[redacted]

The STATE MINING ENGINEER.-

AUSTRALIAN BLUE ASBESTOS LTD.

You will recall that we recently discussed in Perth the future of the Blue Asbestos Industry in this State and that my view was that, with the inexperienced management that has been universally employed in the past, no progress was to be expected. There is no need to remind you that the De Bernales venture has failed, which leaves the future in the hands of Australian Blue Asbestos, Limited, who have spent much money for results which do not offer much encouragement for the further financing of the venture, which is obviously necessary. The position at the moment is serious for the Company and also for this State as a whole, as was indicated to me by the Under Secretary as well as yourself. The object of this report is to outline a general method of mining, with particular attention to improvements in technique, and in reading it, you are asked to remember that it is written more or less from memory, without access to any of the mine records, so that many of the figures quoted are approximate only.

MINING.

Ore can be won either by benching from the gorge faces or by underground mining methods. The total length of all grades of fibre to be got by either method averages about 4 inches, and the mining width of any underground method cannot be much less than 7 feet if modern appliances are to be used, while the amount of overburden that can be economically removed in benching is a direct function of underground mining costs. Rock can be broken from the free gorge faces at a much smaller cost per ton than by any underground method. This fact was realised at Wittenoom and in the early stages all fibre was produced from benches. Overburden was shot from the top of the fibre bearing rock and the waste rock shovelled over the edge of the bench, while the fibre was broken separately. The miners were inexperienced in large scale quarry methods and bored and fired holes which were for the most part only 6 feet or so deep, a depth which some of them had probably used in stopes. No attempt was made to bore holes 20, 30 or more feet in depth and to bull them before firing, and in general to take advantage of the much higher tonnage of rock to be broken per pound of explosive than with short holes. Objections to large scale methods were offered on the spot, and though they have some substance, no effort was made to overcome them, which should have been done before underground mining was tackled. A large part of the costs of underground methods will be attributable to development openings, and since none of these is necessary on the gorge faces, the cost of breaking rock from them is relatively less. It was said that the gorge face was too broken, which would make boring difficult and might dissipate the energy of the blast when firing, but both of these reasons apply equally to shallow holes if not placed correctly. It is worth noting that it is now proposed that blast hole drilling, which has gained popularity in the United States and is now being used at Big Bell, be used underground at Wittenoom. The only conditions under which blast drilling can be used underground are where there are great mining widths (80 feet at Big Bell) and it will be quite useless in the narrow 6 or 7 ft. stopes at Wittenoom, though it should have been used on the outside free faces. There is still a lot of fibre which could be mined from the gorge faces by the use of modern methods, more cheaply than it can be broken underground, though some of it is permanently locked up by the placing of some of the mine utilities.

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DEVELOPMENT.

Underground development was put in hand some three years ago and much work has been done on a bord and pillar basis. The economical exploitation of these deposits demands that the maximum extraction of ore be got from any developed area, which postulates that no matter what mining methods are used, they must be carried to the limits of safe local subsidence at the working faces. As mining is continued, large areas are opened up, causing caving of old workings, but the mining method should be designed so that the caving occurs long after miners or utilities are required in the area. General subsidence can extend to the surfaces of the deposit rendering them unstable and causing much damage.

The stope preparation that has so far been done star within about 200 feet of the portals of the main entries, whil the gorge face extends above the portals at an average angle of some 70° for a height of about 300 feet. If any extensive area is completely stoped out close to the portal entries, subsidence will eventually extend to the vertical face of the gorge and loose rock would then be periodically dislodged from the faces endangering life and various mine installations. Th theory of subsidence, which can be seen in any good coal minin text book, indicates that in the present case the minimum distance from the portals at which ground could be completely stoped without affecting the gorge face would be roughly 600 feet normal to the gorge face and should be considerably greater for preference.

It should be clear that a high percentage of extract at a distance of less than 600 feet from the portal will cause a dangerous set of conditions to ensue, or alternatively, if the danger is to be avoided, pillars must be left so that percentage of extraction is lowered with relatively high costs. These considerations apply to the bulk of the ore which has been developed to date.

The principal factor in development in any mine is speed, which is particularly applicable in the Hamersley deposits in which the valuable content is only 4 inches wide. Most things must be sacrificed to this requirement except in cases where development is far ahead of mill throughput.

Some development ends at Wittenoom have been driven 20 feet wide, the argument being that contractors are paid les than double the price of a 10 foot drive, so that fibre is mor cheaply won from the larger drive. This is true to some exter but it slows down development tremendously, thereby postponing the time that fibre can be won from stoping at much less cost than from any development face. For speed drives should be carried as small as is compatible with the use to which they are to be put, which would be about 9 x 7 for main entries and perhaps somewhat smaller for cross entries. It should be remembered that in narrow drives, although more fracteur is used per ton of rock broken, this disadvantage is partly offset by the fact that the ground breaks smaller and is therefore quicker to remove.

Removal of broken rock from development faces is quicker and cheaper if done by mechanical means. Portable scrapers have been tried, but have not proved a success. Scrapers are efficient and economical only when large tonnages of rock are to be handled from a fixed location. Their performance figures when in actual operation are very attractive, but it is almost invariably found that their use entails much lost time due to trouble with ropes, blocks, and pin holes, and wear and maintenance costs are high. In a Spanish

pyrite mine figures recently given showed that the actual working time was at best 3 hours 35 minutes in an 8 hour shift, and such a proportion of lost time cannot be borne when developing. A further considerable disadvantage in using scrapers in the asbestos deposits is that the ground breaks in flat slabs, which are quite large in wide faces, and the light scraper continually rides over them, whereas in an unbedded one, which breaks roughly spheroidal, the scraper has much more chance of picking up a full load at every trip.

Air operated mine car loaders, or mechanical boggers, as they are called, are in almost universal use in drives of this nature. They are rugged and will bog out a 30 ton drive cut in about 2 hours in the hands of a skilled operator, if trucks can be kept up to them.

In boring time is lost in rigging up and pulling down machines, so that modern rock drill carriages or "jumbos" should be used, mounting two automatic machines on two bars one foot apart, held up to the face by air operated telescopes. This apparatus will increase the boring time of each machine by about ¾ of an hour per shift.

The present practice is to carry the fibre seams at the bottom of entries, but if the over riding importance of speed be admitted, the fibre must be carried at the top of the drive. With a bottom seam, the face must be fired in two sections, the top worthless portion first, and after it has been cleaned up, the fibre bearing rock is shot out. The removal of the first part of the round is made slow and costly by the fibre shelf, and the two firings create two periods of lost time while fumes clear from the face. If all holes were blasted at the same time, the fibre would be mixed with and covered by the waste rock. There would be too large a volume of rock for effective hand sorting before milling, which, incidentally, always entails some loss of the valuable content of an ore, and the alternative would be to mill all development dirt which is very abrasive and would cause very high mill costs.

If, however, the fibre were carried at the top of the drive, all of the above disabilities could be overcome at the expense of a small amount of fibre. The round would be shot out in one firing in which the back holes would be detonated last. By a little experimentation in the placing and charging of all holes, particularly the back holes, no scattering will occur and the fibre can be picked off the top of the pile with very little loss of both product and time, and the rest of the dirt rapidly bogged out with a mechanical bogger. It is imperative that attention be given to this matter and the small fibre loss accepted for the sake of speed.

Briefly, development ends should be driven about 9 ft. by 7 ft. with the fibre seam at the top, using two machines mounted on a jumbo, and a mechanical bogger to which trucks are brought up by a mule or locomotive. All holes are fired at the same time, fibre rock removed, and waste bogged out. It has been found best to complete a round of these operations every shift, that is to bore, fire and bog out, and the length of the round bored is adjusted so that this complete cycle can be worked. Three men are employed on each shift, two miners and a bogger driver. Three shifts per day are worked and faces are driven double ended, that is, while the bogger is cleaning out one face, the miners are boring in another nearby.

Under these conditions, but without the use of a jumbo, the writer had a party of nine men in Wiluna, who took out 168 feet of 8 ft. x 8 ft. drive in a fortnight working single ended only. Their average was about 145 feet, but this performance could not be expected at Wittenoom since

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rock is harder than in most gold mines, and some time must be lost in fibre sorting. First class men should get about 120 feet and average men 100 feet.

Many reasons have been advanced for the wide drives and other practices of the past, and the chief one is that some fibre had to be produced quickly for war purposes, which is undeniable. It is contended that development by the technique suggested would have produced more fibre at lower cost than has been done, and that advancement would have been many times greater, so that the mine would now have a substantial output.

STOPING.

The evolution of a successful method of stoping the fibre bearing deposits after development is the key to the economic future of the deposits. The essential factors involved are -

1. A flat bedded deposit.
2. The fibre is in a number of seams whose total length is only about 4 inches.
3. These seams are enclosed in rocks which are appreciably harder than those found in most metal mines.

Nowhere, as far as can be ascertained, has a deposit been mined under conditions which have conformed precisely to those enumerated.

It is axiomatic in any industry that costs must be as low as possible, and this is especially applicable to the present case and particularly if calculations are based on pre war world prices for asbestos. Clearly the major part of production costs will be incurred in underground workings, and it follows that both efficiency and output must be much higher than anything attained in the past and that the percentage of developed ore extracted must be as high as possible.

One proposed method was that after development, stoping should be done over a width just adequate to encompass the fibre seams, which would be about 2 feet, and which would do away with the mining of waste rock. The chief objection is that the rock is so very hard that the heavy firing so close to the fibre seams necessary to mine them over such a narrow width, would entirely pulverise much of the fibre. More development would be necessary than by any other method.

It seems to be generally accepted that some sort of coal mining system will have to be applied, but this is true in name only. In this respect much loose thinking is in evidence, which may lead to further fruitless expenditure. The points which follow should be considered carefully and are based on an output of 6,000 tons of ore per month, a scale which will have to be approached as soon as possible.

It has been remarked that a greater width than the 2 feet of fibre bearing rock must be broken to preserve the length and quality of the product and therefore the most economical mining width will probably be just sufficient to give head room for men and modern labour saving appliances, but not so wide as to make necessary the removal of any of the waste rock from the workings, or even any further handling of it after firing. This width will be about 7 feet. Boring and blasting

be arranged in such a manner that the waste rock is shot clear of the fibre bearing rock. If the mining width is 7 feet, and the fibre rock width 2 feet, a total of 21,000 tons of rock broken per month gives 15,000 tons of waste rock, which is left in the workings and 6,000 tons of ore which is milled for the production of 896 short tons of fibre. These figures are dealt with further later on.

Referring back to the suggested coal mining methods, it is generally recognised that the techniques of coal breaking and rock breaking underground differ greatly since coal is comparatively soft and is usually associated with very soft rock. The main difference is that the breaking of the coal is nearly always assisted by the controlled subsidence of the soft roof. At times no blasting at all is necessary, and if shots are fired they are very few and light by hard rock standards. The use of roof pressure as an aid to ore breaking is likely to be dangerous and quite impossible at Wittenoom, and all ground can only be broken by heavy firing. At the working faces it would be uesless to have semi permanent installations such as conveyors, as they would be shot to pieces, whereas in a coal mine they are easily used and not subject to great damage from this cause.

In coalfields most boring is done by some form of auger, light rock drills being used occasionally in headings. The heavy rock drill of the hard rock miner is seldom seen. Coal is fired with black powder or other low grade explosive as against high grades of nitro glycerine and kindred explosives in hard rock. Coal must be handled gently to retain a reasonable size, while the object of metal mining is to break the ore small and save work in the milling plant.

Hand building of pack walls and gobs and the pumping of water can be done without at Wittenoom and the amount of development for ventilation only will be much less.

It has been noted that the mining width will be about 7 feet, and experience teaches that the maximum depth at which holes can be economically fired in a mining width of 7 feet is about 6 feet. A length along the face of 8 feet could be comfortably bored out, fired and cleaned up by a party in a shift. At 12 c. ft. of both rock and fibre per ton, the firing would give 20 tons of waste and 8 tons of ore.

If 150 tons of ore per shift is to be mined, working 2 shifts per day at faces, 8 feet wide, it is clear that there will need to be 19 working faces, and in general that,as would be expected in a mine with an ore streak only 2 feet wide, production is made up of small amounts from many faces. Naturally it would be better to have fewer faces each producing a higher tonnage. In the present instance this can be accomplished either by increasing the depth to which holes are bored or carrying wider faces. If hole depth is increased, the amount of fracteur per ton broken in narrow lodes rises rapidly and the heavier firing would be prone to damage the fibre. Greater face widths will mean that if a high percentage of ore extraction is aimed at, when large areas become open, the miners are subjected to greater riskfrom subsidence, and from this point of view, faces must be kept narrow. Another reason in support of narrow faces is that waste rock can probably be removed from them without any further handling after firing, and this will be referred to later. Generally speaking then, faces can not be much wider than 8 feet, 19 of which would supply 6,000 tons of ore per month, but in practice about 15 stope faces working 2 shifts per day and 8 development parties working 3 shifts will produce the required tonnage if faces are fired every shift.

The mining of 6,000 tons of ore per month by these means produces 15,000 tons of waste rock, which occupies one

third more space when broken than when in situ. With a mining width of about 7 feet, and allowing for the removal of all development dirt, as well as stoped ore, sufficient space becomes available to make the removal of waste unnecessary. Small local variations of the mining width will allow of some flexibility in the ratio of waste produced and space to be occupied, and will also assist in making unnecessary the further handling of dirt after firing. In this connection two other conditions will have to be fulfilled. Firstly, the waste will have to be shot in the direction of the maximum dip of the beds, which requires that working faces be roughly parallel to the strike, and secondly holes in waste rock will have to be electrically fired. In a face parallel to the strike, and with 5 feet of mullock and 2 feet of ore, if 2 holes are bored, one near the top and one near the bottom of the mullock seam, and fired separately, the dirt from the first is shot at right angles to the face, but when the second hole is fired, a large part of the dirt from it is shot either up or down in a vertical plane and remains at the face. If both holes are fired simultaneously, the broken rock can only travel at right angles to the face which is left fairly clean. All holes in the stope face should be fired at the same time with those in mullock fired electrically in pairs, after which the fibre is shot and very roughly sorted during bogging to reject with the waste large lumps of valueless rock.

Consider now the handling underground and transport to the mill of the 6,000 tons of ore as against similar operations in a coal mine, bearing in mind that profit margins in both types of mines are likely to be similarly low. It is well known that a 6,000 ton a month coal mine is only a small show, but this figure for asbestos in Australia is much larger than anything yet attempted. It is proposed that full scale mechanisation of handling and transport be installed as in coal mines and conveyors at the face, Joy loaders and other such expensive machines of high capacity are freely mentioned. It will be generally found that mines employing this equipment have an output considerably in excess of 6,000 tons per month, produced from seams several times thicker than the 2 feet asbestos seams. The point is that the capital outlay for these heavy machines cannot be justified unless they can be employed full time, which can only take place when large tonnages are to be handled without much time lost in moving equipment from face to face.

It has been shown that comparatively large quantities of coal are quickly broken from any particular face because the coal is usually broken over the full height of the face, which is 7 feet for comparative purposes, and being soft can be undercut and broken down often with no boring or firing. In contradistinction, at Wittenoom in the same time a much smaller amount of rock can be broken owing to the close boring and heavy firing necessary, calling for many more separated working faces, and from which only one third of the total rock broken has to be transported to the mill. At 15 stope faces heavy firing cannot be done indiscriminately, but must be confined to crib time and knock off time, and therefore loading of ore will have to be done simultaneously at not less than seven faces twice per shift, and the quantity from each face will be of the order of 8 tons.

A small model Joy Loader, if procurable, would probably cost about £3,000 and have a capacity of 15 tons per hour, including time for loading and switching trucks. If faces are to be loaded together, eight Joy Loaders would be required and would operate for an hour per shift in two half-hour periods. Going to the other extreme, allowing for shifting time, two Joy Loaders would be capable of bogging out the whole fifteen faces in a shift, but all faces would be idle part of the time varying from half an hour up to 6½ hours. To counteract this, other working faces would have to be provided for the miners, for which purpose another complete panel would have to be developed at large capital outlay and from which returns would be long delayed.

It should be plain that any mechanisation must be on the basis of a large number of small units rather than a few big ones and this will apply no matter on what scale operations are carried out because high output from a very narrow seam of 2 feet effective width can never be attained unless a large number of separated faces is producing.

Similarly semi portable conveyors for taking ore from the stopes are impracticable on account of the high overhead expense that would attach to them, and because they would be damaged by firing. The only feasible alternative is mine trucks and they will have to be taken right to the working faces. The smallest model mechanical bogger will be the most efficient device for loading trucks. They are very compact, which will be found to be a big advantage in both stope and drive faces.

The small tonnage to be milled has a bearing on development. Small trucks can be used and locomotives do not need to be large, so that the entries themselves are small. If locomotives do not need to be heavy, tracks can be light. The diesel locomotive already on the job should be ideal, and trucks should not be bigger than about 30 cwt. and should be self dumping.

After it is loaded into the trucks at the face, the ore will be hauled through the cross entries to the main entries by small hoists of about 4 H.P. either air or electrically driven, the latter for preference. Since waste is to be shot in the direction of maximum dip, ore must be hauled against it, that is, against a grade of about 1 in 6, or 10° at which normal traction is very inefficient. Full cars will be left at sidings on the main entries and picked up from them by the loco and hauled to the mill bins. The use of hoists in the cross entries conforms to the idea of mechanisation in small units. Even if traction were efficient, long distances for a small number of trucks would have to be travelled in many entries, requiring several locos at a high capital cost.

SUBSIDENCE.

This question has been dealt with here in general terms in several places and it is the most vital single factor to be taken into account when designing stoping methods. Conflicting theories have been advanced, but it is generally agreed that the precise nature of subsidence to be expected in a new area is unpredictable. The subsidence of soft strata in coal mines is quite well understood and can be controlled to a nicety. This understanding is, however, usually based on past experience of similar beds in the same or similar districts. All written observations on the subject appear to be unanimous in the view that the subsidence of very hard brittle strata is virtually uncontrollable to anything like the extent of soft strata usually associated with coal measures. Coal strata start to bend almost immediately that the coal is taken from under them, but hard brittle rocks stand over very large areas until the limiting load is reached, when they crack down suddenly rather than subside. This is certain to occur in the Hamersley deposits, but the chief factor to which nobody can yet supply an answer is whether they will suddenly break off short right up to the working face or only to within 2, 7, 12 or what distance of it. The information will only be gained by careful experimentation and the proposed initial stoping method is flexible to allow for changes which might be necessary.

Although the stoped areas will be full of waste rock, it is clear that this cannot prevent subsidence. It is generally agreed that even if the stopes be refilled hydraulically after mining, some subsidence will still take place if very large areas are opened up. Hydraulic fill would be too expensive in any case, and it follows that if packing of the waste rock cannot prevent subsidence, any handling of it at all after firing is a waste of money, which is the reason that special methods and directions of firing of the waste are proposed here. It must be remembered that the quantity of waste to be broken is 2½ times the amount of ore to be removed.

It will probably be found that subsidence will be greatly influenced by vertical joint planes, which can be easily seen in the weathered rock at the gorge faces, but not so plainly underground, and that when considerable areas are opened, conditions at any working face will bear a direct relation to the vertical joint planes.

Flat dipping deposits in hard rock have been successfully mined in other countries, notably America, and on the Rand in South Africa. In a few of the lead and zinc deposits in the State of Missouri, mining widths, dip, and hardness of country rock are comparable with the Hamersley deposits. Generally speaking, however, widths are greater and rocks softer. Stoping widths in the gold mines on the Rand are usually about 5 feet, dips are mostly steeper and rocks are fairly hard. It is interesting to record that low grade deposits are mined by these means in both countries. The tenor of lead ores has been as low as 5% and zinc ores 2%, while vast tonnages of 4 dwt. gold ore have been mined and to depths now approaching 10,000 feet.

South African deposits resemble our asbestos mines in that the mining width is often double the reef width, so that waste rock is produced in these cases. Pack walls are hand built from waste, while some of it may be hoisted to the surface. It would appear that 5 feet is the most economical width in which human beings can work a 2½ ft. reef in a flat deposit. The basis of all mining in South Africa is the use of native labour, which is usually plentiful and cheap, but inefficient. No such reservoir of labour is ever likely to be available here, and the class of white labour offering in any isolated area has always been inferior and will continue to be so in the future. Hence the need for mechanisation, postulating a sufficient mining width to accommodate various machines, which can not be done under about 7 feet in most cases.

The American mines are worked advancing which calls for a minimum outlay on development before returns are made, and in them faces are turned and firing takes place in all directions. Only ore is broken and is all removed from the face, support for the backs being provided by the leaving of pillars or artificial means. The necessity here for the disposal of waste with little or no handling calls for all firing to be done in the direction of maximum dip and the unknown factor of subsidence make it desirable that initially at least a retreating method be used. Our deposits are large and regular and do not have to be explored as do the lead and zinc, causing semi unsystematic workings. Clearly we are faced with features which call for the use of a stoping method not precisely duplicated anywhere else, but embodying portions of different systems. The scheme now to be outlined to conform with the many points that have been made calls for systematic development followed by retreating stope faces until experience of subsidence is gained. The general outline resembles coal mining practice, but the technique is everywhere in line with hard rock mining practice.

OPOSED METHOD.

The general outline is covered in Sketch No. 1. Employing hard rock techniques as outlined, main entries A A are simultaneously driven and as soon as the position of the first cross entry is reached, it is turned off from both main entries. Driving is then continued double ended and each cross entry face is opened up as soon as possible, the object being to have a number of faces in which both boring and bogging is continuous. One face is bored while another is being bogged, and a mechanical bogger in the hands of a skilled operator will clean out three faces per shift, provided that they are not far apart. As more faces become open, the number of working parties is increased to keep all faces and equipment in continuous operation as far as is possible. Cross entries in the same panel are driven up and down the dip and work must be concentrated on the one panel, in the first instance, rather than using the potential development of adjacent panels to get the required number of faces for full time working. Adjacent panel entries, however, should be started and carried 20 feet or so to avoid interfering at a later date with ore transport in the main entries.

After the cut off line 600 feet from the gorge face is reached, the panels bordering it require some 7,000 feet of total development. 200 feet per month has been allowed for each party, which should be easily attained with complete mechanisation and working multiple ended, and the number of parties will vary from two in the early stages to at least six and perhaps eight in the later stages, so that the first panel should be completely developed in about twelve months. This first panel will call for some 8,000 feet of development. The amount of fibre won from development only will range from about 75 to 300 tons per month near the end of opening up, and the fibre immediately recoverable from each panel after development is about thirteen months supply at the rate of 896 short tons per month. If subsequent panels call for 7,000 feet of development in thirteen months, at the rate of 200 feet per month per party, it is plain that three parties can comfortably cope with this work, although it would be desirable to have four or five until such time as developed ore got well ahead of mill requirements.

There would be no need to wait for the panel to be completely developed before stoping started. As cross entries between main entries are connected faces can be stoped progressively after about three months' work until the sixteen faces are worked in eight pairs. Each face is advanced every shift, boring with two machines mounted on a jumbo and firing one at crib time and one at knock off, one face being bored while the other is bogged as in driving. As the stope face retreats, pillars 30 ft. x 20 ft. are left on 125 ft. centres along the strike and 50 ft. centres up the dip. Waste is left in the stopes and the ratio of space to waste produced is controllable within narrow limits by slight variations of stoping width. No attempt is made to maintain the cross entries through the waste as stope faces retreat, so that the fibre in stope pillars is not retrievable.

The position of pillars on the sketch is very regular, but in practice the method is flexible and pillar intervals are easily varied, especially in the direction of dip. The strike interval of 95 feet between pillar boundaries appears large. Reckoning on 300 feet of rock above the back of the stope to the surface above, and allowing 12 c. ft. per ton, the total weight of rock above the whole panel is 12,500,000 tons. The ultimate strength in compression of very hard homogeneous rock is 15,000 lbs. per square inch, and 10,000 for not so hard rock.

using the latter figure, it can be shown that the 63 pillars of the size indicated theoretically will support a weight of 24,300,000 tons. No account is taken of shear stress because no information even of an approximate character is available. Generally speaking these theories are not to be relied on to any great extent, and experience, which has to be won carefully in the early stages, is the only guide. The backs of the drives that have already been opened up 20 feet wide for long lengths are perfectly flat and as sound as a bell after the area of weathering near the gorge faces has been left behind.

The proposed system is not designed to test mining methods or technique, for they are well understood. Ore extraction should take a secondary role until the subsidence characteristics of the rock are determined and they can not be predicted precisely by anyone. The object of leaving the pillars is not to support the roof over large areas, but to protect working faces in their immediate vicinity. Actually we want the roof to subside, and until it does a potentially dangerous condition can exist. The hard rock is certain to stand over very large areas, and will probably approach its limiting load without many signs of stress, and then break suddenly. After the sudden break its characteristics can be studied and alterations made accordingly. It may be advisable to bore out the first two or three lines of pillars and leave paths to them through the waste, so that they can be fired after the stope has retreated, with the object of forcing subsidence.

Ventilation of each panel should be supplied by an exhaust fan of 20,000 c. ft. per minute and controlled by doors in such a way that the current can be passed along the stope faces after firing. Secondary ventilation by the usual means should be provided in all dead ends.

Sketch No. 2, showing the details of the junctions of the main entries and cross entries, features some rather elaborate track work designed so that immediate switching is possible of full and empty trucks to and from both the panel being stoped and the one under development. The greater necessity for efficiency of mechanical loading, apart from skilled operation, is to be able to keep a continuous supply of trucks up to the machine. Trucks are hauled from the stopes to the main lines by the winch, while they are pushed up the dip by the loco to the development faces, but run down by gravity when full and are fitted with light brakes for control.

Conventional mining steel is in use today, but the economics of changing over to jack bits should be gone into particularly from the transport angle. Detachable bits would cost much less to freight to Wittenoom and also in the mine itself, where long distances will eventually have to be travelled. In view of the hardness of the rock, an efficient steel shop is of cardinal importance. The use of diamond drilling instead of boring with steel has been proposed, but it has not yet been developed to the stage where it can be economically used in very hard rocks.

Survey plans of the workings are kept, but there has been no effort to record on them the amount of fibre in the developed workings. It has been taken for granted, and with some justification, that vast quantities are in sight, but in a carefully costed mine, one must know as near as soon as possible the amount of mineral to be won and marketed from any given amount of expenditure. Fibre widths can be determined visually and plotted on the survey plan every 5 feet and the relative amounts of each grade should be recorded. It may sound laborious, but with experience appraisals can be rapidly made.

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The underground plan that has been put forward here should be fitted into the work that has already been done as far as can be done, and no slackening of production is called for by its adoption, but rather the reverse.

MILLING.

When the ore is crushed, the gangue which is hard and brittle breaks down, maintaining at all times a granular form, while the fibre splits along two perfect cleavage planes, but retains its original unbroken length if not subjected to too rough a treatment. Thus the fibre eventually assumes a fluffy form and can be sucked off the screen by an air current, while the granular gangue passes through or over the screens. In other words, the milling process increases the ratio of surface area to weight to a much greater extent in the case of the fibre than of the gangue, which allows a current of air of the right velocity to pick up the fibre and leave the gangue behind.

By comparison with smelting, roasting, or cyanidation, as used for gold or base metal ores, the extraction of the fibre is a simple matter. These former processes all involve chemical reactions which cannot be observed, so that the actual results of any changes made are not determinable until some later time. The passage of asbestos ore through the mill is observable at all stages and the efficacy or otherwise of any alteration is immediately apparent. The separation is entirely mechanical from start to finish, requiring neither chemicals, water nor crushing finer than about 6 mesh, which means that fine grinding, the costliest operation in particle size reduction, is eliminated. For these reasons an asbestos mill should operate cheaper than almost any other treatment plant if soundly designed and constructed.

Basically the problem of milling was solved about five years ago by Hancock, using a home-made plant built from scrap iron. Since then many improvements have been made and no doubt many more will be made in the future.

The mill at Wittenoom is quite well designed and its construction in the face of many war time difficulties was well done. One of its chief faults has been that insufficient attention has been given to the eradication of dust, which has been treated as an after-thought. When there is no flow of air in the gorge, which does not occur very often, dust conditions in the vicinity of the plant have been terrific. Appreciable time and money have been spent lately on the problem, but efforts were based on wrong principles. A slow current of air distributed over a large area is the principle on which collection of dust from all machines must be based. When this is carried out, and it can be done easily and cheaply, the dust nuisance will disappear. In any dry crushing plant the dust menace must be accepted as a major principle of design, and not as an after-thought.

In the mining method proposed, there are no ore chutes underground, so that it is difficult to arrange for any underground storage of broken ore on which expenses of double handling are not incurred. Mill bins therefore provide the only storage which complies with this requirement. If the mill is to be run over the week end, the bins should have enough capacity to hold six shifts and preferably seven shifts dirt, taking into account the fact that the five day week underground will probably shortly become law.

This calls for a capacity of 465 tons based on a 30 day month milling seven days per week and three shifts per day. Only a fraction of this capacity is now available and the mill has a coarse ore bin only with no fine ore bin after the primary

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crackers, which besides furnishing storage, would give a much steadier flow of feed to the machines to assist in high percentage recovery.

Most metal mine mills of any size operate on a seven day week and three shifts per day. Week end work is costly and the reason for accepting this expense is that the processes are disturbed by shut downs, causing losses that outweigh the extra outlay. This does not, however, apply to the milling of asbestos, which can be stopped and started at any time without any serious disturbances. Whether a plant works at the week end or not depends entirely on whether the extra capital outlay is justified to build a larger mill capable of the same throughput in five days a week, as a smaller mill operating seven days per week.

The fibre bearing rock is hard, brittle, and very abrasive, causing much wear in machines, particularly the rolls. Much of the rock in mill feed contains no fibre whatever, so that when milling costs are established, the question of the capital expenditure and operation costs on a hand picking system will have to be examined in relation to milling costs. Only a rough sorting can be done underground if stoping is not to be seriously delayed.

In an expansion of operations, expenditure on the disposal of mill waste must be envisaged. Present facilities are inadequate and a conveyor will have to be erected to dump waste in the creek below the plant, from where it will be washed away when the annual rains come, which is usually between January and March. Contamination of the present water supply will probably arise from large scale disposal of mill refuse in the area, and domestic water will need to be drawn from further up the gorge.

POWER HOUSE.

The existing plant was built up during war time from any material that became available. Recently one of the prime movers, a secondhand machine, was out of action for five months. Such delays are crippling and could not be countenanced in any attempt to put the mine on a profit making basis. Consideration must be given to the almost complete re-equipment of the power house as soon as engines become available.

You will recall that it was shown in connection with Blue Spec that power costs were extremely high due mainly to the high first cost of crude oil and the heavy transport charges that accrued in getting the oil to the mine. Similar conditions are associated with power production at Wittenoom. The oil is brought by boat to Point Samson , whence it must be freighted by road to the mine, a distance of 200 miles. To combat high prices brought about by handling oil in small lots, it was suggested that Blue Spec, Comet, and Wodgina combine either their own resources or in an approach to one of the major oil companies with the object of erecting a tank at Port Hedland of a capacity equal to that of the smallest oil tanker, or about 2,000 tons, which would supply each minefor twelve months or more and cut costs appreciably. The idea would be equally beneficial to Wittenoom since it appears that their oil consumption may later be of the order of 3,000 tons per annum. If a tank of this size could be erected at Point Samson a 5,000 ton tanker could fill both tanks. A very large road tanker or two smaller ones would then be employed full time in transferring oil to the mine.

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Surface workshops will need extension since the mine must be self sufficient, so far as is economically possible, in the matter of maintenance and heavy repairs.

TRANSPORT.

As in all isolated areas, this item will figure prominently on any cost sheet. At present freights are handled by Barrett and Radley or Tsakalos of Roebourne. They have modern and efficient trucks and their price, which from memory is £4 per ton, is reasonable.

In the propounded expansion 896 tons of fibre would go into Point Samson, while perhaps 500 tons of oil and general merchandise may come out as back loading, representing an expenditure of roughly £5,000 per month, though the contractors would probably reduce their price. It is reasonable to assume that they operate at a profit, and the economic position is such that if there is any profit in any phase of the operation, it should be sought by the producing company. The question of company operated trucks must be gone into if the scale approaches that comtemplated here. Considerable saving may be possible by the use of trucks of 40 tons capacity, as are quite common overseas. Since the round trip would not be done in less than three days, it is clear that at least three such vehicles would be kept fairly busy. The purchase of these vehicles would imply appreciable capital outlay, which may be beyond the means of private contractors, but within the reach of the company. The alternative is a fleet of smaller trucks with probably higher operating costs.

Much money has been spent on the road between the mine and Roebourne and it was in very good order 2½ months ago. It traverses some very rough country, which causes it to deviate some 40 miles to make the descent from the Tableland to the Roebourne coastal plain, which is done down a hill four miles long. The negotiation of the hill on the outward journey from Roebourne is a severe strain on a loaded truck, and two of them have been destroyed on it to my knowledge. For some time it has been proposed to cut both this hill and the extra 40 miles out of the journey to Point Samson by the construction of a new road. The proposed route is through very rough country and the job would be a costly one.

If Australian Blue Asbestos Limited are to spend further large sums in an attempt to expand to the point where freights of the magnitude indicated are to be handled, they would be entitled to press the Government for the completion of the new road, and for continuous maintenance between the mine and the port. The use of large trucks on a short route well maintained or possibly bitumenised would bring costs down to a minimum. The Government, however, would need substantial assurances of the continuity of any operation which calls for heavy expenditure on their part.

The indifferent performance to date must be attributed to the war, which brought shortages and high costs of labour, shipping and road transport, equipment, and supplies, and some of these handicaps would still have been insuperable even if administration had been more experienced. The position can be retrieved, but it should be apparent that much capital expenditure must be incurred, and it should also be remembered that all of the above difficulties still exist in some measure, though they are gradually being alleviated.

Delivery dates for heavy machinery as would be required for the power plant seem to be very indefinite. The labour position is much better than it was, but even when labour is plentiful, good men are always scarce in out of the way places, and companies operating in such districts must be prepared to spend money on social amenities. Between 200 and 250 men would be on the payroll, but a new mining community takes a long time to

assume a settled character, which is brought about only through the family unit. The sooner a townsite with school and the usual facilities of everyday life is established, the better will be the chance of steady progress. The welfare side of the undertaking has been entirely in the hands of the company and their performance in this respect compares more than favourably with that of other mining communities which were brought together in the North West during war time, but further recreation facilities must be afforded to single men.

It is certain that more capital must be provided if the profit making stage is to be approached. Taking into account the unsettled conditions at the moment, any estimate of the money required would be at this distance mostly in the nature of a guess, and the guess is £250,000. The question of what ultimate costs can be expected is also subject to the same instability, but significant points of comparison with other mines are worth recording.

The cost of breaking ore underground is a function of the mining width, the hardness of the rock and the scale of operation. At Wittenoom the proposed scale is in our favour, but the other two factors when compared with the average gold or base metal mines, are fairly unfavourable. On the other hand gold and base metal mines invariably require exploration for which a figure of 2/6d. to 3/6d. per ton ore mined is commonly allowed. No exploration of any kind is likely to be needed in the Hamersleys.

All other mines of similar size encounter water in the workings and pumping costs are continuous, involving appreciable capital outlay and often much overtime work in the week ends. The asbestos can be worked for many years without ever meeting with any water in the workings.

A metal or gold mine in which 21,000 tons of rock per month were broken would need a large set of poppet legs, a man-cage winder and a skip winder, the capital cost of which would be of the order of £30,000. A shaft about 20' x 7' would also be necessary, which to sink, timber and equip with ladders, stages and ore pockets, would cost some £30 per foot. None of this outlay is to be met with at Wittenoom.

In asbestos milling, no water is used, but this is offset to a small extent by the need for efficient dust collection apparatus, which, however, if properly installed, calls for less power than would be required to pump water to a wet milling plant. The mill uses no chemicals, which are expensive and scarce, and are required by most modern extraction processes for gold or metallic ores. Fine grinding, the chief cause of high milling costs, is not needed.

Realisation charges will be higher on the fibre than on any gold, or most metals, with the possible exception of those requiring smelting.

Referring to sketch No. 1, it can be shown that by the time that the panel has been stoped and not accounting for any ore in any of the pillars, about 270,000 long tons of ore will have been won containing 13,300 long tons, or 14,900 short tons of fibre. Indications are that total fibre losses in the mine and the mill will be 20%, so that 11,900 short tons of fibre will become available for marketing.

The total cost under normal conditions of breaking ore underground and hoisting it to the surface of our larger gold mines has been about 9/- per ton. Allthings considered, at Wittenoom, 21,000 tons of rock should be able to be broken, and 6,000 tons taken to the mill for 15/- per ton, when conditions

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become normal, and the 6,000 tons should be capable of being milled for 15/- per ton. Costs would then be as follows -

	Cost per ton	Per long ton of rock broken
Rock broken - 21,000 long tons	15/- long ton	15/-
Ore milled - 6,000 long tons	15/- long ton	4.28
Freight Fremantle - 896 short tons fibre	137.6 short ton	5.87
Fremantle to Sydney - 896 short tons	63.6 short ton	2.71
	Total	27.86/-

Thus fibre could be landed in Sydney at a total cost of some 28/- per ton of rock mined, which on 270,000 tons per panel for 11,900 tons fibre works out at £31.6 per ton of fibre, not taking into account fibre to be won from barrier pillars.

The freight figures are taken from the Yampire investigation and show clearly the necessity for trying to cut down on realisation charges brought about by high freight costs.

The scale of operations contemplated by the company is not known, so that the one envisaged here is somewhat arbitrary, but it is certain that the larger the output, the lower the costs. Up to a point this company is not affected by the difficult question of marketing, which will probably frighten off other powerful groups not heretofore interested, but who were recently toying with the idea of asbestos production. My own opinion is that if a scale of the order of 3,000 tons per month could be approached, the undertaking would stand any competition on a world market. The contention is that full mechanisation in the hands of relatively few average white men, and carefully supervised by even fewer men of above average intelligence, will prove less costly than the use of large numbers of natives employed at a wage of a few pence per day to do inferior work by archaic methods. The latter is apparently the systemin the Cape Blue deposits, which seem to be the chief competitors in the blue asbestos field. It seems that the relative magnitudes and values of the South African and West Australian deposits are similar. The strong competition from white fibre, in the field in which both white and blue can be used for the same purpose, is based on Canadian mechanisation of particularly large deposits, and not on native labour.

The financing of a production of 3,000 tons per month is well within the resources of the Colonial Sugar Refining Company and would of itself give rise to cheaper fibre, particularly when produced by the one company. Clearly, very large outputs will be up against the marketing problem in part at least, and if rock bottom costs are to be attained, a monopoly of production is necessary. Many people, including the writer, do not favour monopolies, but there are exceptions which prove every rule. In the event of very large expansion, apart from savings on mining and milling costs, freight charges would be reduced by the chartering, or even purchase, of shipping for delivery, and the possibility of damming of one of the narrow gorges for the supply of water power would be worth investigation. However, much water must flow under the bridge before a drop runs over a wall in the Hamersley Ranges, but we are dealing with one of the world's major mineral deposits, for which long range ideas, even if only tentative, must be on a commensurate scale.

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SUMMARY.

1. Check up on advisability of further benching from the gorge faces.

2. Institute systematic methods of ore breaking based on experience of large scale mining. This is the key to the problem.

3. Mechanise as far and as soon as possible, but be careful in choice of equipment.

4. Expansion of output to the highest desirable degree.

5. Extend power, workshop, milling, general facilities, in line with expansion of production.

6. Bulk handling of fuel oil should be gone into to save freight.

7. Efficient and continuous operation will justify the claim for a shorter and better road which will cut realisation charges.

8. When production is ahead of demand, fibre may be able to be stored and a boat chartered for freight direct to Eastern Ports.

17th September, 1946.
CFA/PT

DISTRICT INSPECTOR OF MINES.