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ASBESTOS
MINING METHODS

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ASBESTOS MINING METHODS

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The method by which any mineral is mined is determined after careful consideration of the conditions associated therewith. It is governed by such factors as:

- Distance from rail or water transportation
- Elevation above sea level
- Depth of overburden or capping
- Size and formation of orebody
- Cost of production
- Value of product
- Demand whether universal or local
- Percentage of recovery

In certain respects asbestos is unique as compared with metals or other minerals. Its value depends on several features such as the length, strength and color of its fibres and their freedom from iron. In the case of gold, silver, iron, etc., which are recovered in molten form, every particle recovered is saleable and very accurate samples and assays are possible.

With asbestos, estimates of grade and percentage of recovery can be made only by inspection. The higher the percentage of long fibres, the better is the value per ton of ore. The short fibres may or may not be saleable. There is some sale for practically all forms of asbestos but many of the short or finer forms have a limited demand.

With most asbestos ores there is associated limited occurrences of magnetite or magnetic iron. When the fibres are required for electrical insulation, and a large percentage is so used, the presence of iron is highly objectionable. Fibres containing more than two per cent of iron are not suitable for electrical insulation.

The fibres from Arizona and certain small occurrences in sand stone and limestone formations are most nearly free from iron and command a correspondingly high sales value.

Another contrast with mining of the precious metals is that the size of an operation of the latter is expressed in tons per day while an asbestos plant is given in tons per hour. Many asbestos plants treat as many tons per hour as a gold mine, for instance, handles in twenty-four hours. Thus in comparison large tonnages of asbestos ore are required to be mined and milled which necessitates much plant and equipment. Since the yield of the average asbestos mine is less than five per cent a plant must be designed to produce and process several thousand tons of ore per day for a reasonably large output. Asbestos orebodies to be profitable must be extensive. Only very high grade occurrences can be mined by following narrow veins, and such instances are rare. In all cases adequate working places must be provided to maintain grades and production.

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EXPLORATION

Up to the present time practically all asbestos orebodies have been discovered by outcrops. In some cases the exposed rock has a large area and in others there are only projecting rocks here and there.

If the overburden is light a fair knowledge of the rock may be obtained by trenching. Frequently a boom derrick or light cableway is set up and a small pit or trench is opened. Such information however is only sufficient for small operations.

If the exposure is on a hillside an adit with branch drifts may be driven. This information covers only the horizon drifted. But if the exposures are extensive and a large scale operation is indicated the ore body should be thoroly explored by systematic diamond drilling by holes spaced at regular intervals. The boundaries and depth of the ore zone should be well defined before the mining method and location and size of plant can be decided.

The usual practice is to drill vertical holes on squares spaced at 300 to 600 foot centers, then to halve and quarter these spaces as ore is located. When an outline has been established the whole ore zone may be completely drilled on equal spaces not exceeding 100 feet and preferably less. The cores should not be less than AX size which is 1⅛" diameter. These are examined, logged and plotted and sections made at regular intervals. From these data when carefully prepared in every respect plans for an extensive development may be prepared.

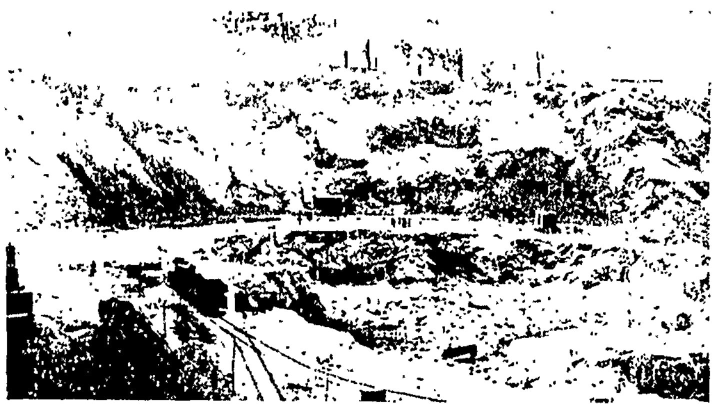
OPEN PIT MINING

Such operations may be carried on by several methods, such as:

a. Side hill cut
b. Overhead cableways
c. Inclined cable or truck haulage
d. Spiral benching by locomotive haulage
e. Multiple benching

These headings refer to the manner of transporting the ore, that is, bringing it to the surface. The method of mining is much the same in all cases.

Stripping of overburden is usually the first step in mining. The depth may be from a few inches to perhaps 75 feet. The latter depth is not warranted except where abundant ore has been assured by thoro exploration.



Open pit mining with cable haulage at Johnson's Company, Thetford Mines, Canada.

Shallow overburden on rough surface may be removed by horse and cart. Generally power shovels and trucks are used at a cost of 50c to $1.00 per cubic yard in place. Lower cost may be possible under favorable conditions. Scrapers are not practical in hard clay with boulders.

Hydraulic Stripping is possible but it requires abundant supply of water, a favorable disposal area and freedom from boulders.

Side Hill Cut. This usually provides low costs. If pit floor and crushers have the proper relation, ore is hauled with minimum grades. A face is started which increases in width and height as work progresses. Barren rock is easily disposed of. Truck haulage is the most satisfactory.

Drilling is done by air at 80 to 90 lbs. per square inch using several types of drills. Toe holes are driven at floor level. Other holes are drilled in the face to suit the formation. These are blasted either independently by fuse or simultaneously by electric caps which are detonated by the mine current or by a hand operated blasting box in which current is generated by a magneto. While loading ore into trucks oversize pieces are set aside by the shovel. These are drilled by pluggers and blasted with a small charge of dynamite. This is known as secondary blasting.

Overhead Cableways. A cableway spans the area being mined and is supported at either end by "A" frames or towers and secured by anchorages in the rock or by counter-balances of rock commonly called "dead men".

The cables are wire ropes 1½ inches in diameter for short spans and loads of 1½ to 2 tons and 2 to 3 inches in diameter for spans up to about 1100 feet and loads of 5 to 10 tons. These large ropes are known as the track cable. On them operates a carriage connected to the hoist by a hoisting rope and a conveying rope. The hoisting rope descends from the cable as a three-part line to the hoisting block to which the boxes or skips are hooked in the pit. The smaller hoists are double drum or drum and spool (the spool for conveying). Boxes are open at one end and dumped by unhooking the front chain.

Larger hoists are three drum one each for hoisting, conveying and dumping. Slacking the dumping drum lowers the front end of the box and releases the load. Small hoists are usually stationary. Larger ones are frequently movable. Either the head and tail towers move on parallel tracks or the head tower is the center of a curved track for the tail tower. The moving towers are operated by separate motors.

Cableways have several advantages They are a comparatively cheap installation. They permit operations to the maximum depth for safety. Operations may be carried on from the pit floor and on the slopes. A level floor is not necessary nor any tracks thereon. Movable towers permit a series of benches to be operated across the pit.

The largest commercial cableway system ever installed was at the King Mine of Asbestos Corporation Ltd. at Thetford Mines, erected while the writer was chief engineer. There were 8 movable cableways of 1100 foot span. Six of them hoisted 5 ton loads on 2½ inch cables and 2 hoisted 10 ton loads on 3 inch cables. The latter, however, were not as economical as anticipated, the boxes being too heavy for easy placing.

Inclined Cable or Truck Haulage. This, as the name implies, is an incline from surface to pit floor.

With trucks the inclination should not exceed 15 per cent. With cables it is usually about 20 degrees unless specially constructed cars are used.

Trucks are used where the incline is in open cut. This method is economical and advantageous. Barren rock is taken directly to dump. Pit operations may be changed from place to place and even the incline may be moved without great expense. Winter operations on steep inclines are somewhat hazardous.

With cable haulage the incline is fixed and more expensive especially if driven thru weak ground. Double track is quite essential. The first cost is more and is increased by bad ground. But operations are much more satisfactory than with a by-pass which causes frequent interruptions from derailed cars and damage to cables thru accident and wear. A by-pass also makes changes to lower levels difficult because of the increased length of cables required.

Cable haulage usually has tracks and a locomotive

in the pit to gather cars which have been loaded by shovels and bring them to the foot of the incline. The ore body must be sufficient for several years operations. The pit floor can be lowered but it is more difficult than with truck haulage.

With sufficient ore and with a three track yard at foot of incline to provide storage and separate loads from empties this form of transportation can handle a large tonnage at low cost. Probably lower than truck haulage because steep grades are less objectionable and the incline is under cover in winter. Doors are required at portals to prevent freezing.

A cable haulage may be used in open cut as well as in tunnels. When tractors or half-tracks are used instead of trucks the grade of 15 per cent may be much increased.

Spiral Benching. This is merely another form of inclined haulage but is usually applied to extensive ore bodies where there is ample space to permit easy grades and the use of standard gauge locomotive haulage. The pit assumes the form of a huge bowl.

Descending tracks traverse the outer edge of the bowl

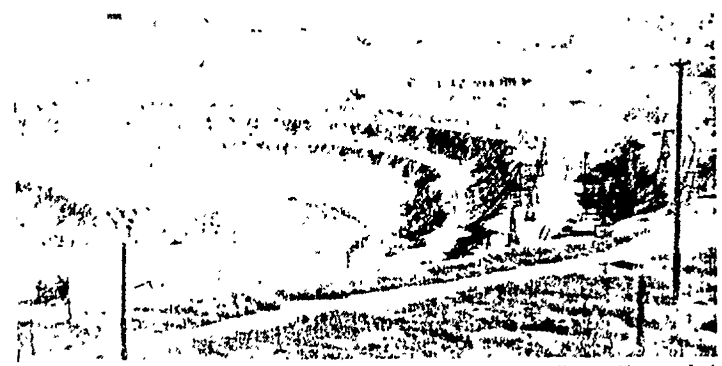


Photo courtesy of Canadian J M Co., Ltd.

A good example of Spiral Benching at the mine of Canadian Johns Manville Co., Limited, Asbestos, Que., Canada.

on the first level and take the next levels successively to the pit floor. The width of the benches which form the successive levels is dependent on circumstances. The proper depth of benches is generally accepted as 35 to 40 feet.

This method of operating calls for large daily tonnages and equipment to produce it. Power shovels of 4 to 8 yards capacity are used, and standard railway cars. Drilling is done by heavy drills handling 40 foot steel supported by a frame or derrick. Staggered rows of holes are drilled parallel to the face and slightly below the next bench floor. Some operators prefer churn drills for such operations. These holes are vertical, usually 5 to 9 inches diameter and are spaced farther apart than the air operated drills. In either case many holes are blasted at one time to provide a large "jam" (a local term) of rock and thus avoid frequent movement of shovels. With either type of drilling there is secondary blasting.

When the upper level has reached and probably passed the limits of the orebody, when benches have been worked out and when the pit floor becomes too small for further development, the spiral system has reached its limit of practical operations.

The best example of this method of mining asbestos is at the Canadian Johns Manville Plant at Asbestos, Quebec. This mine reached its present full scale development of this process thru some of the methods already described. That is side hill cut by wagon haulage, stiff-leg derrick for a considerable time before cableways were installed, then by cableways until the present system was put into operation.

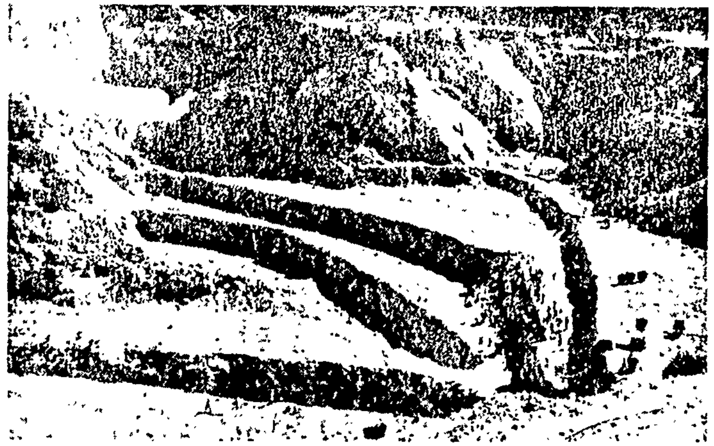
Multiple Benching. As distinguished from Spiral Benching, which is well known, another form might be called Multiple Benching. It would be used where the orebody has considerable surface area, perhaps broken up by bodies of barren rock which can be left in place, and where many working faces are required to supply the daily production. Because of these islands of barren rock Spiral Benching would not be applicable since it requires the removal of all rock.

By this method the ramifications of an irregular ore-

body may be conveniently mined. Work would be started by driving trenches in the center of each area to be mined then expanding the trenches by drilling the walls as a face or bench, the ore being loaded into trucks by shovels and hauled directly to crushers, or dumped into mill holes to a lower level which may be an adit at crusher level or it may have to be hoisted to another level.

As benches are worked out to the contact or as they merge into other benches at the same level new trenches must be cut to a lower horizon, and the process repeated. If mill holes are being used, slopes for trucks will remain at easy grades. But if ore is hauled directly to crusher the incline will increase in length as the pit is deepened.

The walls where benches terminate must be left at a safe slope for protection of workmen as mining is continued on lower benches.



Multiple Benching at Gath's Mine in Mashaba.
(African Associated Mines, Ltd.)

UNDERGROUND MINING

As a general statement all open pit operations, where the orebody continues to depth, ultimately reach the point where apexing walls and steep slopes render further development by this method too dangerous. The nature of an asbestos orebody broken up by faults, cracks and slippery faces makes it necessary to guard against frequent falls and slides.

In the mining of asbestos, wood may not be used because wood particles cause much damage in manufacturing plants. This rules out such methods as top slicing and square settings.

In the early days of the King Mine *glory holes* were recommended but not adopted because they would be dangerous to work and would freeze up in the Canadian winter.

Shrinkage stopes were used successfully at the Beaver Mine (of Asbestos Corporation Ltd.) and at the King Mine, but this system leaves pillars which are practically impossible to wholly recover and where the ore is valuable considerable loss is incurred.

Early in 1930 a pamphlet written by F. W. Maclennan, General Manager of the Miami Copper Company, was published and was carefully studied, in conjunction with other existing data on Block Caving, by the mining staffs of Thetford Mines. It described in detail the mining of copper by this method, by which low costs had been achieved. The system requires a large orebody and one that will cave. The question was how effectively would the Thetford orebodies cave? Because of their much fractured nature it was thought they would cave satisfactorily in most cases.

The King Mine of Asbestos Corporation Ltd. was the first to adopt Block Caving. They installed this system and commenced drawing in July 1933. Much credit is due them for pioneering the application of Block Caving in the mining of asbestos where special technique in back filling had to be developed and which is so different from the porphyries where it had been used.

The Asbestos Corporation Ltd. was so successful in drawing asbestos ore by the Block Caving Method that Johnson's Company were next to follow, and drawing of their ore commenced in November 1940. The Bell Asbestos

Mines are in a more favorable position but are going thru the transitory stage and at the time this article is being written (1941) are preparing for underground mining.

The Canadian Johns Manville Company, largest of the open pit mines, is making preparations for underground mining by Block Caving on a scale to equal their present open pit capacity.

BLOCK CAVING

This method of mining asbestos is attractive because it has several important advantages:

It permits deep mining.

It permits maximum recovery of orebody.

It permits selection and mixing of ores.

It affords low costs for large scale operations.

It is practically free from interruption under winter conditions.

Thus far this method has been used as a final stage of development. The mines now using it have developed from small beginnings using the cheapest known method and gradually enlarging until a maximum economic depth was reached. Block Caving principles and practices were already well developed, largely by the copper industries, before being tried by the asbestos producers, and its application to asbestos mining was therefore less difficult.

There is no reason why Block Caving could not be used for original development if an orebody of sufficient extent were known. The inclination is to strip and use open pit methods which may be cheaper. There exists a fear that fibres would be discolored if overburden is not removed. But if overburden is heavy (exceeding 35 to 40 feet) the cost of removal is great and becomes a burden on operations. If surface drainage is thoroly diverted so the area being mined receives only its own natural precipitation it is quite possible that the cost of stripping could be omitted and this sum applied to the cost of preparations for underground mining by Block Caving.

To date practically all operating mines have been found by outcrops or surface exposures. There may still be such exposures in areas not yet explored.

There may still be orebodies within the serpentinized asbestos belts as good as the mines now operating. If so, and they are not exposed, they can be found only by drilling or other underground exploration.

It will become gradually necessary to develop methods which will permit mining of areas now considered marginal or sub marginal. There are many known cases of this nature, and some of large extent. The present and probably increasing demand for shingle grades with possible improvement in milling practice may bring them into production.

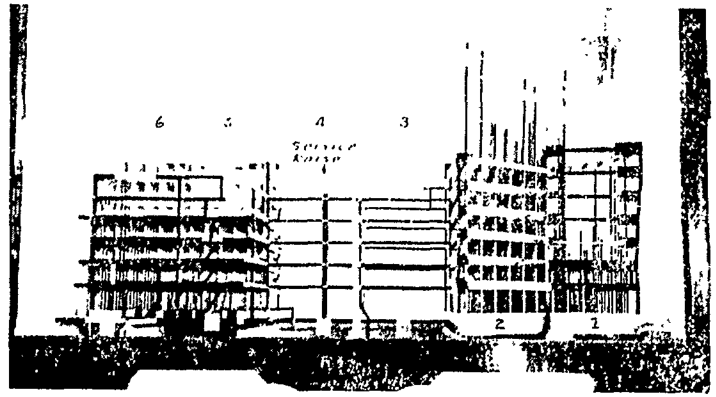
Typical Application of Block Caving to Asbestos Mining. The orebody is divided into blocks of such size that they will cave. Thus far this size is about 160 feet square but modified by circumstances. Height of block is about 300 feet but may go to 500 feet.

A shaft is sunk beyond any possible reach of disturbances from underground mining. Stations, loading pockets and drainage sumps are cut and two drifts are driven to and below the blocks to be mined. The lower or haulage drift is for transporting ore. The upper or grizzly drift (about 51 feet higher) is for transporting men and materials. These are extended under the blocks where there are two grizzly drifts for each haulage drift. Raises are driven, one from each side of haulage drifts up to the grizzly drifts (so called because the top of each is protected by a grizzly with about 16 inch openings.) From these grizzlies double branches are again put up. These when enlarged form the draw points and reach to the undercut. Grizzly drifts are completely timbered with steel sets of 6 inch H beams and thoroly concreted. Openings are left at the draw points.

Raises at block corners, and known as corner raises, are driven from the nearest draw point. As these raises advance fringe drifts at 30 to 40 foot vertical intervals are driven around the block. These provide a plane of weakness on block lines and are sliced at floor and back in

strong ground to further weaken the block line.

When haulage raises and loading chutes, grizzly drifts, grizzly and finger raises are fully developed the undercut is made. This is a series of drifts 7 x 7 on 20 foot centers parallel to grizzly drifts and 20 feet above grizzly floor. Thirteen foot pillars remain. The sides and roof of the 7 x 7 drifts are drilled, draw points fully enlarged to provide for expansion and when all is ready the drill holes are loaded and blasted either entirely or by sections. This may require as much as 20 tons of dynamite. Blasting the undercut leaves the whole block unsupported. It is the strain of this unsupported load which causes caving.



Model of Block Caving Johnson's Company. Blocks 1, 2, 5 and 6 are being drawn. Glass tubes filled with brick dust indicate original height of ore at each draw point. As ore is drawn the brick dust is drawn off. Drawing in No. 1 is nearly finished; No. 2 has just been started; blocks 5 and 6 are roughly half drawn.

Horizontal and vertical black lines represent completed fringe drifts and raises. White lines show proposed work. A cage in the service raise gives easy access to all levels.

This blasted rock fills all the draw points and overflows into the grizzly drifts and haulage chutes. It is drawn off leaving vacancies where the roof is unsupported. By natural caving the roof falls by successive spawling or by settlement of block thru the line of fringe drifts. At grizzlies boulders too large to pass are blasted.

As the block settles backfill from mill tailings is placed from surface to support the exposed walls of adjoining blocks and contiguous surface areas.

Backfill is not needed to cause caving. It is used to avoid disturbance of adjoining properties or permanent surface structures, to prevent freezing in the underground and to support walls of undeveloped blocks. Backfilling on top of clean ore is to be avoided if possible.

In drawing ore considerable care should be exercised to draw uniformly thruout the block. Where hard spots exist these must be drilled and blasted so the block may not be held up at that point. The aim is to cause uniform settlement of the block and, likewise, uniform settlement of the backfill. If sections of the block are overdrawn the backfill of tailings or sand may work down and be drawn with the ore causing dilution. If dilution is excessive operations become unprofitable and ore will have to be left which might have been drawn but for dilution.

Thus dilution and possible loss of ore are an unfavorable factor of Block Caving and must be carefully controlled.

If there is overburden there is always some dilution and consequent loss of ore.

Full details of Block Caving and as applied to asbestos mining can be had by reference to the following published articles:

F. W. Maclennan, Tech. Pub. No. 314, A. I. M. & M.

Block Caving at the King Mine of Asbestos Corporation Ltd., Can. I. M. & M., April 1934.

Notes on Block Caving at the King Mine of Asbestos Corporation Ltd., Can. I. M. & M., November 1935.

King Mine No. 3 Shaft and Equipment, Asbestos Corporation Ltd., Can. I. M. & M., March 1939.

Caving at Johnson's Asbestos Mine, Can. I. M. & M., September 1941.

The writer wishes to acknowledge the cooperation of officials of the companies herein mentioned for permitting reference to their operations.

TREATMENT OF ASBESTOS ORES

Briefly the process is as follows:

With open pit mining it is sometimes possible to avoid removal of barren areas but, generally speaking, the whole orebody is mined. It is therefore necessary to make a rough separation of ore and barren rock in the pit. Barren rock goes to the dump and ore to the crushers. In the earlier days of manual labor rock was blasted to man size pieces and a good separation of crude, mill ore and barren rock could be made. With the larger tonnage now required to meet the demand mechanical handling is necessary. For a long time this was thought impractical because it did not permit full recovery of valuable crude fibre.

Crushers with openings as small as 15 inches by 30 inches were used for the man-size rock. As production increased the crushers changed to 24 x 36 or 36 x 42 and now 48 x 60 is a common size. Such a machine weighs about 200,000 pounds.

After primary and secondary crushing to 3 inches and less, barren rock is partially removed, the ore is dried and goes to a large dry rock storage. This storage serves as a balance wheel and surge and blending bin between mining and milling. The mills further reduce the rock by successive crushing. Fibre is separated by aspiration, graded according to length, bagged in 100 to 125 pound bags and stored for shipment.

The Author acknowledges and appreciates the co-operation of O. C. Smith, President Bell Asbestos Mines; H. K. Sherry, Vice President Canadian Johns-Manville, Ltd., and George Dick, Manager (at time article was written) of Asbestos Corporation Limited, in the writing of this article.

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