in weight.

APATITE.

The apatite deposits of the districts bordering the lower Ottawa on the Quebec side were, at one time, actively mined;

but at present the industry has almost ceased, except as a by-product of the mica mines. The apatite deposits in general are associated with those of mica in the same districts, occurring under the same conditions and in the same veins, so that in some cases the dumps of the apatite mines have been worked over for their mica contents, and mines formerly worked for apatite are now operated for mica.

FELDSPAR.

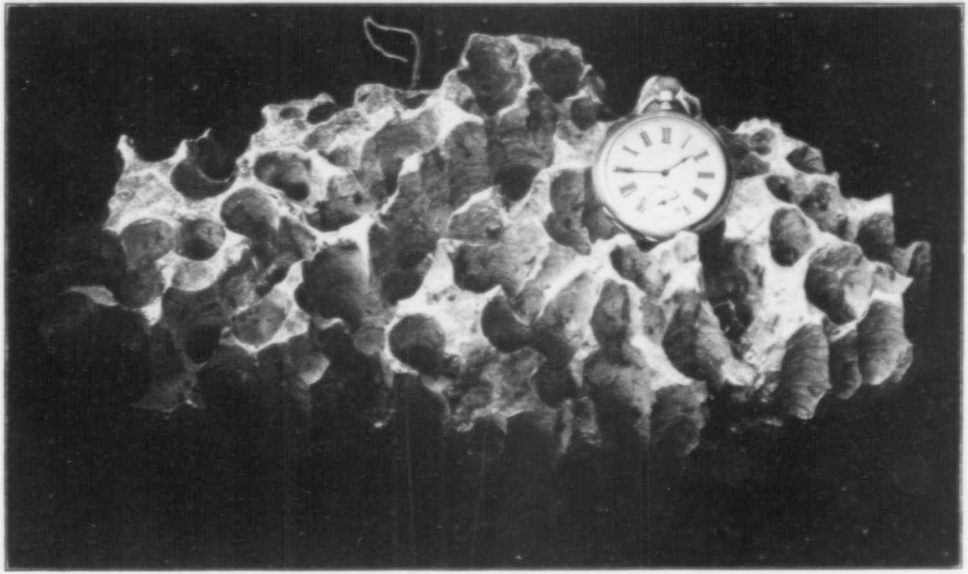
In 1907, potash feldspar, to the amount of 12,328 tons, was recovered in Frontenac county at several localities, from large coarse pegmatite dikes cutting gneisses, etc. The pure feldspar crystals may attain the dimensions of a small house, and the quartz grains, also pure, ten or more feet in diameter.

TALC.

Near Madoc, Hastings county, considerable deposits of talc associated with certain serpentine bodies are being worked, and in 1907 yielded 1,870 tons.

BUILDING AND ORNAMENTAL STONES.

Throughout the Laurentian plateau are numerous bodies of stone suitable for structural and ornamental purposes, and quarries have been opened at many points in the southern part of the area. Massive igneous rocks, granites, syenites, diorites, anorthosites, etc., are available for both building and ornamental purposes; while various kinds of marble, often handsomely marked with serpentine, etc., as well as beautiful blue sodalite, occur in central Ontario, and are eminently suitable for ornamental purposes.



Honeycomb limestone from below water level Georgian Bay.

CHAPTER V.

THE ARCTIC ARCHIPELAGO.

GEOLOGY.

The *Arctic archipelago*, with an area of above 500,000 square miles, lies between the 125th meridian on the west, and Baffin bay and Davis strait on the east. It extends north from the north side of Hudson bay and Hudson strait to 83° N. latitude, a distance of about 1,500 miles, while along the 70th parallel it has a width of over 1,300 miles. The archipelago includes at least twenty islands having areas of over 500 square miles, of which, Baffin island, 211,000 square miles, Ellesmere island, 76,600 square miles, and Victoria island, 74,000 square miles, are the largest.

Though the interiors of the islands are virtually unknown, and even their coast lines imperfectly explored, yet their broad physical and geological features have been fairly definitely determined. In a general way, the elevated country already described as forming an eastern rim to the Laurentian highlands is continued northward through the eastern Arctic islands. The eastern coast of Baffin island is generally high, the land rising quickly to elevations of 1,000 feet or more, after which the upward slope to the interior tableland is more gentle. In the south, the general elevation of the tableland ranges from 2,000 feet to 3,000 feet, while northward, it increases to about 5,000 feet, with hills rising perhaps 1,000 or 2,000 feet higher. Still farther north the general elevation sinks to perhaps 3,000 feet, and so continues into North Devon and on into Ellesmere island, where, however, peaks sometimes rise as high as 5,000 feet.

The western portion of Baffin island has a general elevation of about 1,000 feet. In the islands lying west of Baffin island, and south of Barrow strait, Melville sound, and McClure strait, the same general elevation continues in the case of the more easterly islands, but sinks to 500 feet or less on Victoria island.

It rises again in Banks island, the most westerly of the Arctic islands, to 1,000 feet, and there considerable areas have elevations of 3,000 feet or over. The islands lying north of Melville sound, the Parry and Sverdrup groups, are comparatively low, with general elevations in the interior of 1,000 feet or less, though the eastern members of the Sverdrup islands are high, like the adjoining Ellesmere island.

The physical features of the Arctic islands are reflected in the geology of the region. The elevated districts of the large eastern islands are largely underlain by pre-Cambrian formations resembling those of the Ungava peninsula. Pre-Cambrian strata occupy the greater part of Baffin island and extend northward, but not continuously, through North Devon and Ellesmere islands. The lower, western portion of Baffin island and the islands to the west and northwest are floored with usually flat-lying or gently dipping Palæozoic measures, while the northward lying Sverdrup islands and portions of Ellesmere island are occupied by Mesozoic strata of the Triassic period.

The northwestern portion of Baffin island, and the islands to the west, including Victoria island and part of Banks island, are occupied by Ordovician and Silurian strata, chiefly limestones and dolomites with, sometimes, sandstones and shales. The Ordovician measures are largely confined to Hudson strait, and the northern shores of Hudson bay, while the Silurian measures are more fully developed farther north. The lower members of the Ordovician have been generally ascribed to the Galena-Trenton, a formation found also on the southeastern shores of Hudson bay and in Manitoba. Palæozoic strata older than the Ordovician are known to occur at only one locality in the Arctic region, on the east coast of Ellesmere island, fronting on Smith sound, where Cambrian measures underlie the Ordovician.

The Silurian limestones on Banks island are overlain by Devonian beds, in their turn covered by Carboniferous strata. On North Devon island, and in the southern portion of Ellesmere island, the Silurian beds are conformably overlain by Devonian strata; one section on Ellesmere island indicating a volume of about 8,000 feet, representing beds ranging in age from middle Silurian to upper Devonian.

The Devonian measures extend westward into the Parry group, although these islands are mainly occupied by Carbon-

PLATE XLVIII.

Glacier, Bylot Island, Baffin Bay.

iferous measures conformably succeeding the Devonian strata. The lower portion of the Carboniferous consists largely of sandstones, with important seams of coal, while the upper part is composed of limestones, etc. The Sverdrup islands, to the north, are chiefly occupied by Triassic sediments, with, in the interior, volcanic rocks. These measures also occur on Ellesmere island. Lignite-bearing Tertiary beds have been found occupying low-lying areas at a number of points in the Arctic region, on Baffin and Ellesmere islands and elsewhere.

The Palæozoic strata of the Arctic basin were evidently formed in a sea that, advancing southward, flooded a depressed area, now marked by Hudson bay and the surrounding lower lands. This sea, perhaps at first confined to the far north, seems, in mid-Ordovician times, to have been greatly extended and to have reached Manitoba. Possibly in Ordovician times, but more probably in later Silurian or Devonian periods, the Palæozoic basin may also have extended south of James bay, across the Laurentian uplands, to the region of the Great lakes.

The southern extension of the Arctic Palæozoic sea is indicated by the measures of this system occupying the low-lying country bordering Hudson and James bays, from the mouth of the Churchill river in the west to the foot of James bay in the east, a distance of about 750 miles. The area thus occupied, though generally comparatively narrow, reaches southwest of James bay to within 125 miles of Lake Superior. Towards the west, Ordovician limestones appear on the shore of Hudson bay, but farther east these are succeeded by Silurian limestones and shales, that in places probably rest directly on the pre-Cambrian. South and west of James bay the Silurian is covered by Devonian strata, limestones, dolomites, etc., with beds of gypsum. Southward of the Devonian area the Silurian measures outcrop in places, while in others the Ordovician beds form the southern, outer border of the Palæozoic basin.

ECONOMIC MINERALS.

There is but a slender fund of information bearing directly upon the occurrence of economic minerals in the Arctic region. Gold has been reported to occur at the head of Wagner inlet. Specimens of native copper have been brought back from Baffin island. Mica is mined in a small way on the north side of Hudson strait. This mineral also occurs in quantities on Cumberland sound. Lignite occurs in the Tertiary beds of the northern and eastern shores of Baffin island, as well as on Bylot island. Thin seams of a good quality of bituminous coal occur in the Carboniferous measures of the islands north of Lancaster sound.

On road, north of Swift Current, Sask.

CHAPTER VI.

THE INTERIOR CONTINENTAL PLAIN.

GEOLOGY.

The Interior Continental plain embraces a large tract of comparatively level, rolling country lying between the Laurentian Plateau region on the east, and the Cordilleran Mountain system on the west. Along the 49th parallel, here constituting the southern boundary of Canada, the plain has a width of about 800 miles, but it is reduced to less than 400 miles on the 56th parallel, and may be said to terminate on the shores of Great Bear lake, on the 65th parallel.

The southern portion of this region includes the wide prairie country of western Canada, extending, in Alberta, nearly 400 miles north of the International Boundary, and including an area of above 150,000 square miles of open grass land, bordered on the north by a strip of mixed prairie and woodland. To the north the country, except locally, is at first wooded, but farther north is occupied by gradually thinning forests.

The whole of the Interior plain, save a very narrow strip of about 12,000 square miles in southern Alberta and Saskatchewan, drains northward to the Arctic ocean or eastward to Hudson bay, and the general slope of the land is, therefore, eastward or north-eastward from the Rocky mountains to the edge of the Laurentian plateau. A line drawn from the base of the mountains near the 49th parallel to Lake Winnipeg, shows an average descent of over five feet to the mile, fully accounting for the rapid courses of the rivers of the region and their often marked valleys.

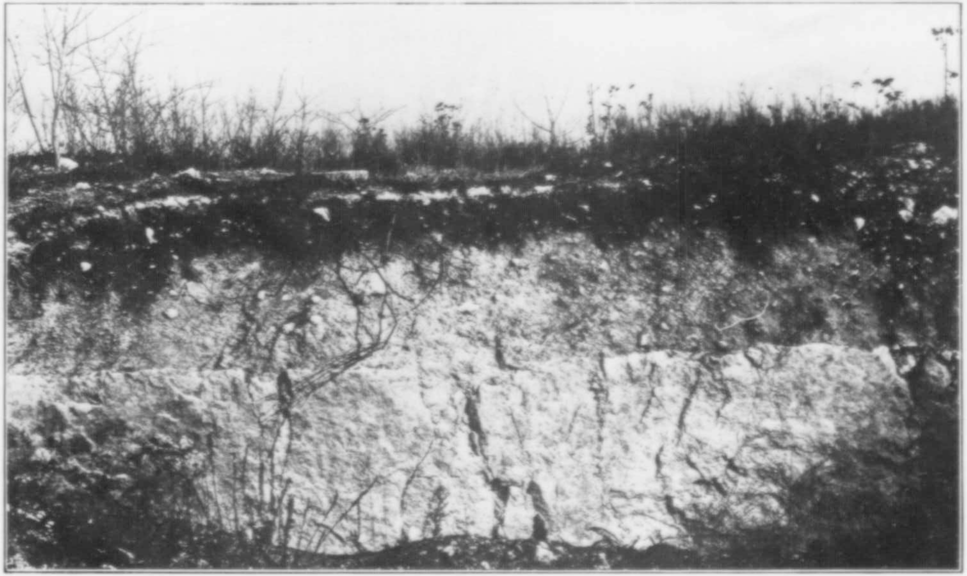
There are in the area south of the 54th parallel two lines of escarpment or more abrupt slopes, which divide this portion of the plains into three parts. The first, or lower prairie level, is that of the Red River valley and the Winnipeg system of lakes. Its average elevation is about 800 feet above the sea, and to the south of Lake Winnipeg it comprises some 7,000 square miles of prairie land, appearing to the eye absolutely flat, although rising uniformly to the east and west. The plain is bounded on the west by the Manitoba escarpment, a remarkable series of highlands, extending over 300 miles northwest from the International Boundary. The summits of this escarpment, broken through by wide valleys cut by the eastward flowing rivers, rise from 500 to 1,000 feet, in places more, above the low plain to the east, once the bed of the glacial Lake Agassiz.

From the Manitoba escarpment, the second prairie level stretches westward for 250 miles to a second escarpment, the Missouri côteau, that extends to the northwest, nearly parallel to the first escarpment. The second prairie level has an average elevation of about 1,600 feet, and its surface is diversified by gentle undulations and low hills rising a few hundred feet above the general level, while the river valleys are often deeply cut and wide.

The Missouri côteau, with a fairly abrupt rise of 200 feet to 500 feet, forms the eastern boundary of the third prairie level, that stretches to the foot of the Rocky mountains. The third level has a general elevation of 2,000 feet to 2,500 feet along its eastern margin, but rises to over 4,000 feet along the borders of the mountains in the west. The surface of the plain is much more irregular than the last, with table-lands, like the Cypress hills and Wood mountain, rising 1,000 to 2,000 feet above the general level, and representing the outlying remnants of a once higher plain, since largely destroyed by erosion.

The region of the Interior Continental plain has had a comparatively peaceful history since early geological times, having been left almost undisturbed by mountain building processes or by the intrusion of igneous bodies, and affected only by continental movements. The country is largely mantled by superficial deposits of soil, etc., concealing, over wide areas, the underlying, gently dipping, very broadly folded, stratified beds, that, in their turn, doubtless rest on the westward extension of the rocks of the Laurentian plateau.

Along the eastern margin of the plains, strata of Palæozoic age rest directly on the pre-Cambrian formations. On the western shores of Lake Winnipeg, and to the south of this body of water, Ordovician measures outcrop. Westwards these are overlain by Silurian beds, in turn covered by Devonian strata



Niagara limestone overlain by till, Gunn's Quarry, Stonewall, Man.

that outcrop to the foot of the Manitoba escarpment, where the Palæozoic measures are overlapped by the much younger Cretaceous sediments that stretch westward to the Rocky mountains, and northwestward for over 1,200 miles. Overlying the Cretaceous beds are others of Tertiary age, occurring in the neighbourhood of the International Boundary, and occupying, in Alberta, a very large area south of the 56th parallel.

The Ordovician measures about Lake Winnipeg consist of sandstones overlain by magnesian limestones, with higher beds of shale and limestone. In age the rocks appear to range from mid-Ordovician to upper Ordovician. They occupy a band of varying width stretching northward from the International Boundary, through Lake Winnipeg, and thence northwestwards for many miles. On the eastern side they rest directly on the pre-Cambrian rocks, while their western edge is formed by the conformably overlying Silurian, or the overlapping Devonian or Cretaceous.

The Silurian consists largely of flat-lying magnesian limestones and dolomites, holding fossils of Niagara and Guelph age. These beds, for the most part, are overlain conformably by others of Devonian age, consisting largely of limestones and shales. It is not certain, however, that either the highest or lowest Devonian beds are present. The measures of this system appear from beneath the Manitoba escarpment of Cretaceous strata that in some places, however, repose directly on the Silurian, concealing the Devonian from view. Farther northwest the Devonian beds again emerge, resting along their eastern margin on the pre-Cambrian, and north of the latitude of Athabaska lake occupying an immense area stretching northward to Great Bear lake and down the Mackenzie valley. The measures of this great northern area, lying in gentle folds, consist of almost 2,000 feet of limestones and dolomites with some quartzites, succeeded by several hundred feet of shales and shaly limestone. The lowest beds of this region are possibly of Silurian age, while the upper division corresponds to the Hamilton, and perhaps to the highest Devonian of all.

The flat-lying Palæozoic measures outcropping from beneath the Cretaceous beds along their eastern border probably extend everywhere beneath the younger rocks of the plains, for they again appear in the west amongst the faulted and folded strata of the Rocky mountains. This mountain range was not elevated until

Tertiary times, and before this period the area of at least the eastern portion of the Rockies was part of the central, level region, submerged beneath the interior sea in which formed the Palæozoic measures of Manitoba. In the west, however, the invasion of the Palæozoic seas appears to have taken place earlier, and to have lasted longer than in the east, for in the Rocky mountains the stratified measures range in age from the late pre-Cambrian to high in the Carboniferous. Since there appears to be such an intimate connexion between the geological history of the strata of the Rocky Mountain front and the measures of the interior plains, the geology of this mountain range will be described conjointly with that of the plains.

In the mountains of southern British Columbia, and adjoining portions of Alberta, occurs a great group of sediments, with a total thickness of over 20,000 feet, largely of quartzites and argillites. These measures are of pre-Cambrian age, apparently deposited in an early sea that continued to exist through Palæozoic times. North of the main line of the Canadian Pacific railway, within the Rocky mountains, a conformable series of over 13,000 feet of fossiliferous strata, largely limestones and shales, represents nearly the whole of the Cambrian system and is directly overlain by Ordovician beds. Along the Bow River pass, the Ordovician measures are conformably succeeded by over 1,000 feet of quartzites and limestones of Silurian age. Above the Silurian beds are several thousand feet of Devonian measures, chiefly limestones and shales, while these are overlain by 5,000 feet to 7,000 feet of Carboniferous beds, divisible into four groups—at the bottom limestones, then shales, then limestones, and, at the top, a series of sandstones and shales.

This great section of Palæozoic measures, some 25,000 feet in all, and the underlying great thickness of pre-Cambrian sediments, appears to be represented, though variously modified both as regards volume and lithological character, throughout the whole length of the Rocky Mountain range. Not only is the total thickness much greater than in the case of the eastern representatives in Manitoba, but lower and higher divisions lacking in the east are present in the west. At the close of the Palæozoic era, most of the region of the Interior plains was withdrawn from the sea, and was not again invaded by it until upper Cretaceous times. But in places, at least, the western portions of this region and the

Gunn's Quarry in Niagara limestone, Stonewall, Man.

site of the Rocky mountains towards the south was at least thrice again a region of deposition: first in Triassic times; secondly in Jurassic times when the Fernie shales were formed; and thirdly, when in early Cretaceous times the coal-bearing, Kootanie group of shales, sandstones and conglomerates, in places 5,000 feet thick, were laid down. It does not appear that either the Fernie or the Kootanie extends far east beneath the overlapping Cretaceous beds, for, followed eastward to where the last exposures are seen, they are found to continuously and rapidly decrease in thickness.

Thus it seems not unlikely that the Interior plain had emerged from the sea before the close of the Palæozoic era. The region was doubtless subjected to erosion, probably sweeping away considerable volumes of strata, yet the process seems to have been such as to preserve the original plain-like surface of deposition. In upper Cretaceous times, when detrital beds again formed in the region, they were received upon a nearly flat surface, so that now there is no marked structural unconformity between the overlying and underlying series. Though lower Cretaceous strata are present in the west, in the east the oldest division of this system is of upper Cretaceous age, and is represented by the Dakota sandstone, that varies in thickness from a few feet to several hundred, and outcrops along the Manitoba escarpment. Farther north, in Alberta and elsewhere, the formation is represented by the tar sands, consisting of rather homogeneous sands cemented by a tarry substance. These beds are also paralleled in the Rocky mountains, but by coarser material of greatly increased thickness. The Dakota sandstones seem to be largely, if not entirely, of freshwater origin, and probably were deposited mainly through the agency of rivers. Though only exposed about the borders of the great Cretaceous basin, they doubtless extend continuously beneath the younger beds of the plains region.

During the succeeding, or Colorado period, the region of the plains was invaded by a sea reaching from the Arctic in the north to the Gulf of Mexico in the south. In this mediterranean sea were deposited dark shales, followed by calcareous shales and shaly limestone, that, along the Manitoba escarpment, increase in thickness northwards to a maximum of about 700 feet. In northern Alberta these measures seem to be represented by several thousand feet of sandstones and shales that, traced westwards into the mountains, become coarser and more arenaceous as they approach the site of the old sea coast. South, near the International Boundary, the beds are, in part, represented by tuffs and volcanic agglomerates.

The marine conditions of the Colorado period continued into the succeeding Montana period, and, in places, perhaps, held throughout this division of Cretaceous time. In the east the beds of this series are represented by a group of shales capped by sandstones of a shoaling sea. These marine beds are, perhaps, also represented in the far north, but over a wide region commencing about the latitude of Edmonton and extending to and beyond the International Boundary, the country during a part of Colorado time was in a fluctuating state, so that brackish and freshwater deposits, with seams of lignite, were formed, and finally were succeeded by true marine deposits. The non-marine beds, the Belly River group, have been brought to light by a broad, anticlinal fold. They consist chiefly of clays and sandstones forming an immense lense, thick in the centre but wedging out east and west. They are underlain by marine shales and sandstones, and overlain by similar beds passing up into more arenaceous measures.

The shallowing seas at the close of the Montana seem to have forecasted a general withdrawal of the marine waters, and the inauguration of freshwater conditions over a large part of the plains region during the time of deposition of the succeeding Laramie group. These measures occupy a large area in Alberta, south of Lesser Slave lake, and, as shown by erosion remnants, were once continuous eastward into Manitoba. The Laramie beds in Canada succeed one another conformably, and apparently were continuously formed during late Cretaceous and early Tertiary times, bridging the gap elsewhere found between the two systems. The Laramie group is very variable in thickness, and may be divided into two portions, a lower one, named the Edmonton, and an upper one, called the Paskapoo. The Edmonton consists largely of argillaceous measures and is coal-bearing. The Paskapoo is much more arenaceous in character, has a thickness of above 3,000 feet, and is considered to be of early Eocene age.

Towards the close of the Laramie, in early Tertiary times, the western margin of the then interior plain-like region was subjected to tremendous earth movements, whereby the Rocky mountains were formed. The strata, traversed by immense dis-

PLATE LII.

Dirt Hills, Sask.

Sod Houses, Eagle Creek, Sask.

locations, were tilted and shoved upwards and eastwards over one another, sometimes for miles. Eastward of the main range, the effects of this mountain building epoch gradually disappear in a series of lower, and lower wave-like ridges; but far eastward the disturbances were still felt, and during this interval the Interior plains appear to have been subjected to erosion.

After the mountain building epoch of Tertiary times the Interior plains again became a region of deposition. The Cypress hills and Wood mountain are formed of argillaceous strata and sandstones overlain by beds of water-worn pebbles with lenses of sand. These measures, formed in Oligocene times, were apparently deposited by detrital-laden, eastward flowing rivers. Probably the present areas are but remnants of a once widely extending tract of beds of similar origin, since destroyed by the processes of erosion that commenced in Tertiary times and have continued to the present day.

ECONOMIC MINERALS.

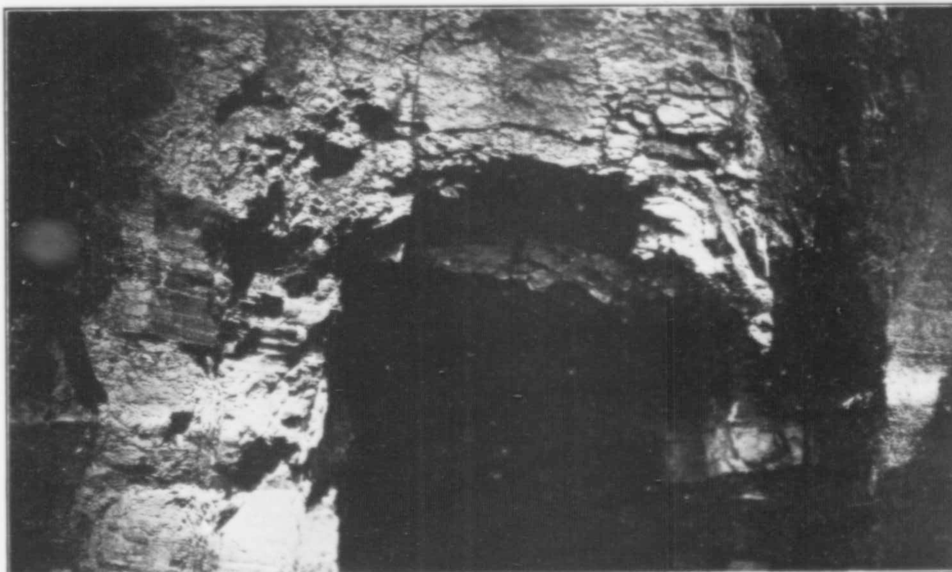
The great areas of farming and ranching land of the Interior plain are markedly deficient in metallic mineral wealth, as might be expected, since they are underlain with a thick blanket of almost undisturbed Cretaceous and Tertiary sediments. Gold dredging is carried on in the sands and gravels of the North Saskatchewan river, below Edmonton; gypsum is mined from the Devonian of Manitoba; salt occurs in Manitoba and in the lower Athabaska; but with the exception of these and materials used in cement, clay manufactures, and building trades, the mineral production is almost entirely confined to fuels, which, however, are very important.

COAL.

Lignite occurs within two horizons of the gently undulating Cretaceous and Tertiary measures of the plains. These horizons are the Belly River, of upper Cretaceous age, and the Edmonton, belonging to the Tertiary. The coal-bearing horizons underlie almost the whole of Alberta south of latitude 55° N., and extend some distance westward into Saskatchewan. In southern Saskatchewan lignite-bearing beds of Tertiary age form the elevated plateaus of the Cypress hills and Wood mountain. The same Tertiary beds form Turtle mountain in Manitoba.

The Belly River formation outcrops over a great curving band, 125 miles broad at the International Boundary and stretching northwards for 300 miles, partly in Alberta, partly in Saskatchewan., North of the Red Deer river, a tributary of the South Saskatchewan, the lignite beds have not been found, or occur but sparingly; but in the south they outcrop at many points, in places, as along the Saskatchewan, in seams 18 feet thick; while at Lethbridge and Taber, about 350,000 tons of a somewhat high grade lignite are annually produced from seams of the Belly River measures. The lignite beds worked are in the neighbourhood of five feet thick.

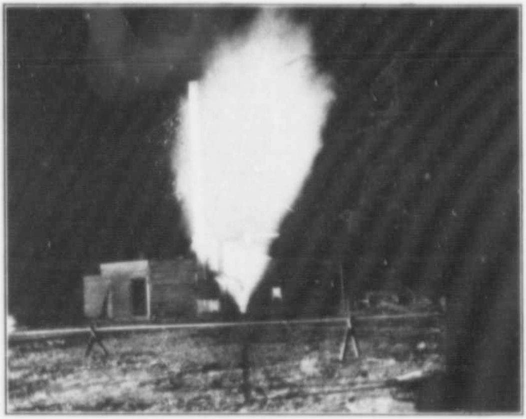
Clover Bar: opening on river, near Edmonton, Alta.



Tunnel on branch of Eagle Creek, Sask.

The coal-bearing Edmonton formation, of Tertiary age, with the overlying Paskapoo, occupies an immense basin, gradually widening towards the north and reaching from the International Boundary almost to Lesser Slave lake. Coal seams outcrop in the Edmonton on both sides of the area of younger Paskapoo, lying basin-like in the centre of the Tertiary area. The lignites have been found outcropping as far north as Edmonton, the

PLATE LVI.



Gas Well, Dunmore, Alta.

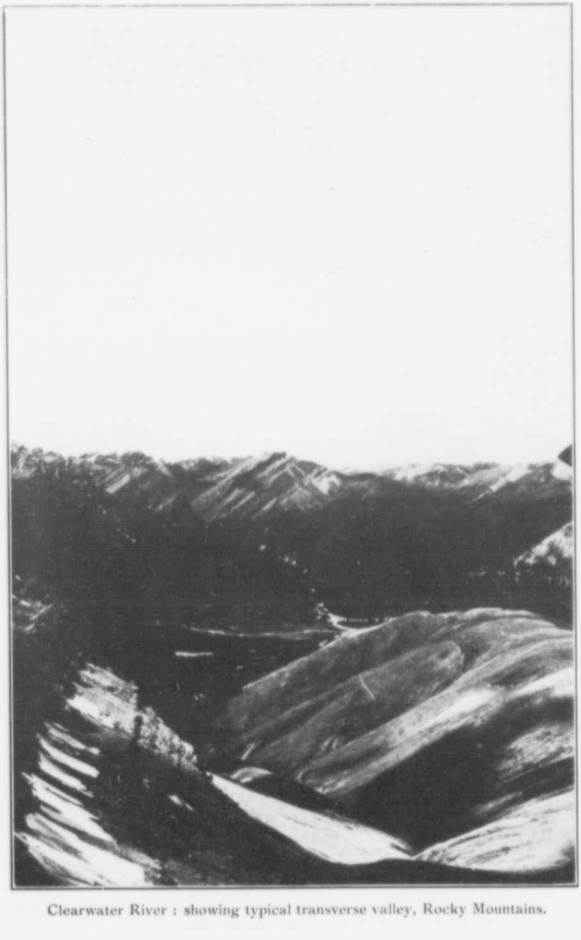
principal mining centre of this coal horizon. In this district, in 1907, over 100,000 tons of lignite were produced, chiefly from one seam that varies in thickness from five to fifteen feet. This lignite seam in places outcrops at the surface, while at other places it lies at depths of 100 to 200 feet.

In Saskatchewan, lignite seams outcrop on the borders of the areas of Tertiary beds that there form elevated districts, apparently representing erosion remnants of a once continuous covering. The Tertiary coal horizons of these areas have been correlated with the Edmonton of the west. In one of these areas, all situated in the south towards the International Boundary in the Cypress hills, a 4 foot seam has been mined. Farther east, at Wood mountain, two seams are known to occur, respectively 6 feet and 8 feet thick. In Manitoba, it has been claimed that the Tertiary area of Turtle mountain also contains coal.

NATURAL GAS AND PETROLEUM.

Natural gas has been found in northern Alberta along the Athabaska. In the south, near Medicine Hat, at several wells drilled to a depth of 1,000 feet, gas was found in the Niobrara, and yielded, in the case of one well, at the rate of 1,500,000 cubic feet per day. Recently a well 1,900 feet deep on Bow island struck a rich gas vein.

Along the Athabaska, in northern Alberta, the basal member of the Cretaceous is known as the tar sands, a formation saturated with great quantities of bituminous matter. There is thus evidence of the probable existence of a petroleum field in the north. Oil seepages also occur in southwestern Alberta. The oil or gas possibilities of the lower Cretaceous measures where capped by the upper members, but not so deeply as to be beyond commercial accessibility, may be considered to be exceptionally good.



Clearwater River: showing typical transverse valley, Rocky Mountains.

Mount Robson, one of the loftiest of the Rocky Mountain peaks, Yellowhead Pass.

CHAPTER VII.

THE CORDILLERAN REGION.

GEOLOGY.

The *Cordilleran region* in Canada embraces the mountainous country bordering the Pacific coast, and having an average width of over 400 miles. It is but a portion of a great mountain system that, commencing in the south and extending northwesterly, occupies nearly the whole of Mexico, and stretches along the Pacific border of the continent through the United States and Canada into Alaska. In Canada, the region includes all of British Columbia, parts of western Alberta, the whole of Yukon Territory, and a large tract in the adjacent western portion of the North West Territories, an area in all of approximately 600,000 square miles.

The western mountain region of Canada, when viewed in detail, appears as a complex assemblage of mountain groups and elevated tracts apparently prohibiting an orderly description. But the presence of several broadly developed, though not always clearly defined structural elements permits the drawing of a generalized picture. Along the eastern front of the Cordilleras, the Rocky mountains, with many peaks in the south rising to heights of about 11,000 feet or 12,000 feet, form a fairly definite range, extending from the International Boundary northwestward to the Liard river, a distance of about 850 miles. The range is bounded on the west by a deep, nearly continuous depression, composed of a series of valleys occupied in the south by the headwaters of the Columbia and Fraser rivers, which empty into the Pacific, and in the north by the tributaries of the eastward flowing Peace and Liard rivers.

North of the Liard river, the mountainous country projects eastwards for a hundred miles or so, and, designated as the Mackenzie system, continues northwards, occupying a large, almost unknown territory some three hundred miles wide between the valleys of the Mackenzie and Yukon rivers. East of the Mackenzie system, whose highest peaks probably do not exceed 7,000 feet in height, a second projection of the mountains forms the Franklin range, bordering the Mackenzie valley on the east between latitudes 63° N. and 66° N. The highest points of the Franklin mountains probably do not reach much above 5,000 feet, and the mountains, dying away to the northward, are succeeded by a great stretch of plain that reaches to the Arctic ocean on both sides of the Mackenzie river.

Along the Pacific border, the Coast range forms a definite mountain range, rising steeply from the ocean to heights of 8,000 feet to 9,000 feet, though broken by numerous, deep, transverse valleys occupied by rivers draining the interior of British Columbia. Westward of the mainland, the mountains of Vancouver and the Queen Charlotte islands to the north may be regarded as part of an outer range separated from the continent by a submerged valley.

Lying between the Rocky Mountain range, with its northward continuations, on the east, and the Coast range on the west, the interior of British Columbia may, broadly speaking, be divided into three portions. In southern, central British Columbia a large area lying east of the Coast range has been designated as the Interior Plateau. Near the International Boundary it is terminated southward by a coalescence of rather irregular mountain ranges, while on the east it is separated from the Rocky mountains by various groups of mountains divided from one another by long, often pronounced valleys. Amongst these subordinate groups may be mentioned the Selkirks, with peaks rising to heights of 9,000 feet to 11,000 feet and over.

Though the Interior Plateau region is, strictly speaking, a mountainous district, yet it is in marked contrast with the more lofty bordering mountain ranges. The country, with a general average elevation of perhaps 3,500 feet in the lower, northern part, is traversed by great valleys, whose bottoms, in the case of those occupied by the major streams, do not lie more than 1,000 feet above the sea. Everywhere the district is broken by ridges and groups of mountains, but these seldom rise higher than 5,000 feet above sea level.

Northward, the Interior Plateau is bounded by an imperfectly known country, occupied by various groups of mountains lying

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Typical Selkirk scenery, B.C.

Interior Plateau, Southern British Columbia.

between the Coast range and the Rocky mountains. This broken, more elevated belt continues north to the boundary between British Columbia and the Yukon. There begins a second plateau region, known as the Yukon plateau, that stretches down the valley of the Yukon into Alaska, bounded on one side by the Coast ranges, on the other by the Mackenzie Mountain system. The use of the term plateau as applied to this northern area is much more appropriate than in the case of the southern area of British Columbia. Though the country is broken by deep valleys sunk 1,000 to 3,000 feet below the surrounding country, yet everywhere the uplands form broad, gently sloping areas, apparently remnants of a once continuous, plain-like region that, with a general elevation of 4,000 feet or more in the south, gradually decreases in height northward to 1,000 feet or less.

The Cordilleran region, except in the far north, is largely a forested country. In the southern interior, however, are wide stretches of open, grass-covered hills and valleys, noted for their fertility. Various districts have long been known to be rich in mineral wealth, and new ones are constantly engaging attention. Large coal mines have been opened up at various points along the Rocky Mountain front, where coal fields are known to occur at intervals for hundreds of miles north of the boundary. Coal mines have long been in operation on Vancouver island. Other coal fields are known to exist in the central interior of British Columbia, and the Yukon Territory. The alluvial gold fields of the Klondike are well known. In southern British Columbia are the notable, immense, copper-bearing sulphide ore bodies of Phœnix, the Rossland gold-copper mines, and the lead mines of Moyie. These are but a few of the better known mineral deposits, and whole districts may be said to be rich in mineral wealth, including ores of platinum, gold, silver, copper, lead, zinc, iron, etc.

The geological history of the Cordilleran region has been complicated in the extreme. Various formations, ranging in age from pre-Cambrian to recent, are widely displayed. At different periods, and often over extensive areas, huge deposits of volcanic matter were poured forth, while at intervals, immense batholitic bodies of igneous rocks invaded and altered the strata. The region from very early geological times appears, during successive epochs, to have been affected by great earth movements that folded and faulted the strata and elevated them into mountain masses, afterwards subjected to intense erosion.

The results of the action of the mountain building forces of the various periods seem to have, in the main, given rise to elevated tracts, whose axes followed a general northwesterly course, like the mountains of the present day. The basins of deposition also seem to have been extended parallel to the same direction, so that now the same general assemblage of formations may be followed for long distances in a northwest or southeast direction, while along sections at right angles to the courses of the mountain ranges a succession of formations is crossed.

The Rocky mountains, and the ranges of the Mackenzie system to the north, are almost entirely composed of sedimentary measures, chiefly of Palæozoic age, but in places including great thicknesses of stratified pre-Cambrian rocks; while in the Rockies, infolded and infaulted basins of Mesozoic strata are common. The Coast range is essentially a complex batholite of granitic rocks of Jurassic age, penetrating Triassic and older rocks such as form Vancouver island. In places along the coast and on the Queen Charlotte islands are basins of Cretaceous and Tertiary beds.

Between the Rocky mountains and the Coast range the country is fundamentally underlain by Palæozoic and early Mesozoic measures, often largely of volcanic origin, folded and faulted, and invaded by granitic bodies frequently of great size, and, perhaps, chiefly of Mesozoic and Tertiary ages. Though Palæozoic and early Mesozoic strata are widely displayed throughout the interior of British Columbia and the Yukon, yet over large tracts of country they are concealed by later Mesozoic and Tertiary beds. In the southern part of British Columbia, Tertiary strata, largely of volcanic origin, occupy whole districts, while in the northern half of the Province, Cretaceous, with, perhaps, late Jurassic beds, are equally prevalent.

The Franklin range is probably largely of younger Palæozoic rocks. The upper Mackenzie valley is chiefly floored by Devonian measures, with a few basins of Cretaceous or Tertiary beds. Farther north the level country on either side of the Mackenzie is occupied by Cretaceous rocks extending a long distance westward.

In southern British Columbia, in the Selkirks and neighbouring ranges on the west, a very large area is occupied by various types

Delta of the Duncan River at the head of Howser Lake, B.C.

Howser Lake, B.C., occupying a north and south longitudinal valley.

Red Deer River: second range, Rocky Mountains.

of schists and gneisses with crystalline limestones and quartzites, all highly disturbed and intricately associated with large bodies of granite, diorite, etc. This complex assemblage, known as the Shuswap group, is probably, in part at least, of pre-Cambrian age, but very likely also includes younger formations. Somewhat similar rocks occur about the headwaters of the Peace river, inside the Rocky Mountain range. Formations presenting certain points of resemblance to these occupy large areas in the Yukon Territory, where, however, it is not at all certain that the rocks are as old as the pre-Cambrian, though they are generally classed as pre-Ordovician.

The great thickness of shales, limestones, etc., of Cambrian age, and the underlying pre-Cambrian beds found along the southern front of the Rockies have already been mentioned. Similar measures seem to be represented along the whole course of the range, and Cambrian and later Palæozoic strata have been found within the Mackenzie Mountain system. The largely calcareous and argillaceous Cambrian measures of the front of the Rocky mountains, when followed westerly through the range along the main line of the Canadian Pacific railway, become less calcareous, and the sediments, on the whole, coarser. In the mountain groups of southern British Columbia, west of the Selkirks, occur several great series of sediments, with an estimated thickness of about 40,000 feet, composed of a lower division largely of calcareous shales with limestones and quartzites, overlain by an upper portion of quartzite, conglomerates and various schists. Traced westwards, the upper division is found largely replaced by volcanic rocks, often in a schistose condition. These extensive assemblages of beds have been described as of Cambrian age, but it is not improbable that at least a considerable portion will yet be found to belong to other series.

Limestones and fossiliferous shales of Ordovician age have been found at wide intervals along the course of the Rocky mountains, and also far north in the Mackenzie mountains. Beds of this age probably also occur in the Yukon. A great series of quartzites and mica schists, some 25,000 feet thick, occurs in southern British Columbia west of the Selkirks and has been placed in the Ordovician, but solely on stratigraphical grounds. As yet, Silurian measures have been recognized at only one locality in the Cordilleran region, along the pass traversed by the main line of the Canadian Pacific railway through the Rocky mountains. Devonian limestones, shales, etc., sometimes forming sections thousands of feet thick, appear to occur everywhere along the Rocky Mountain range. They are present in the Mackenzie system of mountains, and in the northern portion of the Yukon Territory. Fossiliferous Devonian beds have also been found on Vancouver island. Elsewhere, save for the presence of measures possibly of late Devonian age, the beds of this system have not been recognized in the Cordilleran region.

In the Rocky mountains, the Devonian is conformably succeeded by Carboniferous beds largely limestones, and shales, in places 5,000 to 7,000 feet thick. From the palaeontological evidence available, these beds seem to represent only the lower part of the Carboniferous system. Carboniferous strata with, perhaps, conformably underlying Devonian beds, are extensively developed throughout central British Columbia, and continue into the Yukon territory. The beds sometimes consist largely of true sediments, but, more commonly, are represented by great thicknesses, sometimes 5,000 feet or more, of tuffs and various effusive volcanic rocks often overlain by great volumes of limestones, in places 3,000 feet or more thick.

In the Rocky mountains the Carboniferous beds usually are directly overlain by Cretaceous strata, though sometimes beds possibly of Triassic age also occur. In the interior of British Columbia, the Carboniferous strata are often surmounted by immense thicknesses of volcanic material of Triassic age. In the neighbourhood of Kamloops lake these measures, apparently the products of submarine volcanoes as many of Carboniferous times appear to have been, have a thickness of 10,000 to 15,000 feet. Similar beds have been found all through central British Columbia, and, separated by the granite bodies of the Coast range, appear along the Pacific coast and on Vancouver island. Everywhere the Triassic strata, so largely of volcanic origin are closely folded, and on the coast, as well as elsewhere, are usually associated with older measures of Carboniferous age. Possibly in many districts the volcanoes of Carboniferous times may have continued in action with but slight interruptions until the Triassic period.

In a few localities in southern British Columbia, the Triassic volcanoes seem to have remained active into Jurassic times.

Cascade Mountain, Alta., typical Selkirk peaks and transverse valley. The scars on the valley slopes show the courses of avalanches through the timber.

With the exception of the deposits so formed, no formations definitely determined as belonging to the earlier Jurassic epochs are known to occur in the Cordilleran belt, where sedimentation does not appear to have again commenced until late Jurassic times.

During the Jurassic interval, the Triassic and older measures occurring west of the site of the Rocky mountains were faulted and folded, and probably elevated into mountainous masses. At about the same time took place the invasion of the great batholitic bodies forming nearly the whole of the Coast range, extending along the border of the continent for nearly 1,000 miles. The granitic rocks of this range are doubtless not all of the same age, and vary much in composition from basic gabbros to acid granites. Possibly it was also at this time that many of the large plutonic bodies of southern British Columbia formed; though the evidence to the south, in the United States, points to a Cretaceous age for them. They are chiefly of granites, grano-diorites and allied types, and are largely confined to the central portion of British Columbia, south of the main line of the Canadian Pacific railway. Probably they continue much farther north, concealed beneath Cretaceous and Tertiary measures, for they seem to be represented in the northern part of the Province, and in the Yukon Territory.

Before the close of Jurassic times, the deposition of material had again commenced in the Cordilleran region, and continued, over increasing areas, into Cretaceous times. In the southern part of the Rocky mountains the Fernie shales, of late Jurassic age, have a maximum thickness of 1,500 feet, rapidly decreasing eastward. They rest directly on Carboniferous strata, and are overlain by early Cretaceous beds, the coal-bearing, non-marine Kootanie series, in places composed of 5,000 feet of shales and sandstones. In the Queen Charlotte islands a section of over 9,000 feet of strata, representing both the upper Jurassic and lower Cretaceous, rests unconformably on folded Triassic beds. The section consists largely of sandstones and shales, holding coal seams towards the top, and with a thick, intermediate, volcanic group.

Lower Cretaceous rocks also appear in southern British Columbia, largely along the lower course of the Fraser river, east of the Coast range. They sometimes attain a volume of 5,000 feet or more, but show rather wide variations in thickness and character. They seem to be largely littoral deposits, shales, sandstones, and conglomerates. In the central interior of British Columbia, about the headwaters of the Skeena and Nass rivers, occurs a thick volcanic series, possibly of late Jurassic or early Cretaceous age, overlain by a comparatively thin series of shales and sandstones holding seams of coal. In northern British Columbia, and the southern portions of Yukon Territory, occur volcanic and coal-bearing sedimentary beds of late Jurassic and, probably, early Cretaceous age.

At the close of lower Cretaceous times the Canadian Cordilleran region appears to have been withdrawn from the sea, eroded, and doubtless subjected to mountain building forces. Certain plutonic bodies in the interior seem to be of this period. Along the Pacific coast, however, sedimentation continued, and the lower Cretaceous beds of Queen Charlotte islands are there followed by about 3,500 feet of conglomerates, sandstones, and shales. At the same time portions of the coast of Vancouver and adjacent islands were submerged, and a series of coal-bearing sandstones and shales, over 5,000 feet thick, were formed.

Towards the close of the Cretaceous period, or in very early Tertiary times, the formation of the Rocky Mountain range took place. The hitherto flat-lying Palæozoic and Mesozoic beds of the western border of the Interior Continental plain were upturned in long, anticlinal folds, whose axes ran in a general northwest and southeast direction. The forces continuing to act, the folds were overturned, the western limbs thrust over the eastern. In places, segments of the measures were displaced horizontally for as much as seven miles, and the strata have been folded and faulted to such an extent that it has been estimated that they now occupy but half their original width.

The effect of the forces causing the uplift of the Rocky mountains doubtless extended through the whole of the Cordilleran region, but with varying degrees of intensity. During late Cretaceous, and the opening periods of the Tertiary, the region, as a whole, appears to have been undergoing erosion, and during this time the topographic features of the present day were outlined.

During Oligocene, and probably Miocene times, freshwater deposits of shales, sandstones, etc., were deposited in valleys and lake basins over much of southern, central British Columbia. In places these deposits are of but slight extent, but in others they

Northern end of Big Horn range, Alta.: foothills in distance.

Model of Cascade Basin, Rocky Mountains.

occupy large areas. The sediments vary greatly in thickness, at times yielding sections of 5,000 feet or more, and with them sometimes occur beds of lignite. Following the time of sedimentation came a period of volcanic activity, with the formation of beds of tuffs and great sheets and flows of rhyolite, basalt, etc. In places these volcanic beds are 5,000 feet or more thick. Frequently they appear overlying the Tertiary sediments and extending beyond them, filling in old inequalities of the ancient land surface. Similar Tertiary beds occupy an extensive region in central British Columbia, north of the main line of the Canadian Pacific railway, and extend to the Cretaceous basin commencing about the headwaters of the Skeena river.

Though some volcanoes remained active during the Pliocene period and until a very recent date, the Tertiary and more recent epochs appear to have been, in the main, times of active erosion of the land. During the periods from Miocene times onwards, the Cordilleran region apparently was subjected to regional uplifts and depressions, and mountain building processes may still be expected in the Cordillera. In places the Tertiary strata have been folded, and in certain districts in southern British Columbia, occur large bodies of plutonic rocks of Tertiary age.

ECONOMIC MINERALS.

The Cordilleran region is pre-eminently a mining district. Its mines already furnish virtually all the lead mined in the country, almost all the gold, nearly three-quarters of the copper, a quarter or more of the coal, and a considerable proportion of the silver. This high rank has been reached in spite of the fact that prospecting of even the most desultory fashion has been carried out only over a very small, almost insignificant part of the area, chiefly in those districts lying south of the main line of the Canadian Pacific railway.

The comparatively limited amount of prospecting already done has, in the districts covered, marked out various regions as being characterized by the occurrence of certain classes of deposits. The Rocky mountains, and the flanking foothills on the east, contain vast quantities of coal, but apparently are not otherwise rich in mineral wealth. Coal also occurs over other districts in central, southern British Columbia, on Vancouver island, on the Queen Charlotte islands, in the Skeena River country, and in the Yukon Territory and elsewhere.

Rich silver-lead deposits characterize the country lying south of the Canadian Pacific railway, and between the Rocky mountains and the Arrow lakes. To the west and south of this, almost to the Fraser valley, is a district of gold-copper deposits. Along the Pacific coast, both on the mainland and the islands, are many deposits of gold-copper, also in the country of the basin of the Skeena. Iron deposits occur along the coast. Copper and silver deposits mark the southern interior of the Yukon, while placer gold districts, sometimes fabulously rich, extend through the central region from the Klondike in the north, almost to the International Boundary in the south.

Pine Creek, Atlin, B.C.

PLATE LXVIII.

Hydromagnesite Beds, Atlin, B.C.

TABULATED DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE CORDILLERAN REGION.

Element or Mineral sought.	Character and Mode of Occurrence of Deposit.	Example.
Gold......	Alluvial gold in pre-glacial sands and gravels, and in more recent deposits derived from these....	Klondike, Y.T.; Atlin, Cariboo, B.C.
	Auriferous mispickel with varying amounts of copper and iron pyrites occur in bodies replacing country rock along or near contact of igneous rocks of dioritic affinities and in a gangue of garnet, epidote, calcite, etc...........	Hedley, B.C.
	Free gold with a little pyrite and some galena and zinc blende, in quartz fissure veins cutting carbonaceous phyllites......................	Lardeau district, B.C.
	Free gold, argentiferous tetrahedrite, galena, zinc blende, iron and copper sulphide in quartz veins cutting carbonaceous phyllites...............	Lardeau district, B.C.
	Free gold in schistose pyritiferous diabase, and in quartz veins holding mispickel, galena, and pyrite....	Poplar Creek district, B.C.
	In copper-gold deposits. *See* under copper-gold.	
Platinum..	Native platinum occurring sparingly in gold placer deposits.........................	Klondike, Y.T.; Tulameen river, B.C.
Mercury...	Cinnabar in irregular veins of calcite and quartz, cutting Tertiary volcanics and also impregnating sandstones........................	Near Kamloops lake, B.C.
Copper-gold....	Magnetite, chalcopyrite and pyrrhotite in varying proportions occur in large bodies replacing Palæozoic tuffs and limestone, in a gangue of garnet, hornblende, calcite, quartz, etc., in neighbourhood of bodies of granodiorite and Tertiary syenite........................	Boundary district, B.C.
	Chalcopyrite and pyrrhotite with some pyrite and mispickel, occur in veins or in large bodies replacing augite porphyrite near contact with monzonite and in neighbourhood of bodies of granodiorite and Tertiary syenite..........	Rossland, B.C.
	Chalcopyrite, bornite, pyrite, and pyrrhotite with a little calcite in a fissured zone on or near contact of sediments and monzonite...........	Copper mt., near Princeton, B.C.
	Chalcopyrite, pyrite, mispickel, and magnetite with calcite in zones of fissuring in monzonite and sediments........................	Copper mt., near Princeton, B.C.
	Chalcopyrite and pyrite with a little galena and zinc blende in small veins and lenses within a mineralized zone in a quartz sericite schist cut by granitic body of Coast Range batholith....	Britannia mine, Howe sound, B.C.
	Chalcopyrite and pyrite with galena and zinc blende in a gangue of barite with quartz and calcite, forming flattened lenses in schist....	Tyee mine, Vancouver island
	Bornite with subordinate chalcopyrite, a little pyrite and pyrrhotite replacing limestone in a gangue of pyroxene, garnet, and calcite, near granite contact....................	Texada island, B.C.

TABULAR DESCRIPTION OF SOME OF THE CHIEF MINERAL DEPOSITS OF THE CORDILLERAN REGION.

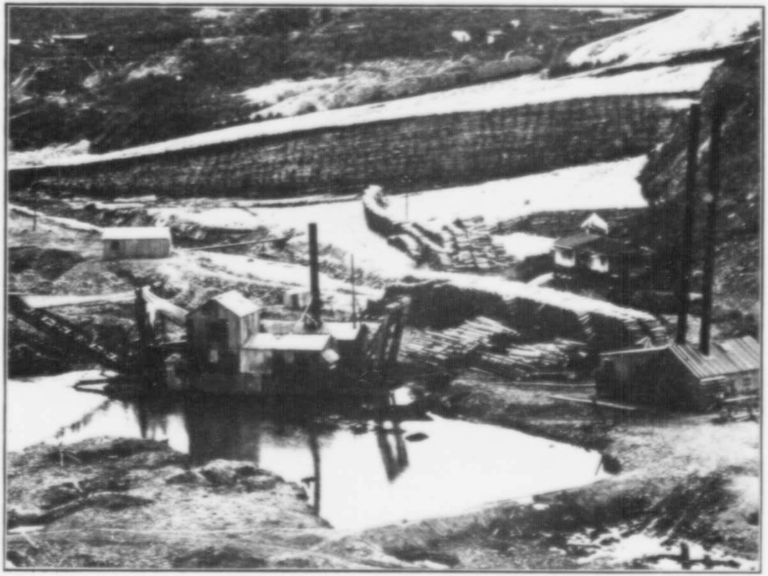
(Continued.)

ELEMENT OR MINERAL SOUGHT.	CHARACTER AND MODE OF OCCURRENCE OF DEPOSIT.	EXAMPLE.
Silver-Lead	Argentiferous galena with some zinc blende and a little pyrite forming irregular lenses in a fissured zone within pre-Cambrian quartzite.	St. Eugene mine, Moyie, B.C.
	Argentiferous galena, argentiferous tetrahedrite, native silver and gold, argentite, zinc blende, copper and iron pyrites, in a gangue of quartz, siderite and calcite in veins cutting sediments.	Slocan, B.C.
	Galena, zinc blende, pyrite, and pyrrhotite in varying proportions, replacing crystalline limestone along a zone of shearing	Kootenay lake, B.C.
	Native silver, argentite, pyrargyrite, argentiferous galena, pyrite, copper minerals, etc., in quartz fissure veins cutting porphyrites	Windy Arm, Y.T.
Iron.	Vein-like bodies largely of hematite with some magnetite cutting pre-Cambrian quartzites . . .	Kitchener, B.C.
	Magnetite in a gangue of calcite, feldspar, and epidote in veins traversing a plutonic rock	Cherry bluff, Kamloops lake, B.C.
	Magnetite in places with copper and iron sulphides in irregular vein-like bodies, replacing country rock, usually limestone, and commonly along contact with intrusive granites.	Texada island, B.C.
Coal.	Anthracite, in Kootanie formation (lower Cretaceous).	Bankhead, Alta.
	Bituminous coal in Kootanie formation	Fernie, Blairmore, Frank.
	Bituminous coal approaching lignite, in Belly River formation (upper Cretaceous), and in Edmonton formation (Tertiary)	Foothills of Rocky mts.
	Bituminous in upper Cretaceous	Nanaimo, Comox, Vancouver island.
	Lignite, in Tertiary beds.	Princeton, Bulkley valley, B.C.; Tantalus, Y.T.

GOLD.

The discovery, between 1855 and 1857, of placer gold on the Fraser, Thompson, and Columbia rivers, and the ensuing rush in 1858, was a primary cause in attracting the attention of the mining world to British Columbia. In 1860 the extraordinarily rich placer deposits of Williams and Lightning creeks in the Cariboo district were discovered, and in 1863, the year of maximum

Fraser River, near Fountain, B.C.



Discovery Dredge, Bonanza Creek, Yukon.

Plate LXXI.

Hydraulicing frozen material on a small scale on Gold Creek, a tributary of Flat Creek, Yukon.

production for this area, nearly $4,000,000 gold was recovered, while up to date the total production has amounted to about $39,000,000.

In 1874, the Cassiar gold field was discovered, and in the first year produced gold to the value of $1,000,000. Some of the other placer gold districts discovered in later years are: Dease lake, Omineca, Atlin in 1897, Big Bend and upper Columbia, Wild Horse creek, Granite creek, and still more recently, Ingenica river, a tributary of the Finlay. In 1907 the total production of placer gold in British Columbia amounted to $828,000, derived, in the main, from the Atlin and Cariboo districts, while the total production of placer gold in British Columbia from 1858 to 1907 has been estimated to have amounted to about $70,000,000.

The placer gold deposits of British Columbia, rich as they have proved to be, have been surpassed by those of the Klondike. As early as 1878 miners began to enter the Yukon district, and finds were made in various districts from year to year until, in 1896, the very rich deposits on the Klondike river and tributaries became known, and in 1897 and 1898 there took place a probably unparalleled rush of gold hunters from all parts of the world. In 1900, the year of maximum production, gold reaching the value of $22,275,000 was brought from the Yukon. In 1907, the amount had decreased to $3,150,000. Following the installation of machinery the gold production is again increasing. The total production of the Klondike district up to, and including the year 1908, has been estimated at $225,000,000, and it has been calculated that placer gold to the value of about $60,000,000, and capable of being extracted, still remains.

The Klondike district lies within the unglaciated region of the Yukon, and is part of the upraised, dissected Yukon peneplain. The oldest gravels in the district, the auriferous White Channel gravels, vary in thickness up to about 150 feet. They were deposited at a time when the Klondike river probably flowed in a direction opposite to that now followed. At the close of the White Channel period, the district was depressed and the Klondike then probably broke into its present valley; and, bringing down immense quantities of material, it rapidly built up a wide gravel bed, that rested upon the White Channel gravels, and is still, in places, fully 150 feet thick.

The depression was followed by an uplift of approximately 700 feet, that affected the whole region bordering the Yukon from the Stewart river northward to the Alaska boundary and beyond. The upraising of the district gave new life to the streams, causing them to deepen their channels, usually along the course of the old valleys, until now they have cut through not only the older gravels, but down into bed-rock to a depth of from 150 feet to 300 feet. During the carving of the present valleys, the process was, at times, arrested, and rock benches cut and floored with gold-bearing gravels; in places these are still partially preserved. The more recent lower creek gravels are also auriferous, and it was in them that many of the fabulously rich claims were staked.

The White Channel gravels, standing at higher levels than the recent stream deposits, are still largely preserved. They are composed chiefly of rounded boulders and pebbles of quartz, embedded in a matrix essentially of sericite scales, and fine, angular quartz grains. The gold they bear, and the quartz they are so largely composed of, were probably all derived from the breaking up of the slightly auriferous quartz veins so abundant in the district. The gravels of the present stream beds, and of the terraces, are largely composed of fragments of schists, etc., derived from the country rocks, while their gold contents have been obtained from the older, White Channel gravels, whose age must date back at least to the Pliocene. The gold in all the gravels is irregularly distributed and often largely concentrated in pay streaks. It always occurs on or near bed-rock, either in the lower five to six feet of gravel, or sunk for some distance in the bed-rock itself. The gold is commonly coarse and the grains quite often angular and sometimes crystalline.

The placer deposits of the Atlin and Cariboo districts are, in a way, analogous to those of the Klondike, since the gold-bearing gravels are of two periods, and the present streams, in general, lie in the broad valleys carved by the older waterways. In both districts the older auriferous gravels are pre-glacial in age and are sometimes heavily buried by glacial drift. The gold contents of the younger, post-glacial deposits seem to have been derived from the older gravels. Gold-bearing quartz veins occur in both districts, thus furnishing a possible explanation of the origin of the placer gold. Other placer districts continue to furnish a small supply of gold, and new diggings will no doubt from time to time be discovered, especially in old pre-glacial valleys.

Typical hillside diggings on Trail Gulch, a tributary of Bonanza Creek, Yukon.

Open-cutting on Eldorado Creek, a tributary of Bonanza Creek, Yukon.

Gold fields, Atlin, B.C.: Claim 2 and 3 below Discovery.

Gold fields, Atlin, B.C.: Claim 37 above Discovery.

Gold fields, Atlin, B.C.: Claim 93 below Discovery, Spruce creek.

Though the bulk of the gold obtained in the Cordilleran region has been derived from the placer deposits of the central portion of the region, from the Klondike in the north almost to the International Boundary in the south, yet a large amount, reaching $4,000,000 annually since 1900, is obtained by lode mining, largely of the gold-copper ores of Rossland and the Boundary district. Various essentially gold-bearing properties, however, occur at many points. Near Nelson, to the west and south of the city, are quartz veins carrying pyrite, chalcopyrite, galena and blende, with gold both free and combined. Similar veins occur in the Salmon River country, but there, also, hold tungsten-bearing minerals.

In the Boundary district gold-bearing veins lie on the outskirts of the low grade, gold-copper deposits, and also between such areas. The veins vary in width up to 10 or 12 feet. The gangue is largely quartz, with calcite and, more rarely, siderite. With these usually occur small quantities of metallic minerals such as chalcopyrite, pyrite, galena, tetrahedrite, rarely argentite, silver, and gold.

The Nickel Plate and Sunnyside gold mines of Hedley are notable, since the deposits consist so largely of mispickel, with which the gold is always associated. Various sediments, limestones, etc., probably of Carboniferous age, form the country rock, and are cut by dikes, and more particularly by igneous bodies of dioritic affinities lying sheet-like and parallel, or approximately parallel, with the bedding planes of the sediments. The ore occurs along the contact of the igneous bodies and the sediments, the latter being highly altered and yielding a gangue largely of garnet, epidote, calcite, etc., in which occurs the mispickel, with varying amounts of iron and copper sulphides, pyrrhotite, hematite, etc. In places the pay ore is as much as 80 feet wide, fading away into country rock on one side, but sharply defined against a dike on the other.

In the Lardeau district are many deposits, with principally lead and silver values, but some are high in gold. One lead, on the Eva group of claims, was first located as a silver-lead property, but afterwards was found to carry high gold values. The deposit consists of two veins lying along nearly perpendicular and parallel fault planes, cutting a band of carbonaceous phyllite belonging to a series of highly altered sediments of Palæozoic or possibly older age. The main veins are connected by numerous cross veins and stringers. The gangue is largely of quartz, with calcite, feldspar, siderite, and sericite, that in places form practically the whole vein, or else carry some pyrite, a little galena and zinc blende, and fine gold in places lying vein-like in the quartz along the margin of the vein. The high grade ore is usually found at the junction of the main veins with laterals.

At the Silver Cup, in the Lardeau district, the deposit also consists of two parallel veins with numerous connecting leads lying in a carbonaceous phyllite, but the gangue is largely quartz carrying argentiferous tetrahedrite, often in considerable masses and still present at a depth of 600 feet. Galena, zinc blende, and some copper and iron pyrites accompany the tetrahedrite. Besides silver and lead, the higher grade ores carry gold to the amount of $12 per ton. The ore is largely localized in lenticular shoots, some of large size, and they frequently occur at the junction of the main and cross veins.

Veins with gold contents occur in the Poplar Creek district. On one property in schistose diabase more or less impregnated with pyrite, there outcrops an almost perpendicular quartz vein, 2 to 5 feet wide, carrying arsenopyrite, galena, pyrite, and free gold, both visible and invisible. The gold forms masses, fibres, and plates, both in the country rocks, the sulphides, and the gangue.

PLATINUM (GOLD).

Platinum occurs with gold in many of the placer deposits of the Cordilleran region, as in the Klondike district, and on the Tulameen river, in southern British Columbia.

MERCURY.

Cinnabar has been found in irregular veins of calcite and quartz, traversing Tertiary volcanics and impregnating sandstone, on Copper creek, flowing into Kamloops lake.

COPPER.

The production of copper in 1907, in the Cordilleran region, amounted to nearly 41,000,000 pounds, of which the Bound-

Poplar Bluff, town of Poplar, Poplar Creek valley (a transverse valley) and Lardeau valley.

ary district furnished about three-quarters. The mines of Rossland accounted for about one-eighth of the total product, while the bulk of the remaining eighth came from Vancouver island. In almost all the districts it is the associated gold, and, to a lesser extent, silver values that allow of the profitable working of the deposits. Besides the copper deposits mentioned in the following paragraphs, many others are known, and not a few are being worked or developed in the southern portion of British Columbia, along the Pacific coast, in the Skeena River district, on the Queen Charlotte islands, and near Whitehorse, Yukon Territory. Most of the deposits of commercial importance are of the contact metamorphic type, formed in the older rocks near the contact of an intrusive body by the gases and mineralizers given off during the formation of the igneous rocks.

In the Boundary district it was not until 1891 that the first of the distinctive ore bodies was located, though previously several less characteristic properties had been found. The deposits, which are of the contact metamorphic type, occur within a series of Palæozoic sediments cut by dikes and comparatively small bodies of syenite of Tertiary age, and near a batholite of granodiorite. The ore bodies are mainly confined to beds of limestone and tuff, that in the mineralized areas are largely changed to aggregates of garnet, hornblende, calcite, and quartz. The ores consist of magnetite, chalcopyrite, pyrrhotite, and small quantities of pyrite and hematite. They are associated with the secondary rock minerals and occur in fissured zones, replacing the country rock.

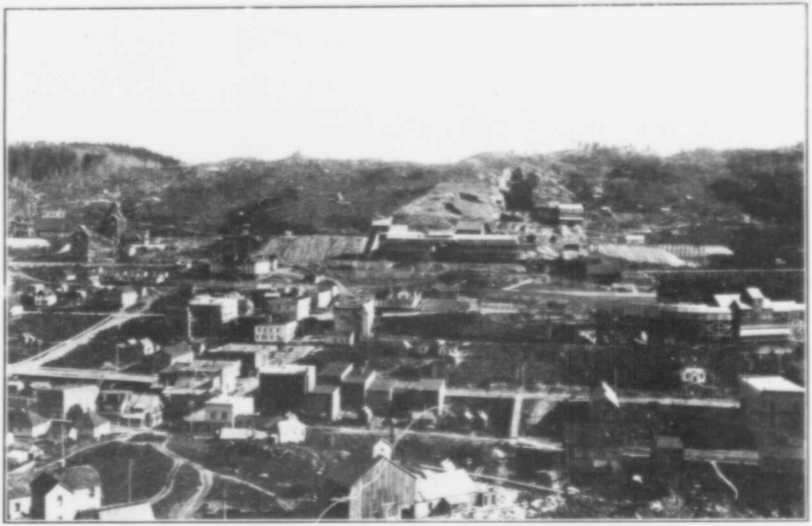
The ore bodies as a rule have no well defined walls, but instead, gradually give way to country rock. They are of all sizes and in certain cases have exceptionally great dimensions. In the larger bodies, magnetite is not evenly distributed, but segregated, though in the case of the Emma mine, the deposit from the surface to the greatest depth yet obtained, about 250 feet, has proved to be practically a continuous body of magnetite, but carrying low copper and gold values. In the more typical mines, the distribution of the various ore minerals, in bands or masses in which one or more of the minerals largely predominates, gives rise to magnetitic ore, calcareous ore, and siliceous ore, that are mixed in suitable proportions to form a self-fluxing ore for smelting. As a rule, magnetite and pyrrhotite are not both abundant at the same time. The chalcopyrite is usually disseminated in points and small stringers, but also occurs in masses of considerable size. In 1908, the average values contained in the 858,432 tons of ore produced by the Granby company were: copper, 1·171 per cent; gold, 0·0503 ozs., and silver, 0·2865 ozs., per ton.

The Boundary deposits are generally characterized by their lack of secondary concentration. In places, however, as at the head of Copper creek, oxidation and secondary concentration have taken place, and at the surface, hematite and limonite occur with malachite, azurite, cuprite, native copper, etc., while deeper down and within masses, appear chalcopyrite and bornite, and below these the unoxidized deposits.

The main mines of the Rossland camp, which during its comparatively short active history of about fifteen years has produced about $40,000,000, are situated near the contact of a body of monzonite and a wide band of augite porphyrite intruded into a group of Carboniferous sediments. The deposits of the Le Roi, and War Eagle, lie within the augite porphyrite body. The main ores consist of pyrrhotite and chalcopyrite, with small quantities of pyrite and arsenopyrite, and occasionally a little magnetite. Free gold occurs and may constitute as much as fifty per cent of the total gold value.

Typical ore consists of country rock more or less altered, containing secondary biotite, etc., with quartz and, in some places, calcite, and cut by reticulating veins, irregular masses and impregnations of the sulphides. There are transitions from typical ore to solid sulphides, or to rock matter, or to gangue with little apparent mineralization but carrying values. In the early days the ore averaged 3 per cent copper, 1½ ozs. of gold, and 2 ozs. of silver per ton; but now the values on an average range from 0·7 per cent to 3·6 per cent copper, 0·4 oz. to 1·2 ozs. of gold, and 0·3 oz. to 2·3 ozs. of silver per ton.

The ore occurs in (1) fissure veins without any accompanying replacement of the country rock; (2) in zones of shearing in which the ore occurs in a network of veinlets eating into and replacing the country rock; (3) in irregular impregnations of the country rock. The last class is the least important. The transition from pay ore to waste is usually rapid, and pay ore is generally localized in shoots varying in width up to, in exceptional cases,



Phoenix, B.C., showing position of Granby mine.

130 feet, and in length from 50 feet to 500 feet or more, while on an average, the vertical dimension is the greatest.

At Copper mountain, not far from Princeton, two classes of gold-bearing copper deposits occur. The mountain is part of a batholitic body of a general monzonitic character, intruding and altering a series of sediments probably of Carboniferous age. One class of deposits occurs at or near the contact of the monzonite, principally with limestone beds. Along the contact both the sedimentary and igneous rocks are traversed by a host of fracture planes, that, away from the contact, are filled with calcite, but near it, are occupied by chalcopyrite, pyrite, pyrrhotite, bornite, and a little calcite.

In the case of the second class of deposits of this locality the ore occurs along zones of fracturing, both in the igneous body and in the sediments. In these zones, the country rock is often brecciated and re-cemented by calcite, or is traversed by a network of calcite veins, sometimes individual veins measuring two feet across, but more generally only an inch or two. The veins, besides calcite, carry pyrite, chalcopyrite, mispickel and magnetite, and sometimes the magnetite entirely replaces the calcite and then forms the gangue of the vein.

A noted copper deposit is that of the Britannia mine situated on the east side of Howe sound on the Pacific coast. The immediate district is occupied by highly disturbed and metamorphosed sediments, possibly of Palæozoic age, with intercalated sills and masses of porphyrites and porphyries, intruded by bodies of granite, etc., belonging to the immense Coast Range batholite. The deposits occur in a quartz sericite schist, in part, at least, derived from carbonaceous slates, while in other places it may represent some of the intercalated intrusives. The ores occur in a mineralized zone that is at least four miles long, and towards its central portion has a variable width of from 300 feet to 600 feet.

The iron and copper sulphides of the ore bodies, with at least part of the quartz, appear to have been deposited during the development of the schistose structure in the quartz schist, during an interval following the period of the granitic intrusions. At a later date, concentration took place in parts of the zone, and lenses of chalcopyrite with quartz were formed in a parallel arrangement along the strike of the schist The lenses range in width from an inch to several feet. The ore consists of finely disseminated pyrite, chalcopyrite in small masses and lenses, and a little galena and zinc blende. At the surface small amounts of secondary bornite and covellite occur. The ore is essentially low grade, but besides copper carries several dollars gold and silver to the ton.

Many copper deposits are known at various places on Vancouver island. The most noted is that of the Tyee mine now largely worked out. The country rock is a schist representing a metamorphosed sediment possibly of Mesozoic age. The deposits occurred in flattened lenses following the strike of the foliation of the enclosing schists. The ore bodies appear to have been greatly elongated; one had a maximum width of 50 feet of clean ore, and a mean width of 20 feet for a depth of at least 150 feet. The ore consisted of chalcopyrite, pyrite, galena, and zinc blende, in a gangue of barite with some quartz and calcite. In the case of about 220,000 tons of ore, the average contents were: 4·5 per cent copper, 7 per cent zinc, and 3 ozs. of silver, and 0·14 oz. of gold per ton.

Other copper deposits occur on Vancouver island, such as those on Sooke inlet. There the ore occurs along zones of shearing within a gneissic diorite. In the case of one such zone, having a width of 200 feet and traceable for at least 4,000 feet, the country rock is traversed by innumerable quartz stringers with sulphides of iron and copper, usually in small patches, but occasionally in small veins and lenses.

Another class of copper deposits found on Vancouver island is such as that occurring at Mount Malahat, where sulphides of iron and copper, with considerable magnetite, occur with various contact minerals in limestone near the contact of dikes and bodies of granitic rocks. Similar deposits occur on Texada island, and are described under the heading of iron.

Near Van-Anda, on Texada island, there are considerable copper deposits, such as that of the Marble Bay mine. At this mine the ore body lies in a zone of brecciation in crystalline and semi-crystalline limestone. From the surface to the 260 foot level, the ore occurs in subordinate shoots, but from that level down to the 771 foot level it forms a continuous body, varying in length from 70 feet to 205 feet, and in width from 5 feet to 45 feet.

Plate LXXIX.

Open cut, Granby mine, Phoenix, B.C.

PLATE LXXX.

Granby mine, Phoenix, B.C.: stope showing pillars of ore.

The ore is bornite with subordinate chalcopyrite and a little pyrite, pyrrhotite, molybdenite enclosed in a gangue of pyroxene, garnet, and calcite. The ore is finely disseminated through the pyroxene or occurs in rather large, pure masses with calcite. The deposit is believed to be of pneumatolytic origin, and probably formed during the period of intrusion of the Coast Range batholite. The ore is high grade, the shipping ores averaging 8 per cent copper and $10 gold per ton.

SILVER-LEAD.

Since silver and lead, as found in the Cordilleran region, are usually closely associated with one another, it has seemed best to combine the descriptions of the deposits of these two metals. The same deposits also have afforded a certain amount of zinc, the amount produced varying with market conditions. Almost all the silver and lead produced in the Cordilleran region comes from southern British Columbia, mainly from the southeastern part of the Province. In 1907 the total production of lead in British Columbia was 47,738,703 pounds, and above three-quarters of this amount came from the Fort Steele district, in East Kootenay. In the same year the amount of silver recovered in British Columbia was 2,745,448 ounces.

By far the largest single producer of lead is the St. Eugene mine, discovered in 1895 near Moyie. The ore bodies lie in a nearly vertical fissure zone, outcropping for a vertical distance of above 2,000 feet on the side of a steep hill. The country rock is a quartzite of Cambrian or pre-Cambrian age. The fissure zone consists of two main, roughly parallel, fissures, two to three hundred feet apart and connected by cross veins. The ore consists chiefly of argentiferous galena with some zinc blende and a little pyrite. During a considerable period of time the ore averaged about 18 per cent lead and carried about 6 ounces of silver. The gangue is usually country rock with some quartz.

The ore bodies are irregular in distribution and shape, but have a general lenticular habit. They lie along the courses of the main and cross veins, and more particularly at the junction of the two sets, where masses of ore up to 60 feet in width occur. In one instance solid ore continued along a drift for a length of 1,000 feet. In height some of the lense-like bodies reach 50 feet to 150 feet.

In the same district the North Star mine, near Kimberley, is of an unusual type. The country rock is an altered, feldspathic sandstone, and the contact of rock and ore bodies is generally sharp. The ore consists of nearly pure argentiferous galena associated with some lead carbonates. The ore bodies lie close to the surface, being merely covered by drift; in form they are basin-shaped, nearly flat-lying, and are of considerable size, one having measured 400 feet in length, 70 feet in width, and 50 feet in depth.

Many silver-lead deposits have been found in the region between Kootenay and Arrow lakes. The deposits occur in fissure veins having gangues of quartz, calcite, and siderite. The ores consist of argentiferous galena, blende, argentiferous tetrahedrite, copper, and iron pyrites, arsenopyrites, argentite, native silver, and gold. The pay ores are generally localized in chutes, and are often concentrated around inclusions of carbonaceous country rock or along the wall-rock, and sometimes in it. The larger ore bodies are generally situated at points of intersection of veins.

The Slocan Star, near Sandon, is a mine of the above class. The deposit occurs along a vein varying in width from 4 to 40 feet and cutting slates. The vein dips at moderately high angles, and the gangue is mainly of quartz, siderite, and calcite with a little barite. The ore is largely galena, with considerable zinc blende and a little tetrahedrite; all these carry silver, and picked specimens of tetrahedrite have been said to carry silver at the rate of several thousand ounces to the ton.

On the east shore of Kootenay lake, opposite Ainsworth, are examples of silver-lead deposits in limestone. The country rocks are various gneisses, quartzites, and crystalline limestones, apparently flat-lying at this locality. They have been classed with the Shuswap group. The ores occur replacing the limestone along certain beds or bands within a zone of shearing some 800 feet wide. The ores consist of pyrite, pyrrhotite, blende, and galena, forming bodies of considerable size, in which sometimes the iron sulphides, sometimes the lead and zinc minerals predominate. The ores are silver-bearing, and sometimes the zinc content is high.

Rich silver-bearing veins occur in the Yukon Territory, on the shores of Windy Arm, Lake Tagish. The veins occupy fissures usually lying in basic porphyrites. They generally are comparatively narrow, though sometimes they attain widths of 8 or 10 feet. They are fairly persistent along the strike, one having been traced for over 1,500 feet. The gangue is largely quartz, containing, besides native silver, a variety of silver-bearing minerals such as argentite, stephanite, and pyrargyrite, all of which are generally present. Pyrite and argentiferous galena always occur in the veins, generally accompanied by small quantities of zinc blende. Various copper minerals are also associated with the above minerals.

IRON.

Though large bodies of iron ore are known at various points in the Cordilleran region, they have, on the whole, been left unworked. Considerable deposits of iron ore in the form of vein-like bodies lying in quartzite have been described from near Kitchener, some twenty miles east of Kootenay lake. The deposits consist of very pure ores, largely hematite, with some magnetite, and vary in width from 5 to 20 feet. They lie parallel with one another in nearly vertical positions, and outcrop at intervals for several miles along a comparatively narrow zone.

A deposit at Cherry bluff, on the south shore of Kamloops lake, at one time produced a considerable amount of iron ore. The deposit consists of magnetite in a gangue of calcite, feldspar and epidote, occurring veinlike, with distinct walls and traversing a plutonic rock.

Considerable deposits of magnetite occur on Texada island and from them some 20,000 tons have been mined. The ore bodies vary in shape from rounded, irregular or lense-shaped masses, to long, vein-like bodies evidently deposited along a zone of shearing. The deposits occur along the contact of limestone with granite or porphyrites, or, apparently isolated, within any one of these three classes of rock. It is believed by some, that in all cases the ore bodies were formed as replacements of limestone, and where the deposits now appear entirely separated from any limestone that the limestone was originally present, and was either completely replaced by the ore or else the remaining portions swept away by erosion. At one locality, a series of lense-like bodies rather closely follows the winding contact of limestone and igneous rocks for a distance of about two miles. Some of the bodies are over 200 feet in length.

The ore is a coarse, crystalline magnetite, locally impure from impregnations of copper and iron sulphides. Some of the ores have carried as high as 3 per cent copper. Quartz, actinolite, calcite, epidote, and garnet are present in small amounts in parts of the ore bodies.

COAL.

The coal produced in the Cordilleran region is almost entirely bituminous, and by far the greater part is of Cretaceous age. Coals of Tertiary age are known at a number of localities, as in the Nicola valley and near Princeton. The Tertiary coals are lignites, and sometimes form thick seams, as in the case of the Princeton area, where an 18 foot seam outcrops on the banks of the Similkameen river. The total coal produced in 1907 was in the neighbourhood of 3,000,000 tons. Though Cretaceous coals occur in the Yukon, on some of the islands of the Queen Charlotte group, within the basin of the Skeena river, and elsewhere, the main development of coal mining has, as yet, taken place on Vancouver island, and within the Rocky mountains and the foothill districts to the east.

On Vancouver island, the coal seams occur in the upper part of the Cretaceous. Coal mining is concentrated in two areas on the east coast of the island, known as the Comox, and the Nanaimo coal fields. The Comox field has an estimated area of about 300 square miles. At one mine, within a vertical section of 122 feet, there are ten seams, with an aggregate thickness of about 29 feet, the thickest seam measuring 10 feet. In the Nanaimo field, two seams, one varying in thickness from 5 feet to 20 feet, and the other from 3 feet to 5 feet, are being mined. The coals are all bituminous.

In the Rocky mountains and the foothills, the Cretaceous coal measures occur as basins amongst the folded and faulted Palæozoic and Mesozoic strata. The basins, generally stretching northwestward and southeastward, and sometimes for very long distances, are known to occur at intervals from the International Boundary to the Athabaska river, a distance of over 200 miles. The coals within the Rocky mountains are bituminous varieties, in places passing into anthracite, as at the Bankhead and Anthracite mines in the Bow valley. Eastwards, in the foothills, as the plains are approached and the regions of disturbance left

PLATE LXXXI.

Bankhead colliery, Alberta.

behind, the lignite coals of the higher members of the Cretaceous are gradually encountered.

Within the mountains and the adjacent foothills, there are three coal horizons. The lowest occurs within the Kootenay formation belonging to the base of the Cretaceous, possibly the summit of the Jurassic. The seams of the Elk River and Crowsnest basins lie within this horizon. The next group of productive measures is the Belly river, situated towards the top of the upper Cretaceous column. The highest group of coal measures lies in the Edmonton of early Tertiary age.

Some of the major coal basins, commencing with the more southerly, are as follows. The southern Elk River basin, with an area of about 300 square miles, and containing the mines at

PLATE LXXXII.

Coke Ovens, Fernie, B.C.

Fernie and Michel. In this basin there are at least twenty-two workable coal seams, having an aggregate thickness of 216 feet, all lying within the Kootenay formation. The northern portion of the Elk River basin, separated from the southern division by a short gap, has approximately the same area and extends as a narrow band far to the north.

A short distance east of the Elk River basin lies a series of narrow basins known collectively as the Crowsnest basin.

which, with certain breaks, extend far to the north to join the Cascade basin that runs north of the Bow river. The Crowsnest and Cascade basins lie in the Kootenay horizon, and in the south include the mines at Blairmore and Frank. In the southern basin twenty-one workable seams occur, with a total thickness of 125 feet of coal.

The Cascade basin, crossing the Bow river at Banff, contains the Bankhead mine, at present the only anthracite producing mine in Canada. In the vicinity of Bow river, the Kootenay measures of the basin contain ten to fourteen workable seams, with from 75 to 100 feet of coal. Northward are other basins. On the Red Deer river, the Kootenay measures hold at least fifteen workable coal seams. with a combined thickness of 114 feet. Other coal basins of Kootenay age lie still farther north, continuing at least as far as the Brazeau river and perhaps farther.

Within the foothills, to the east of the Rocky mountains proper, the Kootenay beds sometimes outcrop, as in the Moose Mountain area. The main basins there, however, lie in the Belly River, that outcrops over bands sometimes hundreds of miles long.

BUILDING AND ORNAMENTAL STONES, ETC.

Excellent building stones of various kinds are found throughout the Cordilleran region. Marble of a high quality is quarried near Lardo, also on the Pacific coast.

CHAPTER VIII.

THE GLACIAL PERIOD IN CANADA.

Preceding the glacial period, Canada, as a whole, had long been uplifted and subjected to erosion. The deep, submerged, seaward continuations of many of the larger drainage channels has been held to show that during parts of Tertiary times the continent had been elevated several thousand feet or more above the sea. Possibly, however, the formation of these, now drowned valleys, may have been due to other causes than the uplift of the continent as a whole.

Before the beginning of the glacial period the long continued Tertiary erosion had produced the main land features of the present day. But the crust of the earth, then as now, was subjected to differential movements, resulting in the warping of large areas. It was by movements such as these, guiding and controlling the ancient drainage, that the depressions now occupied by the Great lakes are believed to have formed.

During the glacial period nearly one-half of the North American continent was, at one time or another, buried in ice that virtually occupied the whole of the Canadian portion of the continental land, and, in the region of the great lakes, extended into the United States to about the 37th parallel, an area in all of above 4,000,000 square miles. The Arctic islands, however, during this period do not appear to have supported glaciers any larger or more important than the local ones at present occurring on portions of Baffin and Ellesmere islands. Nor was the Klondike region, in the Yukon Territory, glaciated, and the same is true of the larger part of Alaska, save about the mountains.

During the glacial period there appears to have been at least three great centres of glacial radiation—the Labradorean, on the Hudson Bay side of the centre of the Ungava peninsula; the Keewatin, occupying a corresponding position to the northwest of Hudson bay; and the Cordilleran, lying within the mountain system of the west. From these three centres, as indicated by the glacially transported material and the markings on the often polished and grooved rock surfaces, the ice sheets moved outwards in all directions, scouring from the surface of the country its disintegrated material, and wearing down the exposed rock surfaces. But, though the general movement was always outwards from the glacial centres, locally it was often guided by outstanding physical features, excepting, perhaps, during the periods of greatest ice development. Whether all these glacial sheets were contemporaneous is, perhaps, not definitely determined, but it at least is certain that they reached their maximum development at different times. Thus there is evidence to show that the Keewatin glacier once occupied territory afterwards covered by the Labradorean, and that the ice tongues from the Cordilleran had retreated from the plains before the Keewatin glacier reached the foothills.

The results of glacial action in Canada are everywhere shown by the presence of boulder clay, moraines, eskers, etc. These deposits, though frequently containing material drawn from far distant sources, are often largely of local composition. In the southeastern portion of Canada, where the relief of the country is low, and the energy of the glaciers was taxed with its load of debris, the evidence goes to show that the erosive power of the glacial sheets was largely confined to the removal and redistribution of the previously existing soil, and the outer, more weathered portions of the rock surfaces. In the mountainous districts of the west, on the other hand, the destructive action of the glacial ice appears to have been incomparably greater. There the presence of "hanging valleys" indicates that the ice sheets wore down many of the main valleys for depths of many hundreds of feet. In the more northerly portions of eastern Canada, where the energy of the ice sheets would be greater than in the south, erosion is also likely to have been important.

The glacial epoch did not consist of one general advance, followed by a simple retreat and disappearance of the ice sheet. Instead, there appears to have been a number of invasions separated by considerable intervals, and as many as six such invasions have been recognized. The evidence of these distinct invasions is furnished by the unconformable superposition of sheets of drift on one another, by the effects of weathering visible on the tops of different layers, and by the presence, between till-sheets, of soil, sand, gravel, etc., containing plant remains. In some cases the plant remains of the interglacial deposits, such as those near Toronto, indicate that during the interval the climate of the region was milder than that of the present day, and this has led to the conclusion that during some of the interglacial intervals the ice sheet may have largely or completely disappeared.

Though the whole of eastern Canada seems to have been buried beneath ice sheets, it is not certain that the Labradorean glacier ever occupied the whole of the country east of the St. Lawrence. The evidence, indeed, seems to indicate that parts of eastern Quebec and the Maritime provinces were occupied by distinct glacial sheets extending from one or more local centres.

The results of the action of the ice of the glacial period in many ways profoundly modified the pre-existing drainage features. Great deposits of glacial debris in many instances filled up the older drainage courses, ponded back the waters, and caused the development of new water courses and the formation of lakes. In many districts a mature drainage system was partly or largely changed to a juvenile one, now expressed by lakes, rapids, and falls.

Preceding, or during the glacial epoch, there seems to have occurred a widespread, downward warping of the northern country of central and eastern Canada. The older, general southward slope of the land was changed to a northward one. Consequently, as the margin of the last ice sheet retreated northward, it acted as a dam on the northward sloping country, impounding the waters with the consequent temporary formation of large and small lakes, in which were sometimes formed thick, lacustrine deposits. Some of the glacial lakes were very extensive. Such a one was Lake Agassiz, occupying the low plain of Manitoba, east of the Manitoba escarpment and extending southward into the United States, with a maximum area in the neighbourhood of 100,000 square miles.

A long succession of glacial lakes formed in the Great Lakes region, at first draining southward, but gradually finding lower and lower outlets to the eastward along the northward retreating ice front. Finally the ice retreated so far as to allow of the advance of the sea up the St. Lawrence valley, at least as far as the foot of Lake Ontario, and up the Ottawa valley some distance beyond Ottawa. During the submergence beds were deposited containing marine shells, etc., and similar deposits have been found in the low country south of James bay, and in the Maritime provinces, all pointing to the once lower level of the land.

With the final disappearance of the continental ice sheet, a general upward movement of the north country was inaugurated, and now the marine beds, in places, are found at elevations of over 500 feet. The upward rise is also indicated by the tilted position of the older beaches and wave-cut terraces of the glacial lakes, once horizontal, but now rising to the north along increasing gradients. The eastern country thus appears, in general, to be re-assuming an earlier condition when the main drainage of Canada was southward.

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CANADA

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