THE JEFFREY MINE

OF

Canadian Johns-Manville Co., Limited

ASBESTOS, QUEBEC, CANADA

Geological Unit ——— Engineering Department

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INTRODUCTION:

The Jeffrey Mine of Canadian Johns-Manville Company, Limited, located at Asbestos, Quebec, some 100 miles east of Montreal, produces approximately 37% of the current Canadian production and approximately 13% of the world production of chrysotile asbestos.

The Jeffrey Mine is currently rated at a production of 600,000 tons of fibre per year. About 94% is exported to the United States and to 70 other countries around the world.

HISTORY:

Asbestos was first recognized in this area by Evan Williams, a slate miner from Wales, while visiting relatives in the early 1880's. Williams persuaded W.A. Jeffrey, a wealthy farmer, to provide the capital needed to develop the asbestos deposit located on a hill on the old Charlie Webb farm. That was in 1881.

Jeffrey operated the mine in a primitive fashion for fourteen years. During that period, production rose from one to two tons per day to an annual tonnage of 2,300. In 1895, Jeffrey had financial difficulties and his interests were purchased by Feodor Boas from St. Hyacinthe, Quebec, and two other associates. Backed by English capital in May 1897 they formed the Asbestos and Asbestic Company. This company built a branch line at Danville from the main line of the Grand Trunk Railway and struggled valiantly against formidable odds to increase output and to improve efficiency. Production did indeed increase and many changes and innovations were introduced at the mine.

In 1916 control of the latter was acquired by the Manville Asbestos Company, which was reorganized two years later under the name of Canadian Johns-Manville Company, Limited.

HISTORY: (Cont'd)

This Company has operated the property since that date.

MINING:

The original mining method was somewhat primitive and consisted of hand drilling and blasting with black powder, cobbing, and transportation with horses and wagons. Later, production methods included the use of derricks followed by aerial cableways and, in 1914, when the latter method was at its peak, there were 21 cableways spanning the pit. The first pneumatic drill appeared on the property in 1900.

In 1914 with a pit nearly 2,000 feet wide, the aerial cableways were becoming increasingly troublesome. It was then decided that a complete change was necessary to increase the fibre production which was approximately 27,000 tons of fibre during that year. Spiral benching was then adopted and, by 1920, this new system was completed with power shovels utilized for loading and steam locomotives for transportation. No major innovations in the mining methods were made until 1950, although the number, size and complexity of equipment increased in the open pit. In 1950 a more flexible system of pit transportation, consisting of diesel trucks was introduced in the Jeffrey pit. In 1944 a program of underground development to prepare for production via block caving commenced. However, the underground operation started only in 1950. The underground layout consisted of blocks 200 feet square and 400 feet high; these were undercut and caved into scraper drifts. The ore was transported by 10-ton cars to the primary crusher underground, and then hoisted to the surface and delivered to the mills by belt conveyor.

Between 1950 and 1960 twenty-nine million tons of ore were extracted from the underground operation.

MINING: (Cont'd)

Improvements and increase in size of open pit loading and haulage equipment, uncoltrollable dilution in the underground mine, rapidly rising mining costs, plus a degradation in fibre quality from underground workings, led to a re-appraisal of mining methods. After a detailed study it was decided, in 1958, to abandon the underground operations and to revert to the open pit. Two 35-ton skips in balance were installed at the southwest corner of the open pit to haul the ore to the surface and several other changes were made in mining, such as blast hole rotary drilling, choke blasting, and explosive bulk handling.

The skipway system will be removed in late 1972 or early 1973 to permit a major expansion of the open pit, involving expenditures of approximately 75 million dollars. This program, which should be completed by 1975, requires the replacement of all production facilities (except the mill), the acquisition of houses and properties along the periphery of the pit, the re-building of a manufacturing plant, the purchase of more and larger equipment. This present development program, which has been based on a completely computerized study, calls for an annual rate of 40 million tons of total material moved, ensuring the production of more than 600,000 tons of fibre per year.

During the 20-year period from 1972 to 1991, 96,000,000 tons of overburden and 506,000,000 tons of waste rock will be hauled away, while 183,000,000 tons of ore will be fed to the mill. Although the 200-ton trucks made their appearance at Jeffrey in 1970, a large fleet of 100-ton and of 35-ton trucks are still in use.

The smaller trucks will eventually be replaced with larger equipment.

MILLING:

The first mill was constructed in 1898 and additional units were added as required in 1909, 1914, and 1924. In 1954, a 12-story building, 430 feet long, 330 feet wide, and 195 feet high, replaced the old milling facilities.

Although milling became increasingly complex as new uses were found for the shorter grades of fibre, and as a wider variety of products entered the market, the process still consists essentially of freeing the fibre by various crushing procedures and removing the fibre by a combination of screening and air classification processes.

One of the major innovations in milling took place in 1959 when a concentrator unit was installed. The philosophy behind concentration is that the ore, when crushed to its optimum size, can be scalped with the loss of only a minimum amount of fibre.

By the end of 1972 $40,000,000 will have been spent to relocate or replace the primary crushing plant and the dryer concentrator complex. A new crusher room, excavated mainly in rock, houses a 72" feed opening (possibly the largest in Canada), gyratory crusher, equipped with a hydraulic setting adjustment. Two dump pockets, each capable of receiving directly and simultaneously the load of one 200-ton truck, are provided.

REGIONAL GEOLOGY:

The igneous complex in the vicinity of the Jeffrey Mine is composed of ultramafic and gabbroic rocks, intrusive dykes of granitic to dioritic composition and a suite of andesitic to mafic volcanic rocks. Field evidence suggests that these igneous rocks are all part of a giant ophiolitic complex. Recent work by Lamarche has indicated that this complex is of Lower Ordovician age, being post-Caldwell and pre-Normanskill (middle Ordovician).

REGIONAL GEOLOGY:

The ultramafic rocks of this ophiolitic complex rest, at the northwest, unconformably on metasedimentary rocks of the Caldwell Group of Cambro-Lower Ordovician age.

The Jeffrey asbestos orebody occurs in highly serpentinized peridotite, adjacent to the Caldwell metasediments. This peridotite is followed to the southeast by a wide zone of barren dunite, also highly serpentinized, in which lenses or concentrations of pyroxenite have been formed by differentiation. Pyroxenite is also present in the upper part of the ultramafic section of this complex and is seen to grade into a gabbro.

Brecciated and pillowed volcanics form the roof of the ophiolitic complex and are conformably overlain by the St. Daniel sedimentary rocks, mainly a wildflysch-type shale of pre-Normanskill age. Resting on the St. Daniel formation is a thick sedimentary sequence belonging to the Middle Ordovician Beauceville formation.

GEOLOGICAL TABLE - ASBESTOS AREA

Wisconsin and younger	Pleistocene and Recent	Clayed silt, sandy silt, some sand and gravel
Beauceville Formation	Middle Ordovician	Slate
St. Daniel Formation	Pre-Normanskill Lower Ordovician	Wildflysch-type slate
Ophiolitic Complex	Lower Ordovician	Serpentinized peridotite, dunite and pyroxenite; gabbro, rodingite, granitic to dioritic rock; andesitic to basic lavas, normally brecciated and pillowed
Caldwell Group	Cambro-Lower Ordovician	Phyllite, slate, quartzite, metagreywacke, amphibolite

CALDWELL GROUP:

Sedimentary rocks and some amphibolite occur on the northwest side of the ophiolitic complex. Northward from the contact, the succession is black and greenish slate and phyllite, impure quartz and metagreywacke.

The phyllite and the slate are thin bedded, crumpled and altered for a distance of several feet from the ultramafic contact. Altered feldspar, epidote, clinozoisite and amphibole can be distinguished in thin section. The beds strike about N60^{o}East with an average dip of 55^{o}S.E.

The impure quartzite is grey to black in color and occurs as narrow, fine-grained bands, always in association with the phyllite. The metagreywacke is a fine-grained, greyish-green, slightly schistose rock containing small lenticular quartz grains.

The amphibolite is dense, medium-grained and black in color, and occurs more generally as lenticular bodies within the phyllite. At some locations, the amphibolite has a layered texture with narrow green, fine-grained bands. In thin section, the amphibolite is seen to be composed of hornblende, epidote and quartz.

OPHIOLITE COMPLEX:

As mentioned earlier, all the igneous rocks in the Jeffrey Mine area are believed to belong to the same ophiolitic complex.

a) Peridotite:

Serpentinized peridotite is the host rock for the Jeffrey orebody and now occupies the footwall section of the ultramafic rock.

It has a width of approximately two thousand feet and is terminated at the southeast and southwest by a zone of intense shearing.

a) <u>Peridotite</u>: (Cont'd)

The serpentinized peridotite is normally green to greyish in color although, in the central portion of the orebody, the rock has a slightly brownish tint. The most common peridotite is flecked with small, irregular black patches consisting of fine-grained magnetite.

Numerous green to brownish grains, showing distinct cleavage faces are readily visible in the fine-grained serpentine groundmass. These grains are bastite, a serpentine pseudomorph after pyroxene, which are usually dusted with magnetite. The number of bastite crystals and pyroxene remnants suggests that the original peridotite contained approximately 10% pyroxene.

Thin section studies indicate that this original peridotite, in most places, is almost completely serpentinized. Aumento, in a recent paper, has shown that the most common serpentine mineral in the Jeffrey Mine area is lizardite with some antigorite. Brucite is also a common mineral in the ore.

The highly serpentinized peridotite weathers rapidly to a brown color. An ore-bearing peridotite only partially serpentinized occurs at the northwest of the main orebody. This rock weathers to a light green color.

b) <u>Dunite</u>:

The second major ultramafic rock type in the Jeffrey Mine area is a highly serpentinized dunite. It is located to the southeast of the serpentinized peridotite and occupies a width of some 2,400 feet. The contact between the peridotite and the dunite is not sharp; detailed field study has indicated that it is gradational over a distance of several hundred feet on both sides of a major shear zone, which generally marks the southeast limit of the orebody.

b) Dunite: (Cont'd)

The dunite is dense, medium to fine-grained and dark green to olive green in color.

The serpentinized dunite can be readily distinguished from the serpentinized peridotite by the absence of cleavage faces or black mottles, and by the typical weathering color, grey to apple green. This peculiar weathering takes place in a period of only a few weeks and accentuates the granular texture. Occasional narrow bands of darker rock edged with lighter material resemble the "painted veins" described by H.C. Cooke in his report on the Thetford area. These are caused presumably by alteration extending outward from hair-line fractures. Other fractures which are common throughout the rock are coated with fibrous altered minerals, mainly brucite.

Two other types of dunite are known to occur in the Jeffrey open pit. One of these is fine-grained, greyish in color and occurs generally in association with sheared rock. Small lenses of chromite are found in this variety and it is believed that some of the mass fibre was developed in this rock. The other type is restricted to the northwest contact. This variety is also highly serpentinized but can be distinguished from the former by its brownish color.

c) Pyroxenite:

Pyroxenite is found in irregular lenses within the serpentinized dunite and also as a band which extends more or less continuously along its southeastern limit. The rock is characteristically coarse-grained, with unoriented subhedral crystals of augite showing prominent cleavage striations and some chloritic alteration. The degree of serpentinization of the pyroxenite varies considerably and is governed mainly by its location with respect to the dunite.

c) Pyroxenite: (Cont'd)

The pyroxenite lenses which occur within the dunite are more serpentinized than the occurrence found in contact with the gabbro.

Fresh surfaces are light or grey-green but weather rapidly to a dark brown or grey color for a depth of several inches below the surface. The contacts of the pyroxenite and dunite bodies form a jagged pattern with a gradational change over a few inches.

d) Gabbro:

Masses of gabbro occur across a width of 100 to 500 feet along the southeast side of the pyroxenite. The exposed contact of the pyroxenite with the gabbro is often sheared but, at some locations, appears to be gradational. At Burbank Hill and near the town reservoir, the gabbro is generally highly brecciated.

The gabbro is a medium to coarse-grained rock and is composed of greenish pyroxene similar to that observed in pyroxenite with feldspar and, locally, coarse black hornblende. In thin section, the feldspar is seen to be highly altered, and some of the hornblende is rimmed with chlorite.

e) Dyke Rocks:

Numerous highly irregular dyke-like masses of granitic to dioritic rocks are found within the serpentinized peridotite and dunite. Rodingite, a rock composed predominantly of grossular garnet with diopside, is also present in the Jeffrey Mine area. In addition, occurrences of albitite are currently mapped in the open pit.

The most common variety of dyke rock is a medium to coarse-grained, reddish diorite composed of 60% heavily garnetized and saussuritized plagioclase and 40% relatively unaltered reddish brown biotite.

e) <u>Dyke Rocks</u>: (Cont'd)

The color of the intrusive rocks is governed by the presence or absence of biotite and by its degree of alteration. Varieties deficient in mica are normally light in color, whereas those containing a preponderance of biotite exhibit the reddish color of the original biotite. On the other hand, those dykes which contain alteration products such as chlorite and/or diopside exhibit greyish or greenish colors, depending on the type of alteration present.

The tabulation appearing on Page 12 mentions the various dyke rock types recognized at the Jeffrey Mine. This tabulation is based on thin section studies of the different rock types and their predominant mineralogical constituents.

Thin section studies of the dyke rocks show the plagioclase to be generally saussuritized and locally altered by garnetization and the orthoclase slightly to heavily kaolinitized. Biotite, as mentioned earlier, alters to diopside and chlorite but, in addition, is replaced by feldspar and fine hematite particles, and by muscovite.

A number of lime-rich and also alumina-rich minerals have been formed within several dykes by hydrothermal alteration. Grossularite, vesuvianite, diopside, and prehnite, are the most common minerals found. These may occur as replacement zones along the dyke contacts, in vugs, veins, or along joints.

The dyke rocks occurring at Jeffrey, particularly those of greatest width, are generally associated with shear zones. These dykes were evidently intruded either into pre-existing zones of shearing or along regular and irregular fractures. There is also some evidence for later shearing.

COLOR	GRANITE	% GRANODIORITE	% TONALITE	% SYENITE	% SYENODIORITE	% DIORITE
RED		Quartz : 29-34 Plagioclase: 26-36 Orthoclase : 18-28 Biotite : 11-17	Quartz : 20-24 Plagioclase: 46-55 Biotite and Chlorite : 25-29		Plagioclase: 42- 43 Orthoclase : 28- 30 Biotite and Diopside : 28	Plagioclase: 62-72 Biotite : 28-38
GREY		Quartz : 26-31 Plagioclase: 28-39 Orthoclase : 17-25 Biotite and Diopside : 11-21	Quartz : 17 Plagioclase: 50 Biotite and Chlorite : 32	Plagioclase: 31 Orthoclase : 54 Biotite and Chlorite : 15	Plagioclase: 42 Orthoclase : 33 Chlorite & Sphene : 25	Plagioclase: 31-59 Biotite, Chlorite, Garnet, or Diopside : 41-69
GREEN		Quartz : 26 Plagioclase: 31 Orthoclase : 19 Chlorite : 16 Biotite : 7			Plagioclase: 43 Orthoclase : 39 Biotite and Diopside : 18	
WHITE		Quartz : 41 Plagioclase: 26 Orthoclase : 21 Biotite and Diopside : 9			Plagioclase: 47-100 Orthoclase : 34 Enstatite & Garnet : 19	Garnet : 65-80 Diopside : 20-35

e) Dyke Rocks: (Cont'd)

Some intrusions are not apparently associated with shearing and these tend to occur at an oblique angle to the general structure of the orebody. These dykes are generally lighter in color and contain little or no mica. The composition of these rocks varies from granite to syenodiorite.

The forms assumed by these intrusions are extremely irregular. Some show good continuity but swelling is characteristic, especially those associated with shearing. Others are lenticular or display extreme contortions in all directions. The dykes found along the joints are generally small and more tabular but their course tends to be irregular, depending on whichever part of the joint system proves easiest to follow. Inclusions of serpentine have been noted, particularly in the red diorite. These inclusions are commonly bleached and are enclosed by a shell of radiating anthophyllite. Many of the dykes have marginal rims of black serpentine, up to four inches in width, in which large flakes of biotite are common.

f) Volcanic Rocks:

The upper part of the ophiolitic complex is composed of volcanic rocks consisting of intermediate to basic lava flows and breccia. Normally, the lava underlies the breccia but is also found to be interbanded with the breccia at other locations.

The lava has a dark greyish-green color and displays, in several exposures, excellent pillow structure containing numerous carbonate amygdules. The indicated strike is N60 East with a steep dip to the southeast. The volcanic breccia consists of rounded to subangular fragments of gabbro, granite and lava in a matrix of intermediate to basic lava. The fragments range in size from pebbles to boulders.

ST. DANIEL FORMATION:

A sedimentary sequence conformably overlies the ophiolitic complex. This succession has been studied by Lamarche specifically in the Thetford - Black Lake area. Lamarche has concluded that this sequence is typical of the St. Daniel wildflysch type sediments and is pre-Normanskill in age. In the Asbestos area, these sediments are essentially black slates characterized by one of the following features - graphite and calcite partially coating cavities or vugs - pyrite and quartz appearing in nodular or concretionary forms - and pyrite cubes disseminated through the rock.

Narrow calcareous bands, not exceeding two inches in width, together with small lenticular bodies of similar material, are interbedded with the slate.

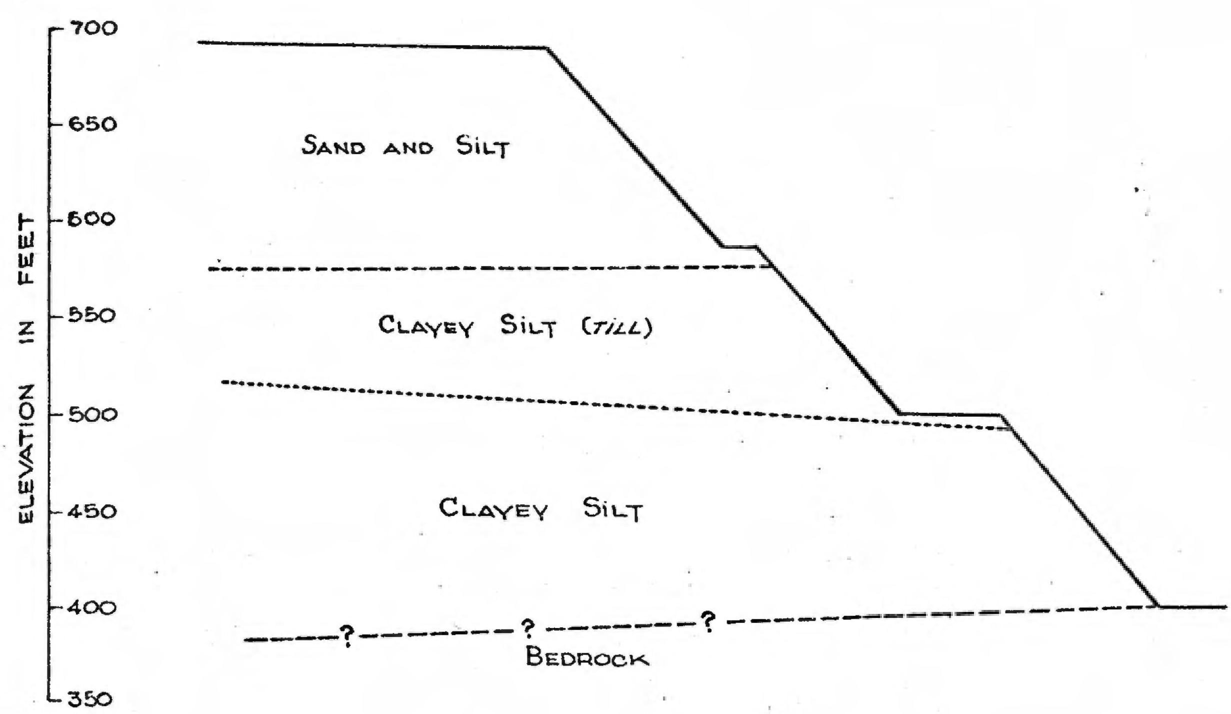
The slate is more fissile than the Caldwell and the Beauceville equivalents. The schistosity is vertical and appears parallel to the bedding.

BEAUCEVILLE FORMATION:

The conglomerate normally forming the basal sequence of the Beauceville formation has not been observed in the Asbestos area. The sedimentary rocks exposed in an old slate quarry, located about 1-1/2 miles southwest of Asbestos, are believed to be part of the Beauceville. Here the slate displays a vertical cleavage which is superimposed on sedimentary bands dipping 75^{0} to the northwest.

WISCONSIN AND YOUNGER:

Two major types of unconsolidated sedimentary material occur in the Asbestos area - a clayey silt, and a sandy silt. Both are believed to have a marine origin post-dating the retreat of the ice-sheet of the last glaciation that has affected our hemisphere. These two types are well exposed in the open pit and their stratigraphic position is generalized in the following sketch:



The clayey silt is a compact, greyish material composed of minor amounts of sand and scattered bands of sand and clay. The upper portion of this silt also contains narrow gravel beds.

The sandy silt is normally stratified and is composed of dense to very dense brown and grey material containing a minor amount of clay, sand, and gravel, with some layers of sand, silt, and clayey silt.

STRUCTURE:

The shape of the Jeffrey orebody resembles an elliptical cylinder raking 60° southeast on the average and plunging steeply to the southwest. In plan the orebody averages 3,000 feet long, 2,000 feet wide, and strikes N30°E.

A major shear zone, paralleling the slate-phyllite contact, forms the footwall boundary of the ore. Another important similar structural feature encloses the orebody along the southeast and southwest perimeter and seems to wrap the orebody completely on the northwest side to eventually abut against the footwall shear zone. Observations made along the northeast side of the orebody indicate that the two major shear zones may also join somewhere beneath the grounds of the Asbestos Golf and Country Club.

Within the orebody many other structural features, such as shear zones, faults and slips are present; their shape, size and dip vary considerably. The direction of these features generally follows the strike of one of the two already mentioned shear zones. The fact that some shear zones cannot be traced very far suggests that they terminate within a short distance or branch into less conspicuous features.

Many zones of shattering contain irregular masses of rock of granitic to dioritic composition.

ECONOMIC GEOLOGY:

Chrysotile Asbestos:

General:

The Jeffrey orebody has been divided into five ore zones, each having its petrological particularities and different grade characteristics. The distribution of the various grades within the orebody is irregular, although the two zones paralleling the footwall and hanging wall contacts contain the best ore in the mine.

The most favorable host rock at Jeffrey is a highly serpentinized, moderately to highly fractured peridotite. Shear zones are either barren or poor in grade.

Type of Fibre:

Chrysotile asbestos ore occurs normally as a stockwork of cross fibre veins although, locally, a preferred orientation of the veins may be noted. Fibre is also derived from slip fibre and mass fibre concentrations.

Cross fibre veins consist of tightly packed fibre oriented at approximately right angles to the walls. Single fibre veins occasionally attain widths of an inch or more and lengths of 30 feet. However, the majority of veins are narrower than 1/4 mesh and have lengths of three to five feet. Vein intersections are usually indefinite and actual cross cutting relationships have not been observed. Many of the veins are composite and contain a highly irregular central parting composed of serpentine and clusters and veinlets of magnetite. The cross fibre is commonly of the silky type but some areas of the mine are known to contain semi-harsh fibre.

Type of Fibre: (Cont'd)

Slip fibre is oriented parallel to the vein walls and probably crystallized during shearing movements. It is more brittle than cross fibre and more variable in strength. It is usually accompanied by fibrous brucite. Slip fibre forms a very low proportion of the commercial fibre produced.

Chrysotile also occurs in the form of mass fibre. It consists of relatively small, unoriented to semi-oriented bundles of fibre, sparsely disseminated through most of the rock. Local concentrations occur, especially near shear zones. The largest concentration of mass fibre rock occurs, in more or less tabular zone, along the southeast side of the orebody. Some occurrences of mass fibre rock may contain as much as 50% chrysotile. Mass fibre is accompanied, at several places, with brucite in small disseminated flakes.

Genesis:

An initial period of intense serpentinization is believed to have commenced when the ultrabasic rock was only partially consolidated. Serpentinization of rock at Jeffrey is generally so uniform that it could be hardly attributed to jointing. Consequently, this first phase of serpentinization probably took place prior to the jointing by autometasomatism, the ultrabasic being flooded with serpentinizing solutions working their way through numerous irregular contacting cracks in individual crystals.

This pervasive serpentinization may have been accompanied by a slight increase of volume producing fractures in rocks. Fracturation was accentuated during the Taconic and Acadian disturbances when the area was subjected to folding producing faulting, shearing, jointing and brecciation.

Genesis: (Cont'd)

Small masses of acid magma were injected along these planes of weakness and the accompanying siliceous solutions caused further serpentinization and alteration of the wall rock.

During this hydrothermal process, magnesia and silica were removed from the wall rock and deposited in the nearby fissures, possibly with more silica, to form colloidal serpentine and, when the stress conditions were favorable, chrysotile.

Consequently, it is believed that most of the fibre veins at Jeffrey have grown between the wall of fissures, the fibre growth being possible by a gradual separation of the walls. This fissure filling hypothesis is opposed to the replacement theory of those believing that the fibres have grown at the expense of the walls of the original fractures, Replacement veins have normally irregular edges whereas, at Jeffrey, the fibre veins have a straight or smooth edge. However, mass fibre occurrences may have a replacement origin and at least some cross fibre veins developed in mass fibre rock areas may also have a similar origin.

Chromite:

Small lenticular pods of chromite have been occasionally found within the orebody in association with serpentinized dunite.

Nickel:

The Jeffrey ore contains, on the average, approximately 0.2% nickel, for the most part in the form of awaruite, a nickel-iron alloy.

Investigation to economically recover this nickel from our tailings has not yet been successful.

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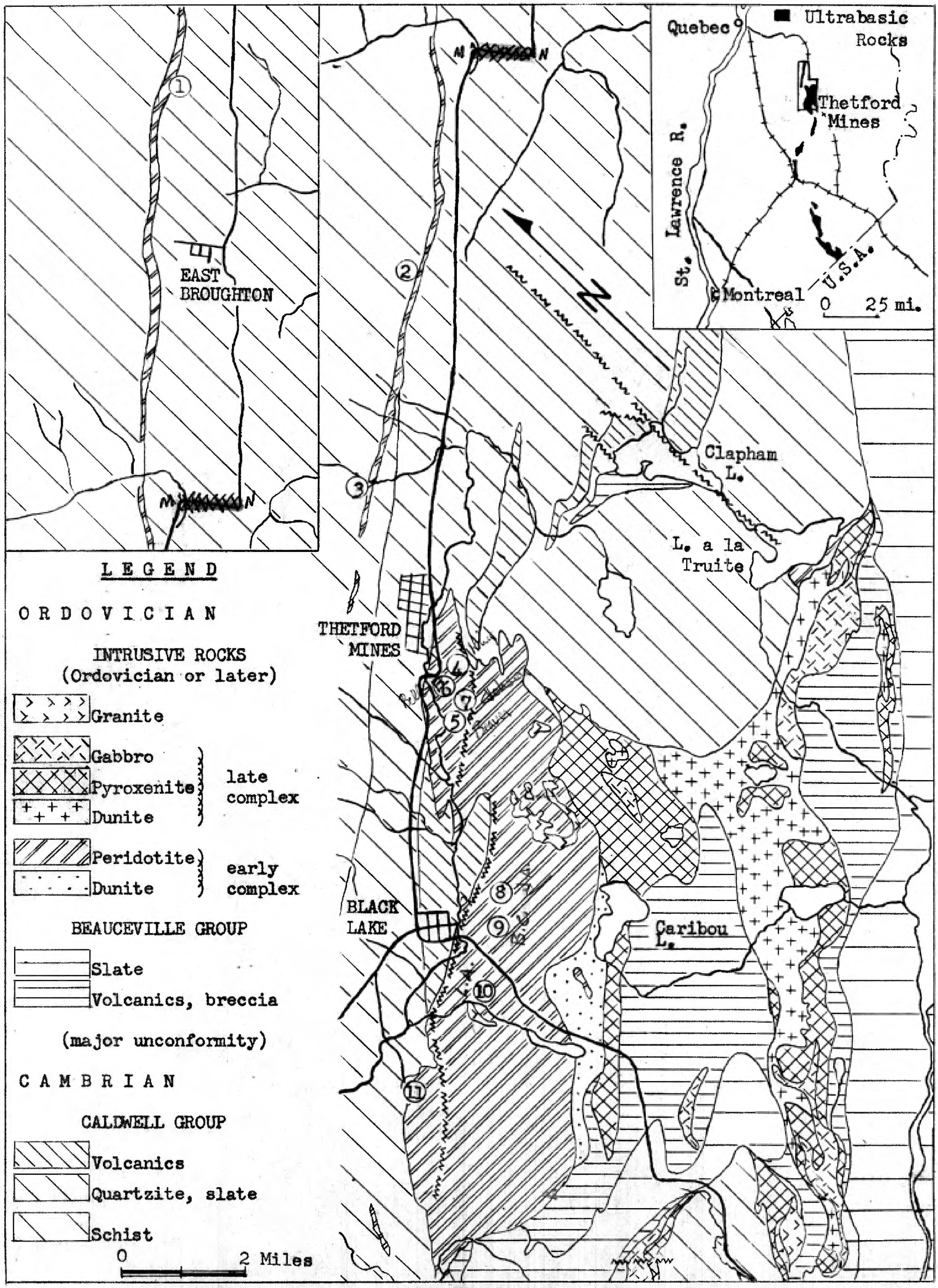
Quebec
Ultrabasic Rocks
Thetford Mines
St. Lawrence R.
Montreal
U.S.A.
0 25 mi.
EAST BROUGHTON
THETFORD MINES
Clapham L.
L. a la Truite
BLACK LAKE
Caribou L.
LEGEND
ORDOVICIAN
INTRUSIVE ROCKS (Ordovician or later)
Granite
Gabbro
Pyroxenite
Dunite
late complex
Peridotite
Dunite
early complex
BEAUCEVILLE GROUP
Slate
Volcanics, breccia
(major unconformity)
CAMBRIAN
CALDWELL GROUP
Volcanics
Quartzite, slate
Schist
0 2 Miles

Figure 1.

THETFORD ASBESTOS DISTRICT

List of Producing Mines

1. Carey Canadian Mines Limited

2. National Asbestos Mines Limited

3. Flintkote Mines Limited

4. - 5. King-Beaver Mine (Asbestos Corporation Limited) 5000/8

6. Bell Asbestos Mines Limited

7. Johnson's Company Limited

8. Johnson's Asbestos Company

9. British Canadian Mine (Asbestos Corporation Limited) 5000/8

10. Lake Asbestos of Quebec, Limited

11. Normandie Mine (Asbestos Corporation Limited) 5000/8

12 - Johns-Manville

Nb d'homme de mine
Nb de tonne de fibre rendu au prix de X

55147
52474
2673