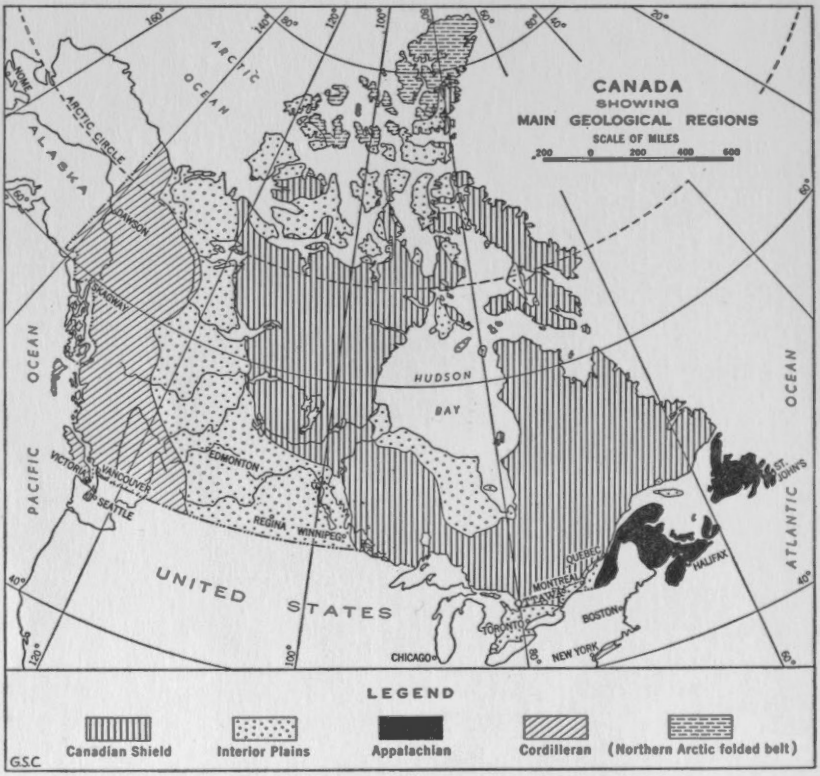
THE GEOLOGY OF CANADA

Reprinted from the Canada Year Book 1951

NATIONAL MUSEUM OF CANADA
DEPARTMENT OF RESOURCES AND DEVELOPMENT
OTTAWA


CANADA
SHOWING
MAIN GEOLOGICAL REGIONS
SCALE OF MILES
200 0 200 400 600
ARCTIC OCEAN
ALASKA
ARCTIC CIRCLE
DAWSON
WHITEHORSE
SKAGWAY
PACIFIC OCEAN
VICTORIA
VANCOUVER
SEATTLE
EDMONTON
REGINA
WINNIPEG
HUDSON BAY
ATLANTIC OCEAN
ST. JOHN'S
HALIFAX
QUEBEC
MONTREAL
OTTAWA
TORONTO
BOSTON
NEW YORK
CHICAGO
UNITED STATES
LEGEND
Canadian Shield
Interior Plains
Appalachian
Cordilleran
(Northern Arctic folded belt)
GSC

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GEOLOGY OF CANADA*

Geologically, Canada falls into the following major divisions: (1) the Canadian Shield; (2) the Appalachian Region; (3) the Interior Plains; and (4) the Cordilleran Region. Nearly everywhere these are sharply demarcated from one another, and each has its own characteristic topography as well as geology. A fifth division, about which much less is known, includes a part of the Arctic Archipelago.

The Canadian Shield is the solid base around which the other Regions are framed. It occupies an area of approximately 1,800,000 square miles, forming an immense 'V' with an arm on each side of Hudson Bay. Physiographically, it is a heavily glaciated region for the most part of low relief, hummocky topography, and highly disorganized drainage. Its surface elevation varies from sea-level to more than 5,000 feet in northern Labrador. It is the great lake region of the world, probably containing more lakes than all the rest of the world together. Its rocks include sedimentary, volcanic and intrusive varieties of widely different ages but all Precambrian. In late Precambrian time the Region was peneplaned, or reduced to low relief, and since then it has experienced relatively little deformation. Vertical movements have, however, repeatedly taken place, some undoubtedly accompanied by faulting, and Palæozoic and Mesozoic seas advanced over parts of it and later retreated from it. In Tertiary time erosion stripped off much of the covering sediments that had been deposited in these seas. Recurrent igneous activity in Precambrian time was accompanied by ore deposition and the Shield is a great storehouse of mineral wealth.

The Interior Plains Region borders the Shield on the west and south. It is underlain by Palæozoic, Mesozoic, and locally Tertiary strata, for the most part flat-lying or only slightly disturbed. The boundary with the Shield is an erosional one, marked by the edges of the overlapping sediments. Small areas within the Shield and larger ones, such as the Hudson Bay Lowland bordering the west coast of James and Hudson Bays, and parts of the Arctic Islands, are outliers of this Region. Southern Ontario and most of the lowland belt along the St. Lawrence River form another area which, though geographically separated in Canada from the western plains, is united with them through the United States to the south. Between the Interior Plains and the remaining two major geological regions—the Appalachian to the east and the Cordilleran to the west—the essential difference is that, whereas the strata of the Plains lie horizontally, those of the other two are for the most part highly deformed as a result of mountain-building movements.

The Appalachian Region includes the Provinces of Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland, and that part of the Province of Quebec lying south and east of the St. Lawrence River. It is a continuation of the Appalachian Mountain System of the United States and, like it, is underlain largely by

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GEOLOGICAL TIME CHART

ERA	PERIOD	CHARACTERISTIC LIFE	OROGENY	TOTAL ESTIMATED TIME IN YEARS
CENOZOIC	RECENT	Man		
	PLEISTOCENE		Cascadian	
	TERTIARY: PLIOCENE, MIOCENE, OLIGOCENE, EOCENE, PALEOCENE	Mammals and modern plants		1,000,000
MESOZOIC	CRETACEOUS, JURASSIC, TRIASSIC	Reptiles and gymnosperms	Laramide	60,000,000
			Coast intrusions	
			Palisade	
PALÆOZOIC	CARBONIFEROUS: PERMIAN, PENNSYLVANIAN, MISSISSIPPIAN	Amphibians and lycopods	Appalachian	200,000,000
	DEVONIAN	Fishes	Shickshockian	
	SILURIAN, ORDOVICIAN	Higher invertebrates	Taconic	
	CAMBRIAN	Primitive invertebrates and algae	Killarnean	500,000,000
PRECAMBRIAN: PROTEROZOIC	KEWEENAWAN, HURONIAN			
		Nil	Algoman	1,100,000,000
PRECAMBRIAN: ARCHÆAN	TIMISKAMING, KEEWATIN		Laurentian	2,000,000,000

G.S.C.

rocks of Palæozoic age. It is a Region that has experienced intense folding and thrust faulting, but the final major orogeny took place not at the close of the Palæozoic, as it did farther south in the United States, but in Middle Devonian time.

The boundary between the Appalachian Region and the Interior Plains Region to the northwest is a major dislocation known as Logan's Line, a thrust fault first recognized by Sir William Logan, founder of the Geological Survey of Canada. It runs from Lake Champlain to Quebec city and thence down the St. Lawrence River between Gaspe Peninsula and Anticosti Island. To the northwest of this break, the strata of the St. Lawrence Lowlands lie flat for the most part, and what faults occur are mostly of the normal type. To the southeast the strata of the Appalachian Region are highly inclined, locally overturned, and the pre-Carboniferous faults are of the thrust variety.

Physiographically, the Appalachian Region is made up of uplands and lowlands. The former represent mountain structures that were peneplaned probably in the Cretaceous period and later uplifted; the latter are broad areas carved out of these uplands in places where the rocks are softer and hence more easily eroded. The highest elevation, 4,200 feet, is that of Mount Jacques Cartier on Tabletop Mountain in the Shickshock Range of central Gaspe.

The Cordilleran Region comprises the mountainous belt of British Columbia, Yukon and adjacent territory. It is made up of a series of ranges and plateaux separated by great linear valleys or trenches trending mainly northwesterly. Within this Region the Rocky Mountains, Foothills, and Mackenzie Mountains in the east are separated from the Coast Mountains of the Pacific border by a wide zone of the Interior Plateaux and Mountains. The rocks of the Region range in age from Late Precambrian to Recent. Proterozoic and later eras are represented over wide areas and locally volcanic eruptions have continued into Glacial and Recent times. The western part was affected by mountain-building movements and batholithic intrusion at intervals throughout Mesozoic time, possibly reaching a maximum during late Jurassic and early Cretaceous epochs. At the close of the Cretaceous period and extending into early Tertiary time, another great revolution, the Laramide, resulted in the folded structures of the Rocky and Mackenzie Mountains. Local deformation, consisting of vertical movements, faulting and minor folding, also took place in later Tertiary time. To the south in the United States this disturbance, referred to as the Cascadian, is known to have continued into Pleistocene and even Recent time. During the Pleistocene most of the Cordilleran Region of Canada was glaciated.

The Arctic Islands of Canada, together with Boothia and Melville Peninsulas, form a geographic unit whose land area exceeds half a million square miles. Geologically, many of the individual areas may be regarded as outliers either of the Canadian Shield or of the Interior Plains, those of the former commonly attaining much greater elevations than those of the latter. On Baffin Island, for example, a range of Precambrian rocks has a height of at least 5,000 feet above sea-level, with occasional peaks rising much higher. The rocks of the Plains outliers are either flat-lying or only slightly disturbed and consist of Palæozoic and younger beds. Triassic and Jurassic strata are known in some of the northern islands, and small basins of Tertiary sediments are found in numerous localities.

All the areas of Palæozoic and Mesozoic rocks in the Arctic Archipelago, however, cannot be regarded as outliers of the Interior Plains. On Ellesmere Island to the northwest of Greenland are folded strata forming mountains with elevations

up to 12,000 feet. Folded rocks are also known to occur on Axel-Heiberg Island to the west with elevations up to 7,000 or 8,000 feet, and air photographs indicate similarly deformed measures on Bathurst and Melville Islands. This gives a length of some 800 miles in a southwest direction to the disturbed zone. The age of some of the strata involved is known to be Ordovician and that of others Silurian and it has been suggested that the folding may have taken place near the close of the latter period. At other places, however, the deformed beds include some as young as Jurassic. Although the amount of information at present available regarding the extent, age, and structural relations of these rocks, and also regarding the time or times at which the orogenic movements that deformed them took place is comparatively meagre, it is apparently sufficient to necessitate the differentiation of the disturbed belt as a fifth major geological region.

Salient Features of each Geological Region

Canadian Shield.—Precambrian time is divided into two Eras. At many places throughout the Shield an older complex of volcanic and sedimentary rocks, commonly highly metamorphosed and injected and intruded by granites and other rocks, is separated by a great structural unconformity from an overlying younger group or groups usually less highly altered but also intruded, locally at least, by deep-seated irruptives. Geological time prior to this erosional interval is referred to as Early Precambrian or Archæan, and the remaining Precambrian time is called Late Precambrian or Proterozoic. It is not thought that the time interval represented by a major unconformity of this type in one area was necessarily precisely contemporaneous with the interval represented by a similar unconformity in a widely separated area. To define, therefore, the exact boundary between the two Eras, the unconformity at the base of the Huronian strata in northern Ontario is selected. Similar breaks in other regions can be correlated only tentatively with this. Perhaps some day, when more numerous and more reliable determinations than at present exist are available on the age of intrusive rocks, Precambrian correlation will be on as secure a foundation as that of later time where life as revealed by fossils is the basis for subdividing geological time.

Over much of the Shield the common rocks are granites and gneisses: many of the latter are hybrid types—altered and granitized sedimentary and volcanic rocks injected by much granitic material—that afford but little information regarding Precambrian history. Elsewhere, however, are scattered areas, many of them small but others of considerable extent, in which successions of other more recognizable volcanic and sedimentary strata occur. These have provided significant geological information and are also important in that they offer favourable possibilities for prospecting.

The Archæan Era is divided into Keewatin and Timiskaming time. The term "Keewatin" was first applied to certain ancient lavas in northwestern Ontario, but was soon extended to early Precambrian volcanic assemblages elsewhere. Work in many parts of the Shield has shown that interbedded with such volcanic rocks are large volumes of sediments. These include bedded ash and agglomerate types, banded iron formation, and clastic varieties metamorphosed to mica schists and quartzites. The Keewatin volcanic rocks are largely basalts and andesites, commonly showing ellipsoidal and amygdaloidal structures, but also include more acidic lavas and related pyroclastic rocks.

Timiskaming time is represented in a number of areas by a group of sedimentary rocks, commonly conglomeratic. They overlie the Keewatin rocks commonly with a slight angular unconformity. With them, locally, are associated volcanic

rocks, so that the assemblage in places bears much resemblance to Keewatin groups. These rocks have been described under many different local names, the Doré Series of Michipicoten, the Windigokan Series east of Lake Nipigon, the Seine Series of Rainy Lake and Steep Rock Lake, the Missi Series of northern Manitoba, etc. These clastic sediments contain boulders of granite believed to have been derived from masses intruded into the Keewatin rocks during an orogeny referred to as the Laurentian.

In the Grenville region of southern Ontario and extending across Quebec into southern Labrador, the oldest rocks are mica schists and gneisses, quartzites and crystalline limestone of what is known as the Grenville Series. In Ontario, another series, known as the Hastings, overlies the Grenville rocks with an erosional unconformity, but with little apparent structural discordance. Both the Grenville and Hastings rocks are intruded by a group of gabbros, anorthosites, pyroxene diorites and pyroxene syenites and, still later, by dykes, sills, stocks and batholiths of granite, syenite and their gneissic equivalents. The age relation of the Grenville rocks to the Keewatin volcanic rocks of the adjacent Timiskaming region is still unsettled and recent investigations seem to imply an almost, if not quite, continuous fault zone along the contact.

Archæan time was closed by a great mountain-building revolution, the Algoman, which was accompanied by the intrusion of granites on a vast scale. Peneplanation followed and on the eroded surface Proterozoic rocks were laid down. Proterozoic time, like Archæan, falls into two divisions, the Huronian and the Keweenawan, and the Huronian, in turn, comprises three recognizable subdivisions, each of which, in length of time involved, is probably of at least period rank.

The Lower Huronian rocks of Canada, termed the Bruce Series, are confined to a narrow zone along the north side of Lake Huron and stretching to about 23 miles east of Sudbury. They consist of the Copper Cliff rhyolite, and impure quartzite, greywacke, conglomerate and limestone, with a total thickness of nearly 15,000 feet. The sediments all show cross-bedding, ripple marks and other evidence of shallow water deposition.

The Cobalt Series accumulated in Middle Huronian time. It rests with little or no structural discordance on the Bruce Series, and overlaps the basement rocks for 100 miles to the north. The Series comprises two formations, the Gowganda and the Lorrain, the former having a maximum thickness of about 3,500 feet and the latter 7,000 feet or more. The Gowganda has at its base a thick boulder conglomerate—a tillite—a rock produced under glacial conditions, and this is overlain by greywacke, the upper part of which is varved suggesting that deposition took place in glacial lakes. The Lorrain consists dominantly of quartzites. Rocks resembling these Middle Huronian sediments occur in several widely scattered areas over the Shield. In the Lake Huron area, Middle Huronian time closed with movements that folded the Bruce and Cobalt Series. These movements were accompanied by the intrusion of great dykes and sills of gabbro, commonly called the Nipissing diabase.

Upper Huronian time is represented, tentatively, by several groups of rocks whose relative age is uncertain—the Animikie of the northwest shore of Lake Superior, the Nastapoka of the Belcher Islands and Richmond Gulf, the Mistassini Series of Lake Mistassini region, late Precambrian rocks of central Ungava, and other groups in the northwestern part of the Shield. These consist of conglomerate,

slate, greywacke, cherty iron formation, carbonate rocks, sandstone, shale and locally volcanic rocks. Towards the close of the period, crustal movements took place accompanied locally by the intrusion of granite.

Rocks believed to have been deposited in late Proterozoic or Keweenawan time are found in widely separated areas of the Shield. The Sibley Series and a younger Osler Series, both occurring east of Port Arthur, part at least of the Whitewater beds of the Sudbury Basin, the Athabasca Series of the Lake Athabasca and adjacent regions, and the Coppermine River Series of the Arctic Coast are some of the more important of these groups. They consist dominantly of clastic beds, but include some interbedded lavas. Late Keweenawan time was marked by uplift, the intrusion of the Killarney granite and other igneous rocks and then by long-continued erosion, so that the succeeding oldest Palæozoic rocks rest on a peneplaned surface of very low relief.

The Precambrian rocks of the Canadian Shield are the source of a great abundance and variety of mineral deposits. Iron formation is present in the Keewatin and Animikie rocks, the iron ores of the Steep Rock, Helen, Magpie, and Josephine mines in western Ontario being in formations of the former and the extensive deposits along the Quebec-Labrador Boundary in rocks of the latter age; gold, copper, lead, zinc, etc., occur chiefly in the Archæan formations; silver and cobalt are associated with the Nipissing diabase; nickel and copper with a Keweenawan irruptive of the Sudbury area; native copper with the Keweenawan Coppermine River lavas; pitchblende, a uranium-bearing mineral, in rocks as young as the Athabasca Series in northwestern Canada; ilmenite in important quantities is present at Allard Lake and other places in the Province of Quebec in anorthosite intrusive into Archæan rocks and titaniferous magnetites are known at many places.

The Shield was heavily glaciated. Polished, grooved and striated surfaces are seen nearly everywhere, and *roches moutonnées*, with well-marked lee and stoss slopes, clearly indicate the direction of glacial advance. Eskers, kames, beaches, etc., can be recognized in many places on aerial photographs of the country. Erosion and deposition by the ice-sheets were responsible for the disorganization of the drainage and the production of the myriads of lakes.

Appalachian Region.—In the Appalachian Region of Canada are rocks ranging in age from Early Precambrian to Triassic. At Saint John, New Brunswick, fossiliferous Lower Cambrian rocks are underlain by a thick volcanic series, the Coldbrook, regarded as Late Precambrian. This is, in turn, underlain unconformably by the Green Head group, composed of crystalline limestone, quartzite, paragneiss, etc., in many respects resembling the Grenville of the Shield. Although considered to be Archæan, it, nevertheless, carries cryptozoan-like forms which have been described under the name *Archæozoon acadiense*. Rocks somewhat similar to parts of the Green Head occur in most of the upland areas of Cape Breton Island and in Newfoundland.

Besides the Coldbrook group of New Brunswick, other groups believed to be also of Late Precambrian age include the Meguma or Gold-bearing Series of Nova Scotia, rather similar assemblages in the Chaleur Bay region and in southwestern Quebec, and sedimentary and volcanic rocks in the eastern part of Newfoundland.

The Palæozoic rocks, which cover most of the Appalachian Region, range in age from Lower Cambrian to Pennsylvanian. Throughout most of the Region and repeatedly during the Era, deposition appears to have taken place in local basins, rocks of the same age varying widely in both lithology and fossil content. In

southern New Brunswick the Saint John group consists of an apparently conformable series, comprising Lower, Middle and Upper Cambrian and also Lower Ordovician beds, and areas underlain by Cambrian strata occur also in Newfoundland, in Cape Breton Island, and in southern Quebec. Ordovician rocks are widespread and all three divisions, Lower, Middle and Upper, are represented. In Late Ordovician time a great deformation, the Taconic, affected much at least of the Region, and was accompanied by the intrusion of masses of peridotite. The thickest succession of Middle Silurian rocks in North America, 8,427 feet of sedimentary and 4,626 feet of volcanic rocks, all conformable, is exposed at Black Cape in the Chaleur Bay region. In the St. George region of New Brunswick, sedimentary deposition during the Silurian was small, but volcanic activity was great. Lower Devonian rocks succeed the Silurian beds in many localities following an interval of erosion. One of the best sections is at the east end of Gaspe Peninsula, where Logan defined the 'Gaspe limestones'. This Series is overlain by a thick assemblage of clastic sediments of Middle Devonian age, known as the 'Gaspe sandstone', and on the north side of Chaleur Bay, near Maguasha, is a succession of Upper Devonian beds noted for the fossil fish which are present locally. Lower Devonian and older strata are intruded by masses of granite and locally mineralized with quartz-carbonate veins, carrying zinc, lead, copper and other minerals. The Middle Devonian rocks are folded and the Upper Devonian only slightly disturbed. Evidently the main orogeny took place in late Lower Devonian or early Middle Devonian time, with renewed movements late in the Middle Devonian and again in diminished amount at the close of the Upper Devonian epoch.

These movements constitute the Shickshockian disturbance, and the results can be seen at a number of places in the Chaleur Bay region where flat-lying beds of the Carboniferous Bonaventure formation overlie tilted and eroded beds of older Palæozoic formations. Granites and related deep-seated intrusions of Devonian age are widespread throughout the Appalachian Region, and Upper Devonian strata carry boulders derived from these intrusive rocks.

The Carboniferous history of the Region was complex. Mississippian time is represented by strata of Horton and Windsor ages. Deposition in Horton time was in local basins, but during succeeding Windsor time a sea submerged much of the Region and locally, as in the Magdalen Islands, intense volcanism occurred. Pennsylvanian time was marked by local orogeny and volcanism, faulting and broad warping movements, and by the deposition of coal with each of the successive Riversdale, Cumberland and Pictou sedimentary groups. The great Appalachian revolution which took place at the close of the Palæozoic Era in the United States to the south had only comparatively minor effects in Canada.

Triassic sandstones, with interbedded volcanic rocks similar to the Palisade rocks along the Hudson River, occur in the Bay of Fundy area. They are broken by faults. On Grand Manan Island a major break brings Early Precambrian sediments alongside Triassic flows, the oldest rocks of the Region in knife-edge contact with the youngest. These fault movements probably took place in Triassic and Jurassic time. During the Cretaceous period the Region was peneplaned. The Tertiary was a time of uplift and erosion, with the development of broad lowlands and local peneplains. The Pleistocene saw the development of local centres of glaciation, and the entire Region was covered by the Labrador Ice Sheet.

The mineral resources of the Appalachian Region include asbestos, associated with serpentinized peridotite in southeastern Quebec; iron, with the Ordovician sediments of Bell Island, Conception Bay, Newfoundland; coal in the Pennsylvanian

rocks of Nova Scotia, New Brunswick, and Newfoundland; gypsum and barite in the Windsor series; and gold, copper, zinc, lead, fluorite, and other deposits most of which at least are genetically related to the Devonian granitic intrusions. The Buchans mine near Red Indian Lake, Newfoundland, is an important producer of zinc, lead and copper.

The Interior Plains.—*Western Canada.*—The Interior Plains of the Prairie Provinces slope gently eastward from an elevation of about 4,000 feet in western Alberta to about 500 feet in southern Manitoba. They show a flat surface interrupted by deep-incised valleys and by many flat-topped hills or mesas. The area of the Plains is divided into three steppes by two eastward facing escarpments, the Manitoba escarpment forming the western border of the Manitoba Lowland, the lowest and most easterly of the three steppes, and the Missouri Couteau marking the eastern boundary of the Wood Mountain Plateau, the third and highest steppe.

The Plains are underlain by sedimentary rocks of Palæozoic, Mesozoic and Tertiary age. Where the Palæozoic rocks outcrop at the western border of the Canadian Shield the oldest sediments are of Ordovician age. Farther west, in Saskatchewan, drilling has shown Cambrian beds to be present. For example, in the bordering part of the Cordilleran Region, the eastern mountains of southern Alberta, and the Mackenzie and Franklin Mountains in Northwest Territories, are thick successions of Cambrian shales, dolomites and limestones.

The Ordovician strata resting on the Precambrian in Manitoba thin westward beneath the Plains and, so far as is known, do not underlie the northern plains of Alberta. In the eastern Rocky Mountains, however, both early and late Ordovician beds are present. Middle Silurian beds less than 450 feet thick are known in Manitoba. Drilling has shown the presence of similar strata in Saskatchewan, and limestones and dolomites of supposedly Silurian age underlie most if not all of the Mackenzie Lowlands. Devonian strata are present under all the Interior Plains; they consist of limestone and dolomite of Middle and Upper Devonian age. Mississippian beds overlie the Devonian in southern Saskatchewan and Alberta and a fringe of unknown width skirts the east edge of the Foothills.

Mesozoic rocks stretch westward from the Manitoba escarpment. They range in age from Triassic to Cretaceous. Marine siltstones, calcareous shales and arenaceous limestone of Triassic age are known to underlie at depth the northwestern part of the central Plains. Jurassic beds overlie the Triassic, where present, or rest on Palæozoic formations in southern Manitoba, southern Saskatchewan, and in southern and western Alberta along the western edge of the Interior Plains. In the west these strata are marine, but towards the east, in Saskatchewan and Manitoba, they grade into a mixture of marine and non-marine beds.

The Cretaceous period saw widespread deposition on the site of the Interior Plains and Rocky Mountains. Lower Cretaceous history included deposition of sandstone, shale and coal beds in a narrow trough along the western border, followed by the spread of such deposits far to the east, and closed with marine invasions from the north. Upper Cretaceous history included a marine invasion of vast extent followed by recurrent advances of delta plains from the west, and closed with widespread non-marine deposition and the complete expulsion of the sea.

Non-marine deposition continued throughout Paleocene time. In the early Eocene, uplift and erosion was followed by deposition of late Eocene, Oligocene and Miocene gravels derived from the newly uplifted Rocky Mountains and to-day preserved mostly on the Cypress Hills and Wood Mountain, residual uplands on an

old Tertiary watershed. The Plains, except for the top of the Cypress Hills and a small area near Rockglen in southern Saskatchewan, were covered by Pleistocene ice-sheets.

The mineral deposits of the western plains are for the most part non-metallic varieties. Coal occurs in Upper Cretaceous beds in Alberta and in Paleocene strata in Saskatchewan. Natural gas is produced in large quantities principally from various horizons of the Cretaceous in Alberta and in smaller amounts from beds of similar age in Saskatchewan. Petroleum is obtained from Devonian, Mississippian and Cretaceous rocks. In the new important fields of central Alberta, the major production is from strata of Upper Devonian age and at Norman Wells in the Mackenzie Valley the oil is also in Devonian beds. Bituminous sands occur along the Athabasca River in the basal member of the Lower Cretaceous. Gypsum and salt are obtained from Palæozoic strata in Manitoba and occur also in Alberta. Deposits of zinc and lead are known in Devonian limestone at localities south of Great Slave Lake; clay, sodium sulphate, and building stone are other mineral products.

St. Lawrence Lowlands.—The St. Lawrence Lowlands stretching from Lake Huron northeasterly to Anticosti Island falls into three subdivisions. The first and most westerly includes Manitoulin Island and the part of Ontario facing on Lakes Erie and Ontario. It is made up of two parts separated by a prominent topographic feature, the Niagara Escarpment, an abrupt eastward-facing rise, 250 to 300 feet high, extending northwesterly from Niagara River to Bruce Peninsula. The Escarpment is due to differential erosion, the softer Ordovician strata having been more easily removed than the harder overlying Silurian dolomite. The eastern border of this subdivision is the Frontenac Axis, a southward projection of the Canadian Shield that crosses the St. Lawrence between Kingston and Brockville. The second subdivision extends from the east side of the Frontenac Axis to Quebec city and has for its eastern border the Logan Fault. The third subdivision, separated from the second by about 360 miles of the St. Lawrence River, comprises Anticosti Island and the Mingan Islands.

The strata of the entire belt are of Palæozoic age, for the most part lying flat or with low dips. They are almost wholly of marine origin and were deposited in seas that swept over a large part of the continent. Differential vertical movements caused these seas to advance and retreat so that the sediments deposited in them vary considerably. There are also local gaps in the sedimentary sequence caused by these movements, which were apparently so gentle that there are no angular unconformities.

In the western subdivision the rocks range in age from possibly late Cambrian to late Devonian. East of the Niagara Escarpment the beds are of Ordovician age. Along the Escarpment these rocks are succeeded by Silurian measures. The lowest of these are the Medina sandstones and shales, which are succeeded by the Clinton dolomite. This is followed by the Rochester shale and Lockport dolomite and these in turn by the Guelph dolomite, the Salina formation of dolomite, shale gypsum and salt and the Bertie-Akron dolomite. The total thickness of the Silurian measures is over 2,500 feet. The overlying Devonian beds consisting of the Oriskany sandstone, the Sylvania and Detroit River dolomite, limestone and chert, the Onondaga and Delaware limestone, the Hamilton grey shale, and the Kettle Point black shale have a thickness of more than 1,500 feet.

In the second subdivision the sedimentary succession begins with sandstone of Upper Cambrian or Lower Ordovician age and includes Lower, Middle, and Upper Ordovician strata, with a thickness of about 6,000 feet. The rocks are locally broken by faults.

In southern Quebec eight masses of alkalic intrusive rocks form the Monteregian Hills, the most westerly of which is Mount Royal at Montreal. Five of these lie in this second subdivision of the St. Lawrence Lowlands; the other three are east of the Logan Fault in the Appalachian Region. These intrusions are post-Lower Devonian in age and may be as young as late Tertiary.

The rocks on Anticosti Island in the third subdivision are of Upper Ordovician and Silurian age, all apparently conformable. Those on the Mingan Islands near the north shore of the St. Lawrence were deposited in the Beekmantown and Chazy sub-epochs of the Ordovician period.

The entire region of St. Lawrence Lowlands was overrun by Pleistocene ice-sheets, and much of the bedrock is covered by debris left by these glaciers. At Toronto, stratified deposits carrying plant and animal remains lie between deposits of glacial material. These layers show that the region was covered at least three times by ice-sheets from the central part of northern Quebec, and that between these advances the region had a climate considerably milder than it has at present. In late Pleistocene time the region was depressed and an arm of the sea extended up the St. Lawrence Valley as far as Brockville and up the Ottawa River Valley beyond the city of Ottawa. In this sea, to which the name Champlain is given, layers of clay were deposited and along its shores deposits of sand accumulated.

The chief mineral occurrences of the St. Lawrence Lowlands include petroleum and natural gas which are produced in southwestern Ontario mainly from Devonian beds but also in minor quantities from those of the Silurian and Ordovician; salt from the Silurian Salina formation in the counties bordering Lakes Huron and St. Clair; and gypsum from different horizons of the Salina in the Grand River Valley. Other materials available at many places are limestone and dolomité used in chemical and metallurgical industries, rock for construction purposes, and clay for the manufacture of brick, tile and cement.

The Hudson Bay Lowland.—The Hudson Bay Lowland bordering the west side of Hudson Bay has a length in a northwest direction of 800 miles, a width of 100 to 200 miles, and an area of 120,000 square miles. It rises from sea-level with a scarcely perceptible gradient to a height of about 400 feet. It is underlain by flat-lying rocks most of which are of Palæozoic age ranging from Ordovician to Devonian. An area of Mesozoic beds, Lower Cretaceous or Upper Jurassic, carrying lignite occurs in the Moose River Basin.

Smaller Palæozoic outliers on Lake St. John, Lake Nipissing, and Lake Timiskaming are mere remnants that have survived erosion in Mesozoic and Tertiary times.

The Cordilleran Region.—The Cordilleran Region comprises an Eastern System of mountain areas, and a Western Belt consisting of an interior system of plateaux and mountains flanked on the west by the Coast Mountains. The rocks of the Eastern System consist almost entirely of sedimentary formations of Proterozoic, Palæozoic and Mesozoic age, that succeed each other without pronounced angular discordance. Evidently basins of deposition persisted here throughout most of these eras. Intrusive rocks are known only in limited areas in the south, and sills and volcanic flows are locally of some importance as horizon markers.

Proterozoic rocks have their greatest thickness of 13,720 feet, and consist dominantly of siliceous dolomites and argillites with lesser amounts of quartzites, and one important sheet of basaltic lava. Lower, Middle and Upper Cambrian, and early Ordovician rocks occur in the Rocky Mountains and Upper Ordovician (Richmond) limestones in the Mackenzie Mountains. Silurian sediments are widespread, but the early Devonian was apparently a time of withdrawal of the sea from the Region as no strata of that age have been recognized. Middle and Upper Devonian limestones and shales are fairly widespread in both the Rocky Mountains and Mackenzie River region. Carboniferous beds overlie Devonian strata conformably in the Rockies, and Permian strata have been recognized on the Liard and Peace Rivers.

Triassic marine beds occur along the eastern flank of the Rocky Mountains, and in the eastern ranges are succeeded by Jurassic marine strata. At the close of the Cretaceous and extending into Paleocene time the Rocky Mountain area was subjected to orogenic forces that produced folding and over-thrusting from west to east, the Laramide revolution. Peneplains were developed in both the Rocky and Mackenzie Mountain areas during Tertiary time, and the present altitude of the Region is due to late Tertiary uplift. In Pleistocene time much of the area of the Eastern System was glaciated, but parts apparently remained free of ice.

The geology of the Western Cordilleran Belt is complex. The oldest rocks are of Precambrian age. The Shuswap rocks consisting of schists, crystalline limestones, gneisses and granitized varieties were at one time regarded as all of Archæan age. It is now known that these rocks are highly metamorphosed formations of mainly Late Precambrian and early Palæozoic ages. The Yukon group of the Yukon Plateau, consisting of schists, gneisses, crystalline limestone and greenstone, the Wolverine complex of central British Columbia, and the Cariboo Series of the Cariboo district, are also at least partly of Late Precambrian age, but Lower Cambrian fossils have been found near the top of the latter two. In southeastern British Columbia the Purcell Series consisting of 45,000 feet of quartzites and argillites is of early Proterozoic age, and is overlain unconformably by late Proterozoic sediments of the Windermere Series, 22,000 feet thick, consisting of conglomerate, slate, limestone, greenstone, schist and paragneiss. The Purcell and the Windermere strata are intruded by basic sills and dykes.

The Palæozoic record is fragmentary. Cambrian, Ordovician, Silurian and Devonian beds are all known locally. In Carboniferous and Permian times great thicknesses of sedimentary and volcanic rocks accumulated under marine conditions over much of the belt; in central British Columbia the Cache Creek group probably reaches a thickness of more than 25,000 feet.

Mesozoic strata range in age from Upper Triassic to Upper Cretaceous. The Triassic and Jurassic periods were marked by intense volcanism, but the contact between the two systems is only locally discordant. Jurassic rocks are widely distributed: the Laberge Series of Yukon has a thickness of 10,000 feet, and the Jurassic members of the Hazelton and Takla groups of central British Columbia are each probably just as thick. Lower Cretaceous strata are also widespread.

The Mesozoic era was a time of orogeny and of great, deep-seated igneous activity; the largest intrusive mass, that of the complex Coast intrusions, is 1,100 miles long and averages more than 50 miles wide. It comprises many phases, ranging in age from Triassic to Tertiary but chiefly late Jurassic to early Cretaceous, and varies in composition from granite to gabbro, the commonest types being

granodiorite and quartz diorite. The Cassiar-Omineca batholith within the central plateau and mountain area, is of similar composition. It has a length northwesterly of more than 500 miles, and a width up to about 25 miles.

The effects of the Laramide orogeny are less apparent in the Western Cordilleran Belt than farther east. During succeeding Tertiary time sedimentation took place in local fresh-water basins and accumulations of marine sediments formed in places near the present shoreline. Volcanism was active from Eocene to Recent times, reaching a climax in the Miocene or Pliocene. In general the Tertiary beds rest with angular discordance on the older rocks; early Tertiary strata lie in open folds, whereas later Tertiary beds are for the most part horizontal.

The Western Cordilleran Belt was largely covered by ice in Pleistocene time the most significant exception being the weathered Tertiary surface of part of Yukon that was not so covered. Near Vancouver, Pleistocene deposits reach a thickness of 1,100 feet and show tills of at least two different ages separated by stratified sands and clays.

The Cordilleran Region is a producer of gold, both lode and placer, copper, silver, lead and zinc and contains also deposits of mercury, tungsten and iron. Aside from a small area near Field in the Rocky Mountains, all the known metalliferous occurrences are in the Western Cordilleran Belt and most of them at least are believed to be related to the late Mesozoic and early Tertiary granitic intrusions. The Region also produces coal, the deposits of which are widespread. Petroleum and natural gas are produced from fields in the eastern division, chiefly in the foothills region of Alberta. Fluorite, gypsum, magnesite, hydromagnesite, phosphate, saline deposits, building stone, and limestone for the production of lime and cement, form other valuable mineral occurrences.

OTTAWA
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1951