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GEOLOGY AND MINERAL RESOURCES OF QUEBEC

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GEOLOGY AND MINERAL RESOURCES OF QUEBEC

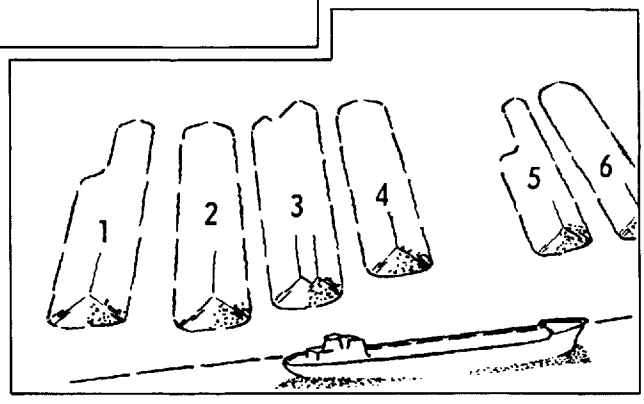
QUEBEC DEPARTMENT OF NATURAL RESOURCES

COVER ILLUSTRATION

FRENCH MINE

OPEN - PIT

AT SCHEFFERVILLE



ORE DUMPS AT SEPT-ILES

1 and 4 - Concentrated iron ore from Carol mine

2 and 3 - Ore from Schefferville mine

5 and 6 - Pellet ore from Carol mine

GOUVERNEMENT DU QUÉBEC

GEOLOGY

AND

MINERAL RESOURCES

OF

QUEBEC

DEPARTMENT OF NATURAL RESOURCES

Honorable PAUL-E. ALLARD, Minister

PAUL-ÉMILE AUGER, Deputy Minister

MINES BRANCH
J.-E. GILBERT, Director

GEOLOGICAL SERVICES
P.-E. GRENIER, Director

QUEBEC, 1969

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ILLUSTRATIONS

INTRODUCTION

The Province of Quebec can be divided into three large physiographic regions: the Laurentian Plateau, the Saint Lawrence Lowlands, and the Appalachians. Rocks of all geological ages are represented, although in very unequal proportions. Very little of the Mesozoic or Cenozoic remains, and it appears that the time from the Carboniferous to the Pleistocene was taken up mainly by erosion. On the other hand, the Precambrian, the earliest and longest of the eras, underlies the largest part of the province and forms the Laurentian Plateau. The Paleozoic is almost completely confined to the Appalachians and the Saint Lawrence Lowlands. Some plant remains and iron mineralization in the Schefferville area of northern Quebec are Mesozoic in age, as are the Monteregian Hills of the Lowlands. Some sedimentary rocks south of James Bay, as well as eruptive rocks in the vicinity of Mouchalagane and Manicouagan lakes, and in the Eau Claire Lake area some 75 miles east of Richmond Gulf, are also thought to be Mesozoic.

No consolidated Cenozoic rocks have been noted in the province. During the Pleistocene, a thick ice sheet covered the area. The retreating ice left numerous boulders, sand and gravel deposits, and other unconsolidated material in its wake. Meltwaters from the glaciers formed Barlow and Ojibway lakes in Western Quebec and, during this period, the Champlain Sea covered the Saint Lawrence Valley and Lake Champlain area. It was in these bodies of water that the clay deposits, the most recent important sedimentary deposits of the Province, accumulated.

The following is a summary of the geology and major mineral deposits of the Province of Quebec.

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* Text prepared by geologists of the Quebec Department of Natural Resources.

** Translated from the French.

THE LAURENTIAN PLATEAU

The name Laurentian Plateau has been applied to that part of the Canadian Shield which underlies the Province of Quebec. The Shield is made up of a wide variety of Precambrian volcanic, sedimentary and metamorphic rocks which were subjected to several periods of deformation, metamorphism and erosion between 4,000,000,000 and 600,000,000 years ago.

The Laurentian Plateau occupies almost 95% of the Province of Quebec. It has a peneplaned surface resulting from prolonged erosion which reduced even the highest mountains to low, rounded hills. A few mountains rise to 4,000 feet above sealeved, but the average elevation of the Plateau is below 2,000 feet. Lakes and rivers cover about 20% of the surface area, and represent considerable hydraulic resources - estimated at more than 200 million kwh by the Hydrology Branch of the Quebec Department of Natural Resources.

The Canadian Shield is divided into seven metamorphic provinces, and four of these - the Superior, Churchill, Nain and Grenville - occur, at least in part, in the Province of Quebec. The Churchill in Quebec is further subdivided into four subprovinces: the Labrador Trough, the Cape Smith Belt, the Belcher Basin, and the Mistassini Monoclinal Zone. The Normanville subprovince within the Grenville represents the extension of the Labrador Trough into that Province (Figure 1).

The Canadian Shield was the scene of four major periods of deformation. The Kenoran orogeny, dated at some 2,500 million years, left traces throughout the Superior Province. The Hudsonian orogeny, dated at some 1,700 million years, affected the Churchill Province. The Elsonian orogeny, dated at some 1,400 million years, was responsible for the large bodies of gabbro-anorthosite in the Nain and Grenville provinces. The Grenville orogeny, dated at some 950 million years, folded and metamorphosed all of the rocks of the Grenville Province.

These major orogenies provide the basis for the four chronological divisions of the Canadian Precambrian: the Archaean, ending with the Kenoran orogeny, and the Lower, the Middle and the Upper Proterozoic, terminated by, respectively, the Hudsonian orogeny, the Grenville orogeny and the beginning of the Cambrian period some 600 million years ago.

THE SUPERIOR PROVINCE

The oldest rocks of the northern two-thirds of the Superior Province include narrow bands of volcanic rocks, moderately to strongly metamorphosed, accompanied by minor metasedimentary rocks, including some iron-formation. The most abundant rocks, however, are granitic gneisses, generally well foliated, which grade in places into banded gneiss and paragneiss. They vary in composition from granite to granodiorite and in color from pink to gray, with the latter, especially, containing several basic inclusions. Granite, granodiorite, quartz diorite and pyroxene gneiss have been found within these granitic gneisses. These rocks are characterized by a yellowish green plagioclase which gives them a greasy lustre on

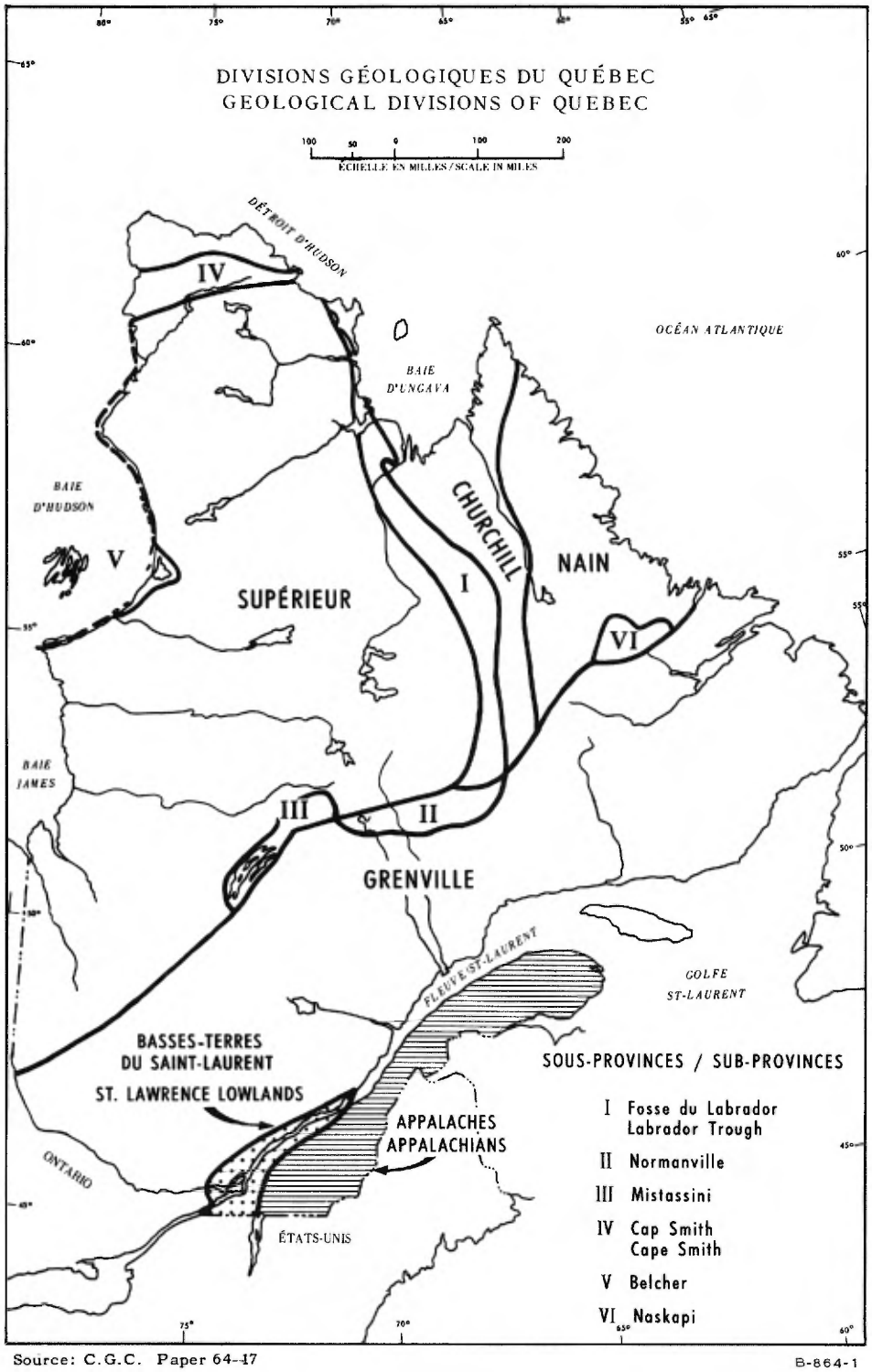

DIVISIONS GÉOLOGIQUES DU QUÉBEC
GEOLOGICAL DIVISIONS OF QUEBEC
100 50 0 100 200
ÉCHELLE EN MILLES/SCALE IN MILES
DÉTROIT D'HUDSON
IV
OCÉAN ATLANTIQUE
BAIE D'UNGAVA
BAIE D'HUDSON
V
CHURCHILL
I
NAIN
SUPÉRIEUR
VI
BAIE JAMES
III
II
GRENVILLE
FLEUVE/ST-LAURENT
GOLFE ST-LAURENT
BASSES-TERRES DU SAINT-LAURENT
ST. LAWRENCE LOWLANDS
APPALACHES
APPALACHIANS
ONTARIO
ÉTATS-UNIS
SOUS-PROVINCES / SUB-PROVINCES
I Fosse du Labrador
Labrador Trough
II Normanville
III Mistassini
IV Cap Smith
Cape Smith
V Belcher
VI Naskapi
Source: C.G.C. Paper 64-17
B-864-1

FIGURE 1

the fresh surface. They weather to a rusty brown. All of the above-mentioned rocks are cut by massive pink, white or gray granites and granodiorites.

The southern third of the Superior Province is characterized by an assemblage of volcanic and sedimentary rocks, generally only slightly metamorphosed, intruded by sills and other more or less concordant bodies of diorite, gabbro and peridotite. These rocks, which have a general east-west trend, were later invaded by intrusives of an essentially albitic character, including granite, granodiorite and diorite.

In some places, such as to the west of Noranda and at Temiskaming lake, this Lower Precambrian assemblage is overlain, in almost flat-lying disconformity, by sedimentary rocks (conglomerate, argillite, graywacke, quartzite) of the Upper Precambrian.

To date, little mineral exploration has been carried out in the northern two-thirds of the Superior Province. Nevertheless, interesting deposits of iron ore have been discovered at Denys lake, some 50 miles southeast of the mouth of the Great Whale river, and at Duncan lake, some 50 miles southeast of Fort George on the east side of James Bay.

The southern third of the Superior Province corresponds roughly to the Western Quebec region, the principal mining region of the Province of Quebec. Figure 2 shows the major mines in this area. It can be seen that they are concentrated around Rouyn-Noranda, Malartic, Val-d'Or, Chibougamau, Joutel and Matagami.

Rouyn-Noranda–Val-d'Or Area

The Rouyn-Noranda area is noted particularly for massive sulfide deposits made up of pyrite, sphalerite, chalcopyrite and pyrrhotite. Although several of these deposits are now depleted, this area continues to produce large amounts of copper, zinc, gold and silver, as well as rare metals such as selenium, tellurium and cadmium.

The Horne mine, owned by Noranda Mines Limited, is the largest in the area and has produced, to date, approximately 50,000,000 tons of copper ore. Along with Quemont, this mine also contains high values (about 0.18 oz./ton) in gold. At Lake Dufault Mines Ltd., as well as at the Normetal mine farther to the north, zinc-silver mineralization is predominant. This was also the case at the Waite-Amulet and Vauze mines, which are now depleted.

All of the massive sulfide deposits have common characteristics. Essentially, they are all located in a volcanic environment that is typified by successive layers of andesitic and rhyolitic rocks. They have been emplaced along contacts, particularly in breccia zones at the tops of the rhyolitic units. The mineralization is accompanied by alteration zones of chlorite, cordierite, sericite and silica, often in "chimney-like" structures. It is believed that this mineralization is related to the volcanic activity and thus predates the main intrusive masses and the other mineral deposits of the area.

Several vein gold mines were formerly active in the Noranda area, and two, the Wasamac and Francoeur, now being worked by the same company, are still in production. They are located along east-west shear zones and are marked by areas of silicification and chloritization.

The Cadillac fault, which crosses the entire region just beyond Val-d'Or, is the site of several gold occurrences, with the producing mines now located between Val-d'Or

and Malartic. The mineralization is associated with subsidiary fractures to the main break, and is located within competent volcanic, intrusive or sedimentary rocks that have been fractured during tectonic deformation, particularly within or bordering the main felsic-sodic intrusive mass. This late mineralization is cut only by Upper Precambrian diabase dikes. The principal mines are: Lamaque and Sigma, near Val-d'Or, and the Camflo, East Malartic and Barnat, near Malartic. The ore, rarely grading more than 0.2 oz. of gold per ton, consists mainly of quartz, tourmaline, arsenopyrite, pyrite, chalcopyrite and native gold. Near Val-d'Or, a deposit of massive and disseminated copper-zinc sulfides (Manitou-Barvue) is associated with felsic volcanic rocks.

Preissac–Lacorne Area

Between Val-d'Or and Rouyn, slightly north of the Cadillac fault, pegmatitic deposits are associated with the Preissac-Lacorne granite. Three molybdenum-bismuth mines are now in production - Molybdenum Corporation, Preissac Molybdenite and Anglo-American. All are located on the periphery of the granitic mass. A nickel deposit (Marbridge), associated with a band of peridotite which encircles the Preissac granite, is also being mined in this area. A large deposit of spodumene (lithium ore) was worked for several years.

Ville-Marie–Belleterre Area

Some 60 miles south of Noranda, at Témiskamingue, another area of volcanic rocks forms an anticline with an axial zone that is largely occupied by a body of granitic rock. This has been termed the Ville-Marie - Belleterre area. Gold deposits within the volcanic rocks, and copper and nickel deposits associated with basic intrusions, have been worked in the past. Asbestos and iron have also been noted in this area.

Matagami–Joutel Area

The new mining towns of Matagami and Joutel are located, respectively, some 120 and 80 miles north of the Noranda - Val-d'Or area. At Matagami, the volcanic and sedimentary rocks have been invaded by a concordant intrusive complex of peridotite, gabbro, diorite and anorthosite, known as the Bell River Complex, which forms a northwest-plunging anticlinal structure.

As at Noranda, this intrusive complex is bordered by a succession of acidic and intermediate volcanic rocks. Between the two units (the Lac Watson Group and the Wabassee Group), at the top of the rhyolites, is a tuffite bed that has been designated as the "key tuffite" horizon because of its association with the principal ore deposits. These deposits comprise bodies of massive sulfides, made up of pyrite, sphalerite, chalcopyrite, pyrrhotite and magnetite. They have been emplaced preferentially within secondary fold structures. The principal deposits are located on the south limb of the anticline, but some have been found on the nose and on the north limb.

The deposit being worked by Mattagami Lake Mines Limited is the largest, with more than 20,000,000 tons, followed by the Orchan and New Hosco deposits. The mineralization here is mainly zinc, with some copper and silver.

To the southwest, in the Joutel area, the massive sulfide deposits of Joutel Copper, Mines de Poirier and Northern Exploration are located in rhyolitic and pyroclastic rocks. A little more than 5,000,000 tons of copper and zinc ore have been outlined to date. A gold deposit alongside the Harricana river (Eagle Gold Mines) has also been discovered.

Chibougamau Area

Copper, gold and asbestos mineralization were first discovered in the Chibougamau area in 1903, but it was not until 50 years later that the first mine, Opemiska, began production. Today, the area is an important copper producer. The most abundant rocks of the area are the acidic to ultrabasic intrusive rocks. They form a stratified complex that has been folded into an anticlinal structure, with granite emplaced along the axial zone. All of these rocks have been cut by numerous fractures, the most important of which strike NE.-SW. and are accompanied by secondary NW.-SE. and east-west fractures. These faults, as well as the small quartzofeldspathic porphyry dikes, have played an important part in the localization of the ore, which consists mainly of veins or lenses of massive and disseminated chalcopyrite in altered anorthosite. Most of the mines contain appreciable amounts of gold. Campbell Chibougamau owns five mines in the area and Patino Mining Corporation, four. The ore reserves were established in 1968 at some 15,000,000 tons with a grade of between 2 and 2.5% copper.

Only one copper mine, Opemiska, some 30 miles west of the town of Chibougamau, is not located within the anorthosite. The mineralization here is associated with a gabbro sill in the volcanic rocks. This sill, more than 2,000 feet thick, is divided into five zones; the upper zone contains chalcopyrite in fractures or as disseminations. The mine treats 2,000 tons of ore a day, with a grade of about 3% copper. The area also contains a gold mine (Norbeau), and deposits of asbestos and iron-titanium-vanadium.

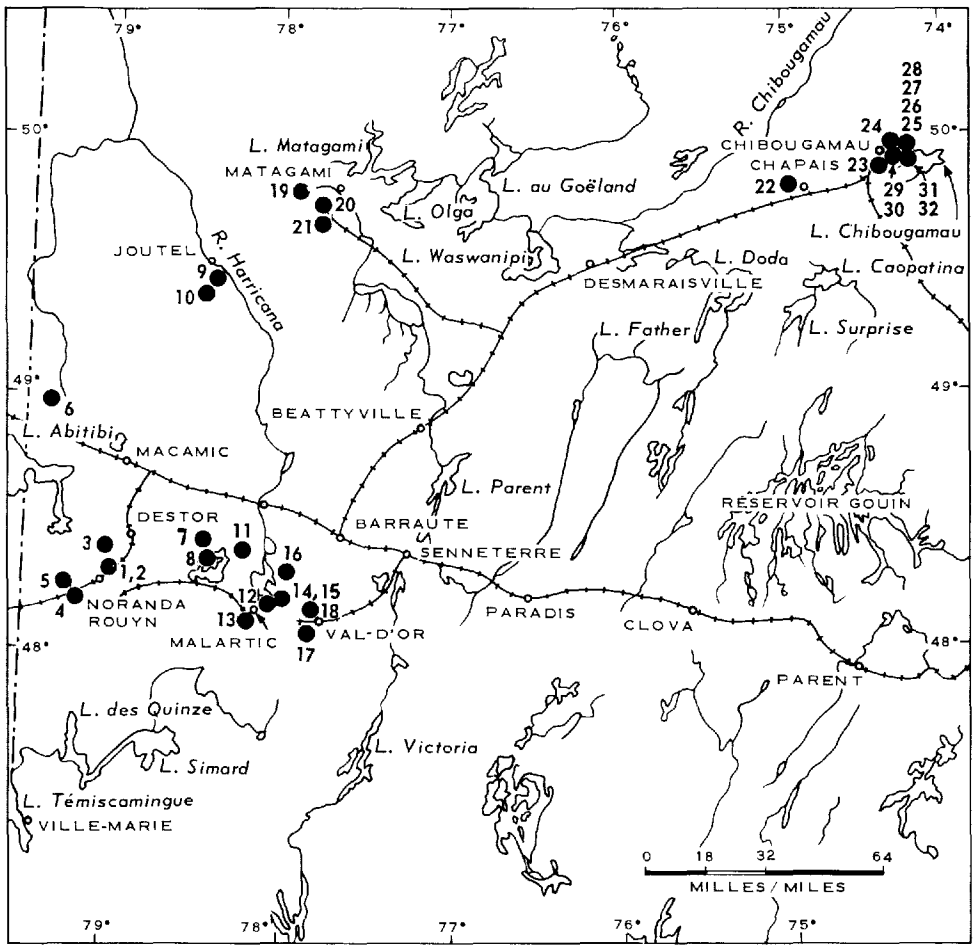
THE CHURCHILL PROVINCE

The Churchill Province surrounds the northern part of the Superior Province. It is made up essentially of granitic gneiss, overlain by zones of volcanic-sedimentary rocks, folded and metamorphosed to varying degrees, which have been recognized as subprovinces.

Labrador Trough

The Labrador Trough, almost 600 miles long and averaging about 40 miles wide, is made up of sedimentary and volcanic rocks injected by a multitude of gabbro sills before being folded with increasing intensity from west to east. Metamorphism is weak or absent in the center of the Trough, but increases toward the east and toward the north and south.

Economically, the most important of the sedimentary rocks is the iron-formation, which may in places be mined as "direct shipping" ore or which may be beneficiated to remove the siliceous gangue and produce a concentrate containing about 68% iron. Figure 3 shows the distribution of the main iron ore deposits of New Quebec.



Argent	○	Silver	Bismuth	□	Bismuth
Cuivre	◖	Copper	Molybdénite	◪	Molybdenite
Nickel	◧	Nickel	Or	♛	Gold
		Zinc	◩	Zinc	

PRINCIPALES MINES DE L'OUEST DU QUÉBEC
PRINCIPAL MINES OF WESTERN QUEBEC

FIGURE 2

DISTRICT DE ROUYN-NORANDA DISTRICT

1. Horne (Noranda)
2. Quemont
3. Lake Dufault
4. Wasamac
5. Francoeur (Wasamac)
6. Normetal
7. Preissac Molybdenite
8. Anglo American Molyb.
9. Joutel Copper
10. Mines de Poirier

DISTRICT DE VAL-D'OR – BOURLAMAQUE DISTRICT

11. Marbridge
12. Barnat
13. East Malartic
14. Marban
15. Camflo
16. Molybdenite Corp.
17. Lamaque
18. Sigma
19. New Hosco
20. Mattagami L.
21. Orchan

DISTRICT DE CHIBOUGAMAU DISTRICT

22. Opemiska
23. Campbell (Mine Principale)
24. Norbeau
25. Copper Rand (Patino)
26. Bouzan (Patino)
27. Grandroy (Campbell)
28. Jaculet (Patino)
29. Cedar Bay (Campbell)
30. Kokko Creek (Campbell)
31. Henderson (Campbell)
32. Portage (Patino)

Of the two main iron-bearing districts of the Labrador Trough, only one, the Schefferville District, about 350 miles north of Sept-Iles, is in production. Here, the iron-formation, composed of carbonates, silicates and oxides of iron, has been leached of its siliceous gangue. This natural concentration has resulted in an ore made up essentially of hematite and goethite and grading at least 55% iron. This material requires only blasting, preliminary crushing and transportation by rail to Sept-Iles, where it is loaded on ships bound for the Great Lakes, the east coast of the United States and Europe.

In July of 1954, when the Iron Ore Company of Canada went into production at Schefferville, reserves were listed at 420 million tons of ore. Since then, the Company has shipped an average of more than 7 million tons per year - 75% from Quebec and the remainder from Newfoundland-Labrador.

The extension of the Labrador Trough to the west of Ungava Bay has been the scene of several intensive exploration programs aimed at the development of widespread concentrating-grade deposits of magnetite and hematite. Among the principal deposits are those belonging to Atlantic Iron Ores at Hopes Advance Bay and to the north of the Arnaud river, Oceanic Iron Ore to the south of the Arnaud river, and Consolidated Fenimore Iron Mines Limited in the Feuilles river and Mélèzes river areas. Although these deposits lie close to the sea, their economic value is still to be established, particularly in view of the short shipping season of a little more than three months in Ungava Bay.

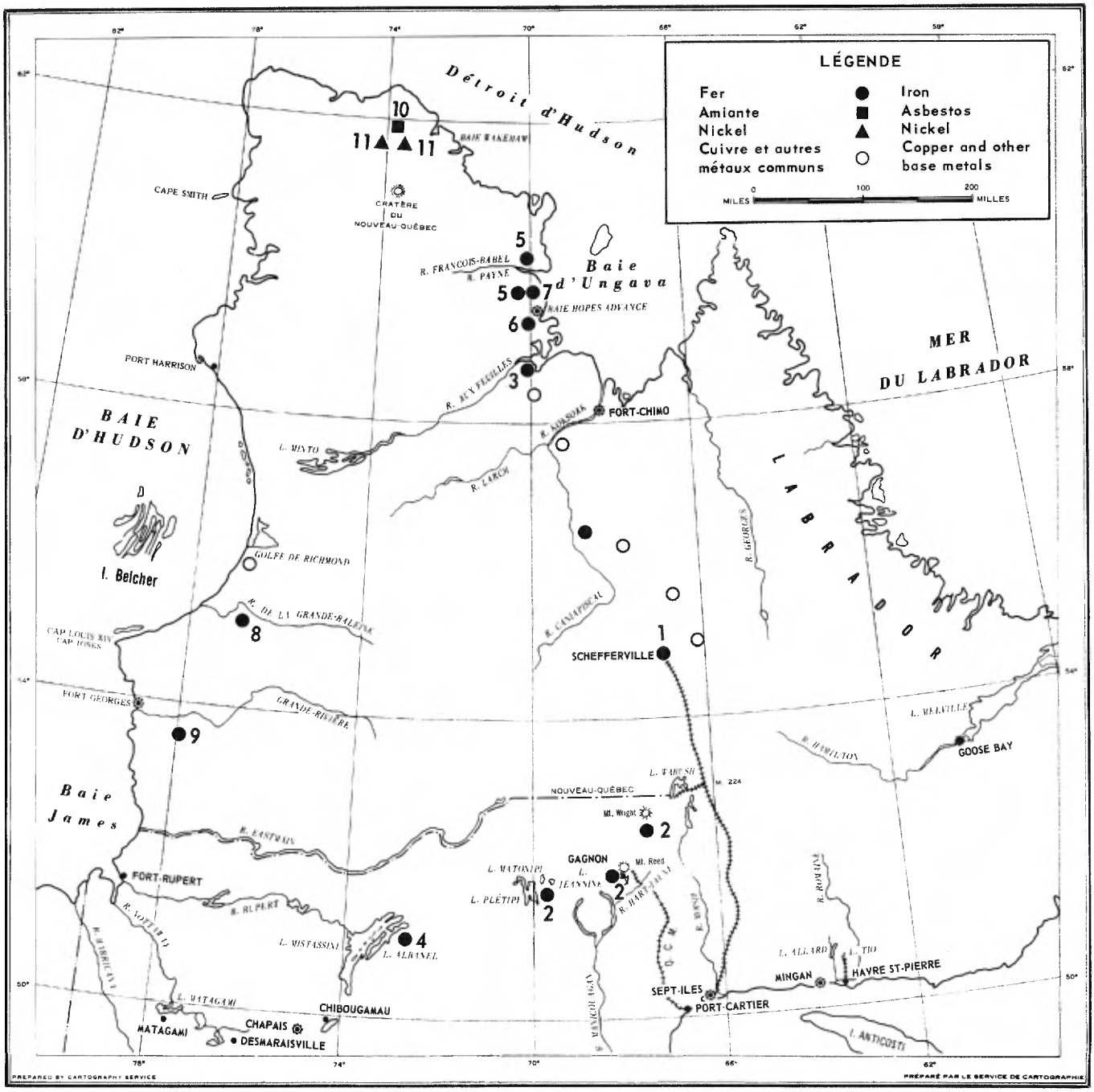
The western part of the Trough is made up largely of basaltic rocks, cut by numerous sills of gabbro and some peridotite, along with argillaceous and dolomitic sedimentary rocks. Copper-zinc mineralization, locally in the form of massive sulfides, has been discovered bordering the sills. In the gabbro, on the other hand, particularly the spotted gabbro, copper-nickel mineralization is common. Copper minerals are found disseminated at several places within the dolomite.

The table below shows the iron ore production of Quebec, Canada and the world.

IRON ORE PRODUCTION
(ton = 2,000 lbs.)

	QUEBEC		CANADA		WORLD
	Tons	$	Tons	$	Tons
1961	5,639,931	53,627,608	20,359,003	187,950,047	564,109,000*
1962	11,292,025	112,251,719	27,359,676	263,004,217	564,550,000*
1963	11,650,787	122,800,862	30,143,649	313,182,963	575,776,000*
1964	15,513,000	161,880,175	38,325,822	404,951,696	637,656,000*
1965	14,821,212	140,478,949	39,959,000	413,064,861	681,186,000*
1966	13,850,867	130,355,516	40,690,723	431,659,083	692,842,000*
1967 (estimation)	14,518,000	135,475,000	41,303,421	455,243,000	696,864,000**

* U.S. Minerals Yearbook.
** Commodity Data Summaries, U.S. Bureau of Mines.



PRINCIPAUX GÎTES MINÉRAUX DU NOUVEAU-QUÉBEC
PRINCIPAL MINERAL DEPOSITS OF NEW QUEBEC

SOCIÉTÉS MINIÈRES MINING COMPANIES

1- Iron Ore Co. of Canada
2- Quebec Cartier Mining Co.
3- Cons. Fenimore Iron Mines Ltd.
4- Albanel Minerals Ltd.
5- International Iron Ores Ltd.
6- Atlantic Iron Ores Ltd.
7- Oceanic Iron Ore of Canada Ltd.
8- Great Whale Iron Mines Ltd.
9- Duncan Range Iron Mines Ltd.
10- Asbestos Corp. Ltd.
11- New Quebec Raglan Mines Ltd.

FIGURE 3

B-864-3

Cape Smith Zone

The northern part of the Superior Province is crossed by an east-west band of sedimentary, volcanic and intrusive rocks lying discordantly, as exposed to the north and south, on granite and granitic gneiss. The intrusive rocks comprise sills of gabbro and serpentinite which invaded the sedimentary and volcanic rocks before deformation occurred. The ultrabasic sills are found mainly in the vicinity of the gabbro or along contacts between sedimentary and volcanic rocks.

Deposits of nickel-copper ore have been found within the Cape Smith zone. Most of the mineralized outcrops can be recognized by the presence of a rusty colored or dark blue capping. The mineralization is made up of massive or finely disseminated sulfides, including chalcopyrite, nickeliferous pyrrhotite, pentlandite and pyrite, occurring as small lenticular masses at the contacts of the gabbro and ultrabasic rocks with the sedimentary rocks. Among the companies now carrying out exploration work in the area is New Quebec Raglan Mines Ltd., with a very promising nickel-copper deposit.

A high-grade asbestos deposit, containing 20 million tons of ore, was discovered by Murray Mining Company in the serpentinite about 30 miles south of Hudson Strait. This deposit is now owned by Asbestos Corporation Limited.

Mistassini Zone

The rocks of the Mistassini zone, bordering the southeast shore and extending to the north of Mistassini lake, are made up mainly of limestone, dolomitic limestone, conglomerate, sandstone and shale. These rocks have undergone only minor deformation.

A vein copper deposit is now being worked by the Icon Syndicate, and radioactive minerals have been noted in the Otish Mountain area. Some lead and zinc mineralization has also been found.

THE GRENVILLE PROVINCE

The Grenville Province, with a width of about 200 miles, extends across all of Quebec. It lies north of the Saint Lawrence River and the Gulf of Saint Lawrence, and cuts across the trend of the Superior and Churchill provinces farther to the north. Where the formations of these provinces extend into the Grenville, they were subjected to a period of metamorphism from 1,200 to 800 million years ago. The mineralogical and structural features of most of the rocks of the Grenville Province indicate crystallization under conditions of high temperature and pressure.

The formations in the southern part of the Grenville Province have a general north-northeast trend. The sedimentary rocks consist mainly of quartzite, crystalline limestone, sillimanite gneiss, and biotite gneiss and amphibolite to the west of Trois-Rivières; to the east, biotite-amphibolite gneiss predominates, accompanied by a few beds of other

sedimentary rocks. The intrusive zones are made up of anorthositic rocks, pyroxene-bearing acidic rocks (charnockites) and granites, and generally erode to a more broken, hilly terrain. Paragneiss is present as discontinuous remnants within these igneous zones. This paragneiss contains a higher temperature mineral assemblage than similar rocks in the metasedimentary zones.

In the northern part of the Grenville Province, biotite gneisses marked by northeast-trending structures form a sort of gradational zone between this Province and the Superior. These gneisses could be metamorphic equivalents of the formations of the provinces to the north, or they could represent an intermediate stage between the typical sedimentary facies of each of the provinces.

Industrial minerals comprise the main mineral wealth of the Grenville Province, with dolomitic limestone, silica and feldspar now being mined. Deposits of apatite, graphite, asbestos, brucite, kaolin and mica are known and some have been worked in the past.

Among metallic minerals, iron, titanium and columbium (niobium) are the principal products. Two lead-zinc mines have been brought into production, and one was still in operation in 1968. In addition, small showings of molybdenite, copper, nickel and uranium have been noted.

Several mineral deposits resulted from the action of intrusive rocks on the metasedimentary Grenville rocks. Thus, the deposits of dolomitic and brucitic limestone and of quartzite are found in the vicinity of bodies of syenite and granite. Mica, apatite, molybdenum, the common metals and iron occur in pyroxenites formed by intrusive reaction with limestone. Feldspar occurs in pegmatites associated with granite, and titaniferous iron is found in the gabbro and anorthosite.

The Kilmar Mine, locates in Ranges IX and X of Grenville township, has been operating since 1908. Here, lenses of giobertite have resulted from the alteration of carbonate metasedimentary rocks by granitic intrusives.

Near Wakefield, 20 miles north of Hull, a brucite deposit is being mined by the Aluminum Company of Canada. Here, bodies of crystalline limestone have been invaded by syenite. The brucite particles, about the size of wheat grains, make up as much as 35% of the altered limestone.

The Calumet Mine has been producing zinc, lead, gold and silver since 1943. The mine is located on Calumet island, 40 miles west of Hull. The mineralization occurs in a silicified biotite gneiss lying between two bands of amphibolite.

Near Saint-Donat, a quartzite of the Grenville Series has been fractured and leached by hydrothermal solutions, resulting in a mass of pure quartz grading 99.38% SiO_2.

In the Oka area, some 25 miles west of Montreal, a carbonatite complex interrupts the Precambrian sequence. This complex is made up of crystalline carbonates and ring-like intrusions of alkaline rocks such as ijolite and okaite. Niobium minerals, mainly pyrochlore, are disseminated in the carbonatite. The deposits of the area have an average grade of 0.5% Nb_2O_5. The first to be brought into production was that of St. Lawrence Columbium and Metals Corporation, which began operations in 1961. About 1,300 tons of ore a day now go through the Company's mill.

An iron mine located in Bristol township, the Hilton Mine, has been in production since 1957, after having been operated intermittently between 1880 and 1917. The ore consists of magnetite accompanied by minor hematite, pyrite and pyrrhotite. The Company's mill and pelletizing plant are capable of an annual production of 800,000 tons of pellets containing 67% iron.

At Allard lake, some 25 miles north of Havre-Saint-Pierre, Quebec Iron and Titanium Corporation is mining ilmenite deposits in an anorthosite-massif. The main deposit contains 125 million tons grading 35% dioxide and 40% iron. About one million tons of ore are shipped annually to the Company's smelter in Sorel, where pig iron and titanium sponge, containing 70 to 75% TiO_2, are produced.

Normanville Subprovince

Several companies have been active in exploration for iron deposits in the Quebec portion of the Normanville subprovince, which is the extension of the Labrador Trough into the Grenville, but only Quebec Cartier Mining Company has reached the production stage.

This company began exploration work in the area in 1952, and has outlined several iron deposits, with a total reserve of at least 1,000 million tons of ore. The iron-formation occurs in intensely folded and metamorphosed sedimentary rocks, which, for the most part, have been transformed into granitic gneiss. It is made up mainly of specularite and quartz, accompanied, in some places, by magnetite. The average grade is about 30% iron.

The Company has constructed a railroad connecting Lac Jeannine to Port Cartier and has built two towns - the first near Shelter Bay (Port Cartier) and the second in the vicinity of Jeannine lake (Gagnon). Their concentrator, treating some 20 million tons of ore annually, produces some 23,000 tons of iron concentrate a day.

THE SAINT LAWRENCE LOWLANDS

The Saint Lawrence Lowlands extend from Lake Erie northeastward to just north of Quebec City. In the Province of Quebec, the Lowlands are bounded by Ontario on the west, by the Laurentian Plateau on the northwest and by the Appalachians on the east. This gives them a triangular form, covering some 6,700 square miles.

The Lowlands plain is broken in places by stream valleys and by five of the eight Monteregian Hills:* Mount Royal (769 feet); Mount Saint-Bruno (715 feet); Mount Johnson (875 feet), Mount Saint-Hilaire (1,437 feet); and Mount Rougemont (1,250 feet). The three other Monteregian Hills - Yamaska (1,470 feet), Shefford (1,725 feet) and Brome (1,755 feet) - are in the Appalachians.

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* The Monteregian Hills are made up of feldspathic rocks, mainly syenites, nepheline syenites and essexite. They are more or less circular, and were emplaced along a gently curved line. Many associated dikes and sills, of variable composition, have invaded the horizontal strata in the vicinity of the hills. The Monteregian intrusives were injected after the Appalachian orogeny, and are Cretaceous or Jurassic in age.

All of the consolidated rocks of the Lowlands, except for the Monteregian Hills, are sedimentary in origin and Cambrian, Ordovician or Devonian in age. Lying unconformably on the Precambrian basement, they are made up of sandstone, limestone and shale. These rocks, which are up to 10,000 feet thick in the Nicolet River area and more than 4,000 feet thick in the Montreal area, lie in horizontal beds disturbed, in places, by faults and open folds. Among the main rock types noted, (from oldest to youngest) are: the Potsdam sandstone, the Beekmantown dolomite, the Chazy, Black River and Trenton limestones, and the Utica, Lorraine and Richmond shales. Several of these formations are extremely fossiliferous. Anticosti Island, with an area of about 3,300 square miles, is underlain by undisturbed beds of Ordovician and Silurian limestone and shale.

Other Paleozoic rocks, resembling those of the Saint Lawrence Lowlands, overlie certain parts of the Canadian Shield. They are found at Lake Saint-Jean and along the Saguenay river, south of James Bay, in the Mouchalagane and Manicouagan lakes area, on the Mingan Islands and in a few other places.

The mineral resources of the Lowlands are entirely different from those of the Canadian Shield. There are no metallic deposits, but some of the rock formations are used directly as construction materials or for other industrial purposes. In addition, natural gas has been noted in some of the strata of the Lowlands, particularly between Quebec and Montreal. The only exploitable gas reservoir found so far is near Trois-Rivières, where the gas is in a fine sand between the clay and the bedrock.

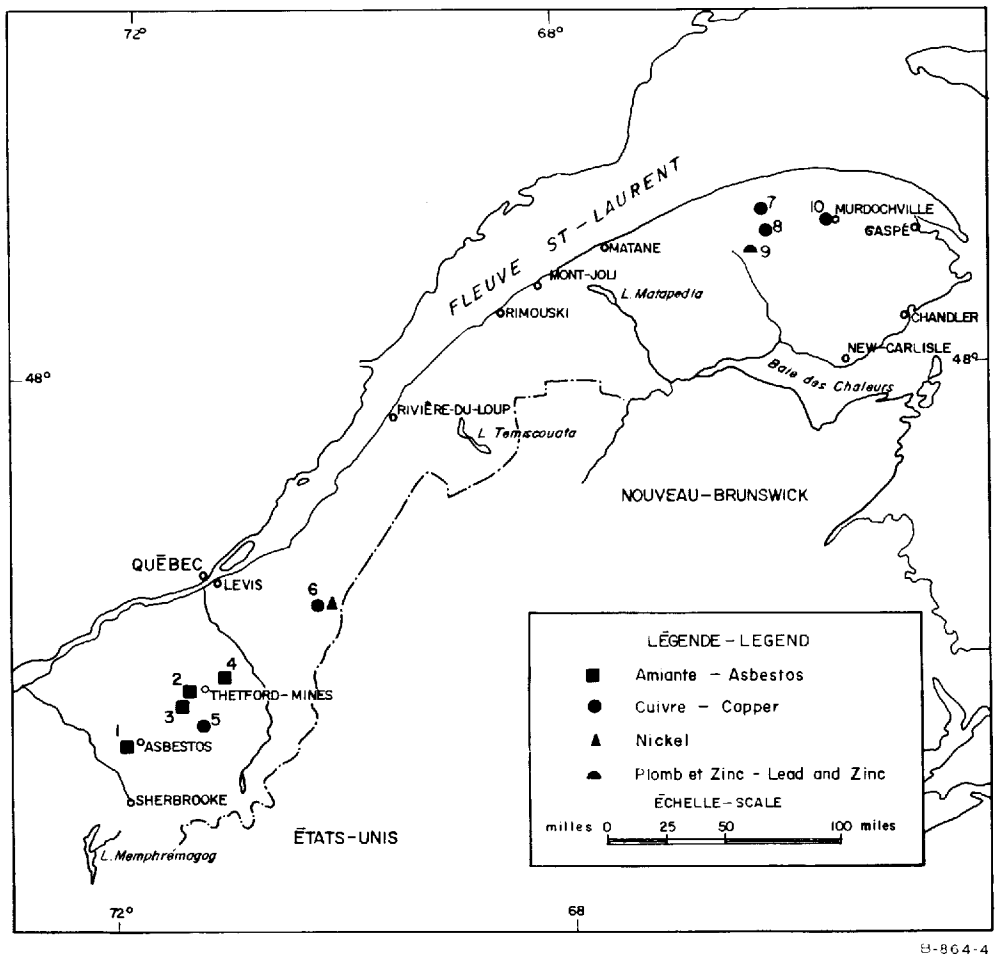
In places, the Potsdam sandstone is pure enough to be mined as a source of silica, and quarries have been operating for several years in the Sainte-Clothilde and Beauharnois areas to the south of Montreal and at Saint-Canut to the north. The Trenton and Black River limestones are used by the important cement manufacturers in the vicinity of Montreal, Quebec and Hull. They are also used for agriculture and are employed in the manufacture of lime. The Lorraine shale is used in the manufacture of brick, particularly at Laprairie.

Sandstone, limestone and some types of igneous rocks from the Monteregian Hills are used as construction materials.

THE APPALACHIANS

The Appalachian region is situated to the southeast of the Laurentian Plateau and the Saint Lawrence Lowlands. It is part of a chain of mountains extending from southeast of the United States to Newfoundland. In Quebec, the Appalachians make up the entire Gaspé Peninsula and the Eastern Townships area. They are bounded on the northwest by the Logan Fault and the Saint Lawrence Lowlands.

The Appalachians are formed essentially of Paleozoic sedimentary rocks, deposited some 200 to 600 million years ago.



PRINCIPAUX GÎTES MINÉRAUX DE LA RÉGION DES APPALACHES

PRINCIPAL MINERAL DEPOSITS OF THE APPALACHIAN REGION

FIGURE 4

PRINCIPALES MINES / PRINCIPAL MINES

1. JEFFREY
   NICOLET
2. KING-BEAVER
   JOHNSON
   NATIONAL
   FLINTKOTE
3. BRITISH CANADIAN
   NORMANDIE
   LAKE ASBESTOS
4. CAREY CANADIAN
5. SOLBEC
   CUPRA
   D'ESTRIE
6. TERRITORY MNG
7. MADELEINE
8. TERRA NOVA
9. FEDERAL
10. GASPÉ COPPER

Interlayered with the Paleozoic sedimentary rocks are lava flows and other volcanic rocks of similar age. This assemblage has been strongly folded, overturned and subjected to igneous injection, mainly in the form of peridotites and granites. Two main periods of orogeny have been recognized in the Appalachians. The first period, the Taconic, took place at the end of the Ordovician; the second, the Acadian, is Devonian in age. These two periods of mountain building, accompanied by igneous intrusion, were responsible for the present form and structure of the Appalachians. In general, almost all of the structural features, such as fold axes, faults, bedding and lineation, as well as the ultrabasic, intrusions, are oriented in a northeast direction, parallel to the arc forming the mountain chain. Only the granitic masses cut across this structural orientation.

The Appalachian region contains several deposits of both metallic and industrial minerals. Among the major deposits (Figure 4) are asbestos, copper, copper-zinc accompanied by gold and silver, copper-nickel, and talc. The asbestos deposits of this area are among the largest in the world. Chromite, placer gold, lead-zinc deposits and indications of petroleum and natural gas have also been noted. Some of these deposits have been developed to production.

Several of the deposits are closely associated with intrusive rocks and were formed by hydrothermal solutions. In the Thetford Mines - Asbestos area, for example, the peridotite intrusions which contain the asbestos deposits were altered, in several places, to massive serpentine, and then to fibrous serpentine or chrysotile, by hydrothermal solutions. Serpentine is also the host rock for the deposits of talc and steatite. Chromite is found as lenticular masses within the peridotites and pyroxenites of the Black Lake area. In the center of the Gaspé Peninsula, small deposits of lead and zinc have been noted in Devonian sedimentary rocks which have been subjected to igneous intrusion, and copper deposits are associated with siltstones and porphyry intrusions.

The copper, zinc and lead deposits of the Eastern Townships are associated with volcanic rocks, and the copper-nickel deposits are associated with a peridotite.

Some sandstones of the Gaspé Peninsula form reservoir rocks in which petroleum and natural gas have been found.

THETFORD MINES–BLACK LAKE AREA

The Thetford Mines area is know as the western world's most important producer of asbestos. Here, 10 companies produce about 90% of the Canadian production and 43% of world production.

The asbestos of the Thetford Mines district is a fibrous variety of serpentine called chrysotile. It occurs as cross-fibres normal to the vein walls. Fibres formed parallel to the vein are generally of inferior quality. The cross-fibres are usually less than ½ inch in length, but may be up to 4 or 5 inches long. They generally fill the entire vein, although a few veinlets of serpentine parallel to the vein walls have been observed within the cross-fibre veins. The borders of the asbestos veins are made up of serpentine, with, progressively farther out, serpentinized peridotite and, finally, unaltered peridotite. It is generally believed that the asbestos was formed by the action of hydrothermal solutions on serpentinized peridotite.

The Jeffrey Mine: - In 1881, Canadian Johns-Manville Company Limited began mining an asbestos deposit in Shipton township, near the town of Asbestos. Since then, this mine has continued to grow. The company's mill, treating 20,000 tons of ore per day, is capable of producing 600,000 tons of fibre a year, a production that is entirely proportional to the size of the deposit. The orebody is mined by both open-pit and underground methods. It has a generally cylindrical shape, elongated in a N.30°E. direction, and measures some 3,000 feet in length by 2,000 feet in width. Shear zones form the walls and roof of the deposit. Small masses of Devonian granite and syenite have injected the ultrabasic bodies and make up about 2% of the ore. These acidic intrusions seem to explain the origin of the hydrothermal solutions which led to the alteration of the serpentinized peridotite along fractures by the addition of silica and water. The main accessory minerals are brucite, talc, picrolite and magnetite.

In 1962, the ore reserves at the Jeffrey mine were estimated as being sufficient to support a production of 550,000 tons of asbestos fibre a year for another 75 years.

The other mines in the area, such as the King-Beaver, British Canadian, Normandie, Lake Asbestos, National Asbestos, Johnson's Asbestos, Flinkote, Carey Canadian and many others, are in a geologically similar environment.

SUTTON-STOKE MOUNTAIN AREA

The Eastern Townships have been justly named "the cradle of Canadian copper mines." Since 1841, in fact, numerous copper discoveries have been made, and several hundred pits and exploratory drill-holes were started between 1859 and 1866.

Although the copper deposits of the Eastern Townships were never as important as those of the Noranda and Chibougamau areas, they contributed in large measure to the beginnings of our mining industry. The major mines were the Eustis, Moulton Hill, Quebec Copper and Weedon. The Solbec and Cupra mines, to the south of Disraëli, are now the only producing metal mines in the Eastern Townships.

The mineralized zone includes the Sutton and Stoke mountain chains, and extends from the United States border to the Chaudière river. This zone, 125 miles long by 35 miles wide, is characterized by intrusive bodies elongated parallel to the general structural trend. The copper mineralization is confined mainly to the volcanic rocks.

Within or in the vicinity of the ultrabasic intrusions, nickel and chromite accompany the copper mineralization. The Territory Mining deposit, some 50 miles southeast of Quebec City, is made up of two zones - one nickeliferous, the other cupriferous. The mineralization occurs mainly in silicified and carbonatized slate, but is also found in the associated serpentinite. The deposit contains slightly more than a million tons of ore.

The Solbec and Cupra Mines: - These mines are located within a band of pre-Silurian acidic to basic metavolcanic rocks, injected by dikes and sills of quartzofeldspathic porphyry.

At Solbec, mining began in 1962 on a lens of massive sulfides, containing close to 2 million tons of ore, striking N.40°E. and dipping 45 degrees southeast. The major sulfides present are pyrite, sphalerite, chalcopyrite and galena, and the ore also contains

appreciable quantities of gold and silver. The grade is approximately 1.8% copper, 4.5% zinc and 1.5 oz.of silver per ton. The vein walls are rich in sericite, chlorite and quartz.

At the Cupra mine, three miles to the southwest, production began in 1964. The geological environment is similar, with a lens of massive sulfides about the same size as that at Solbec, and the grade is approximately 3.8% copper, 3.7% zinc and 1.3 oz. of silver per ton. The deposit extends at depth or to the property of D'Estrie Mining.

CHAUDIERE RIVER AREA

In 1823, gold placers were discovered near Beauceville, where the Gilbert river flows into the Chaudière river. Between the middle and the end of the 19th century, about $3 million worth of gold was recovered from the Chaudière river and its tributaries. This gold is thought to originate in nearby quartz veins, although none of these veins have yet been mined. In 1961, Beauce Placer Company began dredging operations in the pre-glacial valleys.

THE GASPE AREA

Copper mineralization was discovered in Holland township, near the York river, in 1921, but it was not until 1955 that mining began in this area. In 1964, and again in 1966, metamorphic zones containing copper mineralization were discovered - one bordering the granite massif of the McGerrigle mountains, the other some distance to the south. The first of these deposits belongs to Madeleine Mines; the other, belonging to Terra Nova Mines, has not yet been developed. Occurrences of lead and zinc have been noted near mounts Albert and McGerrigle in Boisbuisson and Lemieux townships, but they have not yet been completely explored.

Gaspé Copper Mines: - In Holland township, disseminated sulfides occur in altered sedimentary rocks such as siltstone, Devonian limestone and skarn, with associated porphyries. In places, the sulfides fill fractures in both sedimentary and igneous rocks. The ore is low grade and consists of pyrite, chalcopyrite, molybdenite and scheelite, as well as alteration minerals such as malachite and azurite. From April, 1955,to December of 1966, Gaspé Copper Mines Limited treated more than 25,000,000 tons of ore to produce some 325,000 tons of copper, 100,000 ounces of gold and 4,500,000 ounces of silver, as well as bismuth and molybdenum, for a total value of more than $200,000,000. The Company's mill will be treating 11,000 tons of ore a day when the Copper Mountain deposit is brought into production. As of January 1, 1968, reserves at the main (Needle Mountain) deposit were 29,389,000 tons of ore grading 1.40% copper, with values in gold, silver, bismuth and molybdenum. In addition, reserves at the Copper Mountain deposit, now being prepared for open-pit mining in 1968, are estimated at 31,000,000 tons of ore grading 0.71% copper.

The Federal Mine: - In Lemieux township, Lower Devonian shales and shaly limestones have been invaded by bodies of syenite and diorite. Tension fractures and other fissures are filled with white quartz and carbonates, accompanied by sphalerite, galena and minor pyrite, marcasite and chalcopyrite. Small amounts of amethyst quartz have also been found. The main vein systems trend north-south. Several veins have been discovered, and considerable development work has been done, but no mining has yet been undertaken.