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Examination and Valuation of Chrysotile Asbestos Deposits Occurring in Massive Serpentine

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The critical shortage of asbestos fiber in the world today brings to the foreground the question of locating and developing new deposits. The object of this paper is to discuss some of the more important factors which should be considered in the examination and valuation of a new asbestos enterprise.

Some of the more important uses of asbestos fiber are for textiles, heat insulators, building materials, filters and a series of other uses. The properties of this mineral, such as fibrous structure, color, strength, silkiness and flexibility, coupled with resistance to fire, certain chemical action and decay make its application unique for certain industrial uses which consume over 200,000 tons annually.

These same unique properties which make this mineral so valuable also make a deposit one of the most difficult to appraise accurately, because of the many undeterminable and varying factors which must be considered before a deposit can properly be termed commercial. The majority of the asbestos fiber today, having the above mentioned properties, is sold by grades which are based on fiber length. Present day fiber prices vary over a wide range from $80 to $225 for crude fibers and $300 to $20,00 per ton for milled grades. For valuation purposes a careful study should be made of existing fiber prices and markets.

Examination of Deposits

In carrying out prospecting and examination of a deposit, considerable caution is required to get the necessary information in the form that will have the most value for the final determination.

There are two main classes of asbestos fibers, chrysotile and the amphiboles, the chrysotile being, by far, the most important both in abundance and uses. This paper will stress mainly chrysotile deposits, however, the amphiboles have many important uses, especially amosite and crocidalite. Their valuation presents special problems as other factors may be involved, especially as they are not graded according to any well defined and adopted standard but usually according to the use for which they are being supplied.

Most chrysotile deposits occur in two main types of rock, (1) mainly in basic igneous, such as dunite and peridotite, (2) to a lesser extent in sedimentary rocks, such as dolomite and limestone. All of these require a certain degree of metamorphism to be favorable to asbestos formation. Approximately 90 pct of the asbestos deposits are derived from serpentinization of dunite or peridotite, whereby the magnesium-silicate olivine was altered to hydrous magnesium-silicate serpentine. Under certain favorable geological conditions, this serpentine takes a fibrous form having a definite crystal structure, probably due to molecular rearrangement, and is known as chrysotile. The fiber veins are usually ir

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regularly distributed in the rock mass, some being continuous only a few feet and others may continue up to hundreds of feet, known as the closed and open vein respec-



FIG. 1—CHRYSOTILE ASBESTOS VEIN SHOWING CRUDE ASBESTOS AND MILL ORE.

tively. They vary in width from $\frac{1}{32}$ to $\frac{3}{4}$ in., but at times veins up to 5 in. have been found.

In these deposits asbestos is commonly found in two main forms, "cross fiber" (Fig 1) where the fibers are normal to the vein and "slip fiber" where the fibers lie in the same vein more or less parallel with the vein walls, both of commercial value, though cross fiber is usually preferable and has more extensive uses.

The serpentinized areas which contain asbestos usually take the form of large massive ellipsoidal bodies or well defined sills or bands, which because of segregation were especially favorable to vein development and may contain anywhere from insignificant quantity up to 15 per by weight of asbestos fiber. The fiber content and fiber length vary considerably between one deposit and another, as well as within the same deposit.

REQUISITE DATA TO BE OBTAINED DURING PROSPECTING AND EXAMINATION

The first requisite is to establish the exact properties and quality of the fiber, followed by a chemical analysis which may indicate what known fiber it resembles, and if it has any special properties, such as freedom from iron, which would give it a premium value. This should then be followed by systematic examination to determine how much fiber the various mineralized areas contain and of what different lengths and proportions.

1. A careful geological study of the area, noting all contacts, barren intrusions, fiber areas and degree of serpentinization, and so forth, followed by a proper geological map. Usually because of the nature of the basic rocks, asbestos deposits show considerable outcrops which can be easily blasted open for examination. It might be well to mention that some experimental work with geophysical methods has been tried in asbestos deposits using magnatometer and electrical induced-current methods. While these were helpful in outlining serpentine

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areas, they did not conclusively prove the presence of asbestos fiber.

2. If a mineralized area has favorable indications from visual inspection it should be divided into definite areas for prospecting purposes and 100-ft square is a convenient unit. This can later be divided into 10-ft strips for logging all surface indications. Surface prospecting, depending on the overburden present, usually takes the form of blasting open the outcrops, small open cuts, trenching and test pits, followed by diamond drilling to prove depth. In certain locations a tunnel and cross cuts may be advisable, since in addition to exposing fiber indications, it will yield a good sample of ore for test purposes. Where the deposit is not exposed on surface, conventional methods of underground prospecting are usually applied.

Each favorable area should be carefully measured and all veins over $\frac{1}{32}$ in. in width, should be logged taking into account the presence of any slip fiber. However, care should be taken in measuring the vein width that is continuous, as frequently broken or divided veins occur and what may seem like a $\frac{1}{2}$-in. vein is in reality two, $\frac{1}{4}$-in. veins (Fig 2). Where possible photographs should be taken of the area exposed as these may later be enlarged and the fiber veins measured. I have found photographs very useful in this work as they take into consideration all the rock exposed. There is a human tendency when sampling, to take only the rock that contains fiber. From this, an approximate fiber content may be calculated for each area (Fig 3).



FIG. 2.—CHRYSOTILE ASBESTOS VEIN SHOWING BROKEN VEINS.

From each exposed area a representative sample of the ore should be taken, varying in quantity from one to a thousand tons, depending on the zone of influence which the area will have, the information desired, and the facilities available for testing it. The term "representative sample" as used here requires some comment. It should be

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taken in such a manner as will not cause a concentration and distort the results, as all the rock will have to be mined, milled and paid for, unless it is low grade and of

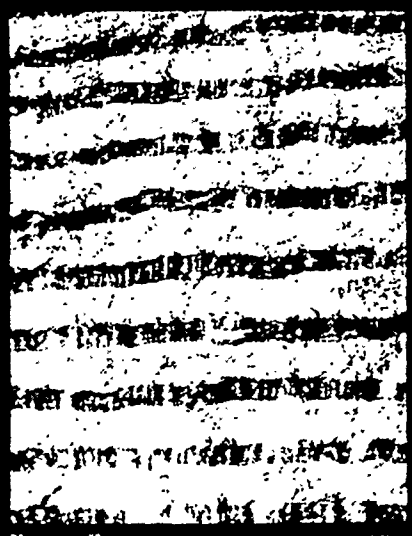


FIG 3—CHRYSOTILE ASBESTOS SHOWING RIBBON-ROCK STRUCTURE.

sufficient size to be left in place depending on the mining method. For example, a part of an area may contain 1.5 pct of fiber with veins over $\frac{1}{2}$ in., while another part may contain .5 pct fiber with most of the veins under $\frac{1}{4}$ in. Both areas separately, would be graded as poor ore, but together, the value of the ore would be raised to economic or medium grade ore with the addition of $\frac{1}{2}$ in. fiber as a sweetener.

DIAMOND DRILLING

As in most other deposits the extension of surface indications must be proved in depth by diamond drilling. Standard practice now seems to be the use of 1⅝-in. diameter core with AX tools. The drilling to start usually consists of a few spot holes followed later by a carefully laid out program so that each hole will be assigned a definite zone of influence and yield as much new information as possible. Holes are usually laid out on 100-ft centers, depending on conditions and information desired. Angle holes are often used to establish the outbounds of the deposit. A check made of three operating mines indicated that a foot of hole was required to prove anywhere from 200 to 450 tons of ore, which means that the zone of influence assigned to a hole is being somewhat standardized. To a large extent this will depend on the nature of the deposit.

The cores should be carefully logged, showing the geology and all fiber veins over $\frac{1}{32}$ in. in width.

The core is usually read in sections of 5 ft and the veins in each section are carefully measured. From this, the fiber content can be fairly closely estimated. The terms good ore (over 5 pct fiber content), medium ore (3 to 5 pct content) and poor ore (0 to 3 pct content) are used to designate sections of the core. However, there being no accepted standard, these terms are somewhat elastic and should be defined in each report, since some mining companies use other classifications.

It is considered good practice to take the core from two or three different holes and have them crushed up and the fiber recovered to serve as a check against the original readings and a plus or minus factor may be determined. The other cores are always saved and used for future reference.

The sludge from the drilling should be collected, examined and correlated to the core readings, especially in areas where core is badly broken up and may have destroyed the fiber veins.

In slip fiber deposits, it is not possible to measure the veins and readings are usually done by visual inspection as compared to some known core, the fiber content of which has been confirmed by test-mill results. In such deposits test samples are an absolute necessity to obtain the fiber content and the fiber length. The cost of dia-

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record drilling usually varies from $0.50 up to $3.00 per foot.

Testing Ore Samples, Pilot Test Mill

In new deposits, the test samples are not always of the size the engineers may want them to be, but are determined to a large extent, by the capital available for exploration. While some estimate of the grades that may be expected can be obtained from the fiber length measured during surface and core readings, the exactness will depend to a large extent on past experience of the observer. As a guide, the following fiber lengths when milled usually will give grades in the following groups: 1/16 to 1/8 in., group 6 and 7; 1/8 to 1/4 in., group 4 and 5; 1/4 in. and over, group 3.

If a deposit is in the vicinity of an existing asbestos mill, the samples should be sent there to determine the fiber content and the classification of different grades of fiber for each sample. In such a case, mill efficiency would have to be considered because a certain destruction of the fiber length in the milling process is inevitable. Furthermore, some loss in the mill tailings and fan exhausts has to be taken into account and this is usually 0.5 to 1 pct of the total fiber content and usually consists of the shorter, group 7, fibers. However, for new deposits that cannot use any surrounding facilities, a pilot test mill is almost a necessity, not only for testing the samples, but it may obviate very useful modifications necessary for a mill to treat the particular type of ore efficiently.

Asbestos milling practice is based on crushing the ore, drying, fiberizing in hammer mills to free the fiber, then screening and aspirating the free fiber (this usually in two or three similar stages), then cleaning the fiber and classifying it in trommel type graders. The difficulty of the problem of classifying the fiber in order to get the most economic values out of the ore, may be realized when it is considered that coming from the deposit, various lengths of fiber in various proportions are found and it is necessary to make standard grades of predetermined tests. After a deposit has been worked for some time, the mill is adjusted to produce certain standard grades favorable to the particular deposit, however to a large extent, this is governed by market demands.

A flow sheet of a typical pilot test mill would consist of: a 6 by 18 in. jaw crusher; horizontal 18 in. by 16 ft rotary dryer; 4 by 10 ft shaking screen with air suction; vertical or horizontal-type fiberizer; shaking screen with aspirator; fan and collector; a cleaning screen, a rotary grading trommel and a Quebec Standard Testing Machine. The cost of such a unit, including power, would be around $30,000.

Representative samples of the fiber produced from the ore samples should be tested in the Quebec Standard Testing Machine to obtain the grades of fiber. It is always advisable in new deposits to send samples of the fiber to various manufacturers for test purposes.

Asbestos fiber, following Canadian practice, which is now considered world standard, is divided into nine main groups and each group is subdivided in grades, giving a total of approximately 25 standard grades of fiber, each having a different test and value.

Crude Fibers (hand processed)—

Group 1—Crude No. 1, 3/4-in. staple and longer.

Group 2—Crude No. 2, 3/4-in. staple and longer up to 3/4-in.

Mill Fibers (machine processed)—

Group 3—Textile spinning fibers (testing over 0—8—6—2).

Group 4—Shingle fibers (testing below 0—8—6—2 and including 0—1.5—9.5—5.0).

Group 5—Paper fibers (testing below 0—1.5—9.5—5.0 and including 0—0—8—8).

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Group 6 Waste stucco, plaster fiber testing below 5 and 8 and over 5 and under 11.

Group 7 Shorts testing 5 and 11 and below.

Group 8 Sand weighing over 55 lb per cubic foot and under 75 lb.

Group 9 Sand and gravel, weighing over 75 lb per cubic foot.

The testing machine consists of a nest of four rectangular screens held in a frame on a table which is actuated by an eccentric. The top screen has ½-in. openings, the second 4-mesh, the third 10-mesh and the fourth is a pan, though at present, a 35-mesh is often used. For a test a pound sample is put on the top screen and the machine run for two minutes at 300 rpm. The amount of fiber remaining on each screen is then weighed and recorded in ounces which determines the test.

Fiber Valuation of Deposit

Fiber prices are those that would be obtained in a competitive market, but as this is not usually known at such an early stage, it is advisable to use for calculating purposes, the Canadian prices in effect at the time, less about 8 to 10 pct for a safety factor. However, some mines in Africa and Russia do not use the standard Canadian test designation but have their own standards and prices. In such cases their standards should be clearly defined and preferably translated in terms of the Canadian standard, both of which, are fundamentally based on fiber length.

By averaging the surface readings, the core holes and ore test sample results from the various areas examined, the average fiber content for the deposit may be obtained.

Following the same procedure for estimated grades of fiber and calculating this in terms of average per ton value, then by combining the two and knowing the possible ore tonnage, an average value per ton of ore may be established for the deposit. Given sufficient volume, the average value per ton of ore under present day conditions would be approximately $1.25 to $1.50 to be worth consideration, however other factors may be involved which may vary these figures.

From this it is evident that in an asbestos deposit two important variables are present, the fiber content and fiber length, and in most cases one helps to compensate for the other.

Other General Factors to Be Considered in Valuation

1. Proximity of fiber to market, to determine if favorable or unfavorable freight differential should be considered.

2. Tariffs on imports, depending on country in which deposit is located.

3. Mill efficiency. Asbestos ore varies so much from one deposit to another that milling practice has to be modified to suit each particular ore. Such factors as moisture content, hardness of rock, harshness or softness of fiber have to be considered besides the overall efficiency which is based on fiber recovery.

Asbestos ore, unless concentrated in relatively rich small pockets which can be worked economically by hand for crude fibers, usually has a relatively low per-ton ore value and has to be worked in fairly large tonnages with low mining and milling costs. Deposits with a fiber content of 1.5 to 2 pct are being worked but in most deposits, about 5 to 7 pct is considered average.

4. Certain low-grade areas may have to be excluded unless they can be worked together with other better grade areas to bring them within the economic limits.

After a careful estimate of the mining, crushing, drying and milling costs are made, knowing the average ore value, the commercial possibilities of a deposit can be established.

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