ON THE ASBESTOS DEPOSITS OF THE EASTERN TOWNSHIPS OF QUEBEC.¹

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INTRODUCTION.

During the past thirty years the asbestos industry in Quebec has advanced in proportion to the greatly increased market. From an output estimated at 700 tons in 1878, the first year of any noteworthy production, the yearly yield of asbestos amounted in 1907 to 62,018 tons valued at \$2,482,984, exclusive of the by-product "asbestic" which reached the value of \$22,059. The total production of asbestos in Quebec now amounts to more than 400,000 tons, having an aggregate value of \$18,000,000. These mines, which have been for some time the principal source of the world's supply, in many cases still have reserves in sight that are practically inexhaustible, and undeveloped or partially developed deposits are yet unused in several localities in the asbestos district.

GEOLOGY OF THE DISTRICT.

The asbestos deposits of southern Quebec occur in serpentine rocks and as yet are mined only in that district between the international boundary line and the Chaudiere River, commonly known as the Eastern Townships (map, Fig. 22).

The serpentines and allied rocks of this district form part of a series which extends from Alabama to Newfoundland. In Quebec they form a belt beginning at the south near the west side of Lake Memphremagog and extending northeasterly through the counties of Brome, Shefford, Sherbrooke, Richmond, Wolfe, Megantic and Beauce, and farther northward they again appear in the Shickshock Mountains of Gaspé. The area occupied by these rocks in the southern part of the province is

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usually less than five miles wide. In the Thetford-Danville district they are probably of Cambro-Silurian age, while at East Broughton they are thought to be Precambrian.

The rocks of this belt are peridotite, generally much altered to serpentine; pyroxenite, frequently altered to talc; hornblende

FIG. 22. Map of Eastern Townships of Quebec, showing the areas of Asbestos Deposits and the Geology.

granite; diabase and a breccia the matrix of which is some basic volcanic. These rocks give the district in which they occur a rather distinctive topography marked by rugged hills which easily distinguish it from the subdued ridges of the older formations on the west.

ECONOMIC GEOLOGY.

THE LOCALITY OF THE MINES.

The principal asbestos mines are reached from the railway stations of Thetford Mines, Black Lake and East Broughton on the Quebec Central Railway, and from Danville on the Grand Trunk Railway. Thetford Mines is 76 miles from Quebec, 167 from Montreal, 318 from Boston and 475 from New York by railway.

The hills of this district, though numerous, are rarely more than 300 feet in height and the vicinity of the mines, except at Thetford, where they are within the limits of the town, is covered with rather dense second-growth. There are no large streams available for water power in the immediate district and power is supplied over transmission lines by two electric power plants, those of the St. Francis Hydraulic Power Company at Lake St. Francis, six miles from Black Lake, and the Continental Light and Power Company, Shawinigan Falls, some 90 miles distant. The latter supplies the greater part of the power required in the district.

RELATIONS OF THE ROCKS.

The serpentinite is an alteration product of the peridotite, which with the pyroxenite forms a single igneous intrusion, probably a laccolite. Granite occurs as dykes and isolated masses which are thought to be nearly contemporaneous in age with the peridotite. Diabase occupies larger areas than the more basic rocks and is probably intruded between them and older adjacent rocks. The breccia is frequently found along the edges of the diabase and may be associated with it. Its matrix is rather basic and it contains angular fragments of peridotite, pyroxenite, granite and various sedimentary rocks. The whole series lies between sediments of Ordovician age on the east and old slates thought to belong to the Pre-Cambrian, or possibly to the Cambrian system, on the west.

THE ASBESTOS.

The asbestos, as is well known, is of the chrysotile variety, that is, the hydrosilicate of magnesium, and is similar in chem-

FIG. 23. Vertical section of the N. E. wall of a small asbestos pit at Black Lake, Quebec. White areas = peridotite; cross-hatched areas = asbestos; Dotted areas = serpentine. Scale: the largest vein is 2 inches wide.

ical composition to the serpentine rock in which it occurs. It is distinguished by the well-known fine fibrous structure due to the aggregation of parallel thread-like crystals arranged transversely to the veins which it forms.

CHARACTER OF THE VEINS.

It occurs in gash veins which are from mere lines to two and sometimes three inches in width. The veins develop probably first along the joint planes of the rock and afterwards in any fissures or cracks due to other causes. Hence the main veins often indicate original jointing and show the approach to rectangular arrangement. As all the rock of the district has been shattered and broken by regional metamorphism, a more or less parallel series of minor veins occurs in the openings thus formed. As the alteration of the rock advances partings are developed tending to round the corners and edges of the larger blocks, and crescent-shaped veins form in the small crevices afforded during this process. The three types of veins may be seen in the accompanying diagram (Fig. 23).

Another feature which this diagram is intended to show is that the asbestos veins are invariably accompanied by a band of pure serpentine on either side. Specimen 2048 (Fig. 25), which represents the average rock of this locality, is a peridotite consisting of about 90 per cent. of olivine, the remainder of the rock being orthorhombic pyroxene and a few grains of feldspar. Specimen 2049 (Fig. 24) is from the serpentine which has resulted from the alteration of the peridotite. The serpentine band is proportionate in width to the asbestos vein. In

FIG. 24. Serpentine resulting from the alteration of peridotite. Shows a few grains of chromite.

forty-nine measurements of veins selected at random in the principal pits the width of the asbestos vein was a little more than one sixth of the serpentine. To be more precise, the ratio of the asbestos vein to the entire band of serpentine and asbestos was found to be 1 : 6.6, and seventeen of the forty-nine measurements showed practical unanimity with that ratio. These measurements included veins varying in width from one quarter to two inches. Hence the proportion between the asbestos and pure serpentine in these rocks seems to be a fairly constant one.

The veins are formed by the growth of minute crystals of

chrysotile. In most cases there is a parting in the vein, indicating that it has been formed in separate parts. The parting is marked by a film of chromite or magnetite, more commonly the latter, and the ends of the crystals, that is the walls of the veins, also frequently have a similar coating. Occasionally the fibers have grown without break across the entire width of the vein,

FIG. 25. Olivine serpentized along the margin of the grains. A forked vein of serpentine on the right hand side shows minute fibers of asbestos. A single crystal of pyroxene is seen on the left.

but this is rather exceptional. The fibers usually stand perpendicular to the side walls, but in a few cases they are arranged obliquely. Another peculiar feature of the veins is that the fibers are frequently bent as though by differential movement of the wall rock, but as most of the veins fill only small gashes in the rock, such movements do not seem possible. Dr. G. P. Merrill¹ has suggested that this bending may be due to the

¹ *Bulletin of the Geological Society of America*, 1904.

growth of fibers from one wall only and that they become bent by continued growth after reaching the second wall. Dr. Merrill also considers the jointed fibers to be the result of crystals growing from both walls until they nearly meet, when the interval between them may become filled by iron ore.

ORIGIN OF THE VEINS.

J. Hyde Pratt¹ regards the asbestos veins as crevices, due primarily to contraction and cooling and dehydration, which have been filled by infiltration of serpentine, and suggests that in the later processes of alteration, in which the peridotite has been serpentinized, these serpentine veins have become changed to asbestos.

Dr. A. P. Low, deputy minister of the Department of Mines of Canada,² considers the cracks in the rocks due to shrinkage and also to dynamic metamorphism, and that they have been filled by solutions brought in by heated water accompanying the intrusion of the associated granite. Under pressure these solutions have solidified in crystalline form as asbestos.

Dr. R. W. Ells³ gives the opinion that the veins of asbestos are fissures filled by lateral secretion in a way analogous to the formation of many quartz veins.

F. Cirkel⁴ believes the crevices which have given rise to the veins have been formed by partial dehydration and in part by fracturing resulting from the intrusion of the granite. The effects of increased bulk on the hydration of the peridotite to form serpentine and of the loss of volume by subsequent dehydration and loss of silica, as suggested by Merrill and Kemp, are also considered by Cirkel to be partial causes of the formation of the asbestos vein.

The vein matter is admitted by all to have been derived from the country rock, with which it is identical in chemical composi-

¹ Bulletin U. S. G. S., 1904.

² Report on the Chibougamau Mining Region, 1906.

³ *Bulletin Geol. Sur. of Canada*, 1903, and elsewhere.

⁴ "Report on Asbestos," Mines Branch of the Department of the Interior of Canada, 1905.

tion. Considering the number of the veins and their width and position in some parts of the rock, they can hardly be conceived of as ever existing as open fissures; for instance, veins of 200 feet in length and from one and a half to two inches in width are occasionally found running horizontally under great depths of rock. In such cases gravity alone would make such open fissures impossible. Again, the width of the vein seems to depend upon the width of the serpentine band out of which it is formed. Then, as the serpentinization of the peridotite appears to be a continuous process, at least not to have taken place at one definite period, consequently, in the writer's opinion, these veins must not be considered as having filled fissures but rather as replacements of the serpentine on either side of fracture lines. When the growth takes place outwards from each side of the line of fracture, the asbestos vein so formed has a parting in it; when replacement occurs on one side of the fracture only, the fiber of the vein is unbroken. Just what determines the limits to which the fibers may grow, that is, of the width of the vein, cannot be told, but their total mass seems to be in some measure proportionate to that of the pure serpentine of the rock.

As far as known, the proportion of asbestos to serpentine rarely exceeds 15 per cent. of the rock and even this is very exceptional. Whether the asbestos occurs in a few large veins or many small ones seems to depend on the amount of fracturing of the rock. In this connection the conditions at East Broughton are interesting for comparison with those of other parts of the district. Here the rock is evidently much older than that at Thetford Mines and seems to be wholly reduced to serpentine. There seems to be less chromite disseminated through the rock, and pyroxene, which is rarely absent from the rock at Thetford and Black Lake, is seldom, if ever, found at East Broughton. There are here the conditions for forming the greatest amount of asbestos that the rock will admit of. The proportion of asbestos is quite as high as in any other part of the district, though nearly all the wide veins have become too far altered and are useless. The asbestos of good quality occurs chiefly in narrow veins more uniformly disseminated throughout all parts of

the rock. Thus it is not uncommon to find narrow veins running near together and in parallel direction. Sometimes ten per cent. of the rock is thus composed of veins not more than one thirty-second of an inch in width.

In the concentration of asbestos, the longer fiber of good quality is chiefly recovered by hand separation, while the shorter fiber is sent to the mills, where it is mechanically separated. At Thetford a certain part of the rock mined never goes to the concentrating mills at all, while at East Broughton practically all the rock passes through mechanical concentrators. The significant feature of the asbestos at East Broughton is that the wider veins which are fairly numerous are partially replaced by calcite, thus forming a sort of opicalcite, and indicating a further process of alteration. The successive stages of alteration have therefore been, first, from peridotite to serpentine; second, from serpentine to asbestos; and third, from asbestos to opicalcite or a related mineral aggregate.

OCCURRENCE OF THE DEPOSITS.

The asbestos deposits of the Thetford district all occur toward the northern edge of the peridotite band and within a distance of some ten miles along its length. The serpentine in which they occur is generally distinguished in hand specimens by its greater softness and lighter color. The softness is due to the degree of serpentinization which depends probably on the proportion of olivine in the original rock more than on any other one feature. The lighter color is apparently due to the presence of less chromite, which occurs in minute grains through all portions of the rock. Peridotite, with a considerable admixture of pyroxene, and thus approaching pyroxenite, occupies large parts of this belt and is known to the miners as "bastard serpentine." Small bodies of it are commonly encountered in the working mines and are called "heads." Microscopically these agree with the barren serpentine above referred to in having a larger proportion of pyroxene and consequently less olivine—that is, they are more siliceous.

THE GRANITE.

Small bodies of granite, seldom exceeding a few hundred feet in length, are very numerous in the peridotite in the vicinity of the asbestos mines at Thetford and Black Lake, where they are generally believed to be essential to the good quality of a deposit of asbestos. They occur as dykes, much faulted and broken, and in a great number of small, irregular masses whose relations to the serpentine are extremely difficult to determine.

In composition they vary from an acid phase near aplite in the smaller dykes to hornblende granite in larger masses and in some of the largest to hornblende biotite granite. This tendency to become more basic as the bodies are larger seems to be a quite constant one.

In their relation to the peridotite they sometimes have a well-fused contact and are quite as coarse-grained at the edges as elsewhere. In one well-marked case there is an exception to this rule and the edges of a granite mass are finer and more acid than the central part. In another there is an intermediate type of rock between the granite and the peridotite which has the composition of gabbro-diorite. But more frequently they are surrounded by a layer of "gouge" which conceals the original relations of the rocks. As the granite is the more resistant the gouge is chiefly developed at the expense of the softer peridotite or of the intermediate rock if there were one.

Many of these masses of granite are so isolated from one another that it is very difficult, if not impossible, to conceive of any connection between them. While they are very numerous in the more basic part of the peridotite belt at Thetford and Black Lake, they are rarely found in the acid portions where the peridotite approaches a pyroxenite in composition.

These facts suggest the possibility of the granite being a final and extremely acid product of differentiation of the general magma of which the basic equivalent is the olivine-rich portion of the peridotite. Such a differentiation might be analogous to the well-known case of the micro-granite and norite which have been derived from a single magma in the nickel field at Sudbury,

Ont.¹ Such a relation, if finally proven, would corroborate the experience of miners who look for asbestos in the serpentine that is associated with the granite.

On the other hand, it should be noted that no granite of importance is known in the serpentine at East Broughton, where asbestos occurs abundantly. This, however, is a relatively small occurrence of serpentine, much of the rock is drift covered and rock exposures are few, and granite may exist in the covered parts of the locality.

SUMMARY.

The results thus far gathered from a study of the asbestos district, chiefly in the county of Megantic, may be summarized as follows:

1. That there are two varieties of asbestos bearing serpentine which differ in age and degree of alteration and probably in original composition.
2. That the source of the asbestos is the country rock.
3. That the veins are formed by infiltration in crevices, enlarged by replacement.
4. That the crevices may be joint planes and fracture planes, due to dynamic metamorphism and to weathering.
5. That serpentinization of the walls precedes the formation of asbestos and there is a proportion between the two processes of approximately 7:1, thus giving a maximum of about fifteen per cent. of asbestos.
6. That asbestos veins ultimately undergo alteration to ophi-calcite or a related product.
7. That the granite is possibly contemporaneous with the asbestos-bearing peridotite.

¹ A. E. Barlow, "Nickel and Copper Deposits of Sudbury, Ont., Geol. Sur. Can., 1901. A. P. Coleman, Ontario Bureau of Mines, 1903.