

UNDERGROUND MINING MECHANISATION AT ROAN CONSOLIDATED MINES SINCE 1965

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ABSTRACT

A brief description of the ore deposits at RCM's two large underground mines at Luanshya and Mufulira is followed by details of the main mining methods used immediately prior to mechanisation and at the present time. The objectives of mechanisation are listed together with additional benefits that have accrued. Experience with various types of mechanised mining equipment, loaders, trucks, drill rigs and raiseborers is described as are the steps taken to speed up ground support. The article concludes with a description of ventilation, underground maintenance, tyre usage and training.

INTRODUCTION

Roan Consolidated Mines (RCM) operates five copper mines together with concentrating, smelting and refining facilities for a primary refined production capacity of 320 000 tonnes copper per year. Sixteen million tonnes of ore are milled annually and of this 91% comes from three underground mines, Luanshya, Mufulira and Chibuluma. The other two mines, Chambishi and Kalengwa, are mined by open pit methods. RCM's remaining ore reserves at June 1971 were 310 million tonnes at 3.00% copper. Luanshya and Mufulira rank among the world's largest underground mines. Copper production commenced at Luanshya (then Roan Antelope) in 1931, at Mufulira in 1933, and at Chibuluma in 1956. Two new underground mines, Baluba (close to Luanshya) and Chambishi are being developed to produce an

additional 46 000 tonnes copper per annum from 1973. RCM currently employs some 23 000 people.

LUANSHYA OREBODY

The Luanshya deposit is a synclinorium of sedimentary beds in the form of a basin, which is underlain and completely surrounded by much older schists and granites (see fig. 1). This basin is some 22 km long, up to 8 km wide, and some 1200 m deep. The ore formation, an argillite, lies near the base of the sediments and is underlain by conglomerates, quartzites and arkoses. Economic ore occupies a position roughly in the middle of the argillite and varies in thickness from a few metres to 18 m with an average of 8 m. The hangingwall and footwall are both arbitrary and determined by copper content. Chalcopyrite, bornite and chalcocite are the main ore minerals and occur disseminated in the argillites. From the eastern outcrop a slightly overturned syncline plunges westwards reaching a depth of 800 m before rising and being compressed into a number of very tight attenuated folds between two granite buttresses. Further west the folding becomes more complicated and a large drag fold develops on the south limb. This drag fold in pitching north-westwards develops several other minor folds. Further west again the folds open out into a wide synclinorium with the north limb developing several drag folds as it swings eastwards into Baluba where another smaller synclinorium is developed. The ore horizon is best developed on the south limb of the

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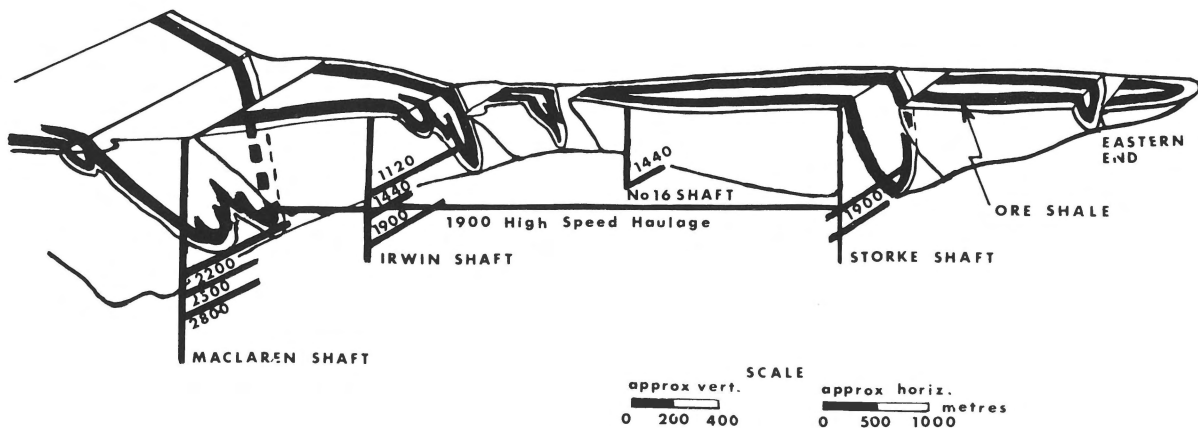


Fig. 1
Idealized Block Diagram – Luanshya

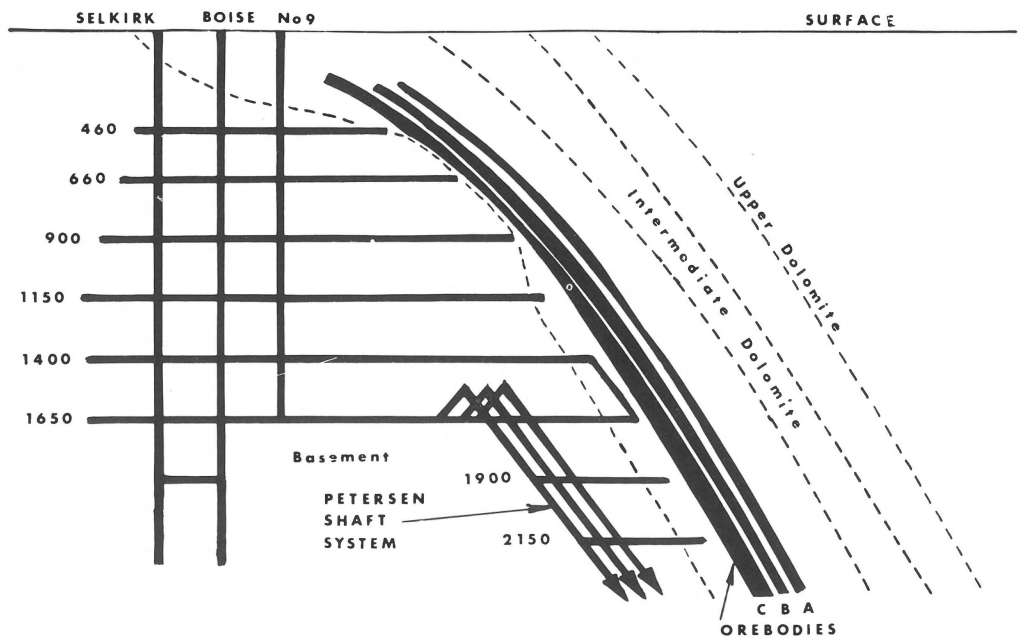


Fig. 2
Section through Mufulira.

syncline and is mineralised for 9 000 m along strike. The ore reserve grade is 2.71% copper.

MUFULIRA OREBODIES

The mineralisation in the form of disseminated chalcopryrite, bornite and chalcocite occurs in three superimposed horizons known as the A, B and C orebodies (see fig. 2). These orebodies have a general dip of about 45° to the northeast, but in folded areas this dip can vary from horizontal to vertical or overturned. The lowermost or C orebody is the largest of the three orebodies and persists over a strike length of 5500 m and has an average true thickness of 14 m. The middle or B orebody overlies the eastern portion of the C orebody for 2700 m and has an average true thickness of 11 m. The A or upper orebody also overlies the eastern parts of the B and C orebodies over a strike length of some 1800 m with an average true thickness of 9 m. The host rocks are grey, glassy quartzites, arkoses and dark-grey graywackes; the inter-orebody beds are composed of white and pink quartzites with minor dolomite and shale bands. The ore reserve grade is 3.16% copper.

OUTPUT

Luanshya mine is equipped for a monthly output of 540 000 tonnes of ore at a grade of 1.7% copper, Mufulira mine for 730 000 tonnes ore at 2.5% copper and Chibuluma for 55 000 tonnes ore at 4.2% copper. All main shafts are located in the footwall in good ground conditions, and main levels off these shafts are spaced at vertical intervals of approximately 80 to 90 m. The lowest production levels at the large mines are currently at about 650-700 m below surface.

PREVIOUS MINING METHODS

At both large mines the dolomites of the hanging-wall beds are heavily water-bearing over the entire strike lengths of the orebodies. The water occurs in the weathered portions of the dolomites and the depth of weathering persists in some areas to 600 m and more below surface. As the mining methods involve the mass caving of all the beds above the

orebodies after they are mined, it has been and still is an essential prerequisite that all the hangingwall beds are drained at least to the predicted line of cave of the lower mining level in order to prevent large quantities of uncontrolled water breaking through into the mine workings. This drainage is achieved by large diamond drillholes and crosscuts.

Drainage apart, there is not much similarity between the two mines. Luanshya is characterised by:

- (a) narrow orebody widths over long horizontal distances;
- (b) footwall and orebody rock strengths which are variable and generally tend to be weak, necessitating extensive support;
- (c) weak hangingwall rocks which break prematurely and dilute the ore;
- (d) extensive areas where the orebody has been subjected to intense folding.

In direct contrast to these conditions, Mufulira is characterised by:

- (a) superimposed orebodies with large orebody thicknesses over a relatively short, concentrated, strike length;
- (b) very competent rocks, footwall, orebody and hangingwall, which permit the development of openings of large cross-sectional area requiring little or no support.

These two features of Mufulira invited the introduction of the latest mechanised equipment. Mufulira's success encouraged Luanshya, with its poorer ground conditions, to follow suit.

In the early 1960's Mufulira employed two main stoping methods, block caving and sublevel open stoping, with each method accounting for half of the total production. Block caving was used in the eastern part of the mine, where the three orebodies were superimposed, the B and C orebodies, together with the low grade inter-orebody combining to form a true thickness of ore of 30-36 m. This thickness prevailed over a strike length of some 1500 m. A block was defined as 61 m along strike and some 76 m up dip, the latter being the distance between the main haulage levels. Sublevels were at 7.5 m vertical intervals and this fact, coupled with the small cross-section, precluded economic mechanisation of the mucking operations, which meant that the time required to develop a block was two years. Extraction

of the ore took place through drawpoints on a 10 m x 10 m pattern in the footwall and ore was passed either through grizzlies into a branch orepass system or scraped along strike to a central block orepass. The monthly output per block was 36 000 tonnes and productivity was low. Two factors led to the decision to abandon this method of mining:

1. neither the development layout nor the extraction method lent itself to any high degree of mechanisation;
2. the physical attitude of the orebodies, vertical and in some places overturned, in the new caving areas would not suit a block caving method, as fewer extraction points would have meant reduced monthly output per block.

Sublevel open stoping at Mufulira in the early 1960's consisted of one of two methods dependent on the dip of the orebody, the thickness of the orebody and the nature of the hangingwall which governed the pillar interval.

Conventional sublevel stoping was used where it was necessary to use regular rib pillars either to control the hangingwall caving or to allow the stopes to be sandfilled; the dip was less than 40° and the ore width in excess of 14 m. This variation used two, three or four chain (or crown) pillars down dip between main levels. Chain pillars were 9 m thick and rib pillars up to 6 m wide along strike. The strike and back lengths of the stopes were varied dependent on the dip and competence of the orebody. On the eastern side of the mine it was possible to carry stopes along the strike of up to 55 m over a back length of 91 m whilst on the western side of the mine stope strike lengths were limited to 25 m and back lengths limited to 37 m. Rarely did the monthly output exceed 9 000 tonnes ore.

Continuous retreat open stoping was used mainly in the A orebody, where a very competent hangingwall allowed for large areas of unsupported hangingwall to stand without danger of dilution of ore in drawpoints close to the advancing stope face. The dip was greater than 45° and the ore width was 6 to 17 m. This variation used two or three chain pillars per main haulage level. Back lengths varied from 25 m to 90 m. Following slotting at one end of the stope mining proceeded continuously along strike for distances of 30 m to 183 m before a rib pillar was left. Chain pillars of 9 m on dip were blasted out in

sections along strike to allow the hangingwall to cave sufficiently far behind the mining faces to prevent excessive waste dilution in the working drawpoints. The stopes were laid out with such strike lengths that before hangingwall caving occurred a rib pillar had been left and a new stope started. The production rate was 22 000 tonnes ore per month.

At Luanshya the mining method used was sublevel open stoping with regular pillars with variations to suit local conditions, particularly where the orebody was flat or highly folded. The back lengths of the stopes varied from 30 m to 91 m with a strike length of 12 m to 18 m. Rib pillars of 6 m were left along strike between stopes, due to the weak nature of the ground. Crown (or chain) pillars of 9 m were left to prevent dilution from the old mined out stopes above. After a stope had been taken out the rib and crown pillars were blasted together. Once these pillars had been taken out, caving of the hangingwall followed, often to surface. Extraction was by means of grizzlies and stope chute boxes. The production rate was on average 20 000 to 30 000 tonnes ore per month.

OBJECTIVES OF MECHANISATION

In summary these were to reduce operating and capital costs, increase productivity and minimise dilution whilst maintaining the same or better mining recovery. These objectives are common to many mining improvements and it is therefore considered that some details, particularly relevant to RCM mines, merit further comment.

1. Labour costs, in common with most developing countries, have increased rapidly.
2. The mines have high labour overheads as they provide a considerable infrastructure of housing, hospitals, roads and training establishments.
3. The labour force's aspirations are towards increased responsibility and versatility and away from unattractive manual work.
4. Concentrated production by using multi-face continuous retreat mining was required by Mufulira to increase its copper production, whilst at Luanshya it was required to maintain its copper production from the fewer numbers of stoping faces available and large tonnages available only from flatter dipping sections.

5. Luanshya required to minimise costs in order to remain competitive with its low grade and mining conditions which were becoming increasingly complex.
6. RCM wanted to minimise manpower on non-productive work, such as the installation and maintenance of grizzlies and loading chutes, and development cleaning.
7. RCM wanted to concentrate supervision and technical requirements to hasten Zambianisation.

Most of the objectives have been achieved. The cost benefits, however, are difficult to quantify as a result of rising inflation. In addition to those expected, several other major benefits have resulted, namely:

- i. The main access openings to a new stoping block can be developed and equipped with only a little knowledge of the geology of the block since;
- ii. There is now so much more mining flexibility in that:
 - a. variations in the dip or width of the orebody can be readily overcome by moving the extraction haulages up or down dip and from the footwall to the orebody or the hangingwall;
 - b. it has been possible to increase the rate of advance of stope faces along strike which has led to fewer major ground pressure problems.
- iii. The unproductive period, when no revenue is earned by the face, is minimised, since the major access openings can be developed in half the time it took for the old conventional method and consequently developed ore reserves can be reduced;
- iv. Stope faces can be designed for 15 to 20 m vertical intervals only instead of double or treble this interval with the old conventional mining methods.

MECHANISED MINING METHODS

Before the decision to mechanise further was taken in the mid 1960's, three steps had been taken which were essential prerequisites of any further mechanisation. The first important step was the introduction of crushers underground and the second

was the introduction of large capacity tramping cars underground. These two steps, coupled with the introduction of wider spacings on grizzlies and larger opening steel chute boxes enabled large rocks to be handled from the stopes to the shafts without detriment to hoisting capacity. The third step was the shortening of back lengths of stopes by:

- a. stoping out the block of ground between the grizzly level and the haulage floor, using tracked drawpoint loading, with Atlas Copco LM 250 loaders; and
- b. introducing intermediate haulage levels between the main haulage levels, particularly in the flatter dipping areas, and in areas of less competent ground.

The advantages of large rock handling and short backed stopes quickly became apparent in terms of improved recoveries and dilution. However, the difficulties, time and costs required to develop, equip and service intermediate tracked haulages prompted the search for a more efficient means of development and extraction from intermediate levels.

The mechanised mining methods at Mufulira are conventional sublevel caving, cascade, mechanised open stoping and longitudinal sublevel caving, whilst those at Luanshya are mechanised open stoping, open stoping with mechanised extraction and longitudinal sublevel caving.

Fig. 3 is a block diagram showing sublevel caving at Mufulira. Extraction levels are located at 15 m vertical intervals and are connected between main haulage levels by 12° inclined roadways located in waste below the footwall of the C orebody. These inclined roadways are provided every 500 m along strike. Each level consists of a slotting drive in the footwall of the C orebody, and extraction drive in the hangingwall of the B orebody and crosscuts connecting these two drives at 10 m centres. Orepasses and ventilation raises are provided every 60 m along strike in the hangingwall of the B orebody. All drives and crosscuts are 4.3 m x 4.3 m cross-section. Slotting is done along the footwall drive and retreat is along the crosscuts, en echelon to the hangingwall drive. A similar echelon is maintained between levels with the upper level being in advance of the lower level.

Fig. 4 shows different sections of the cascade method at Mufulira. Cascade provides for the com-

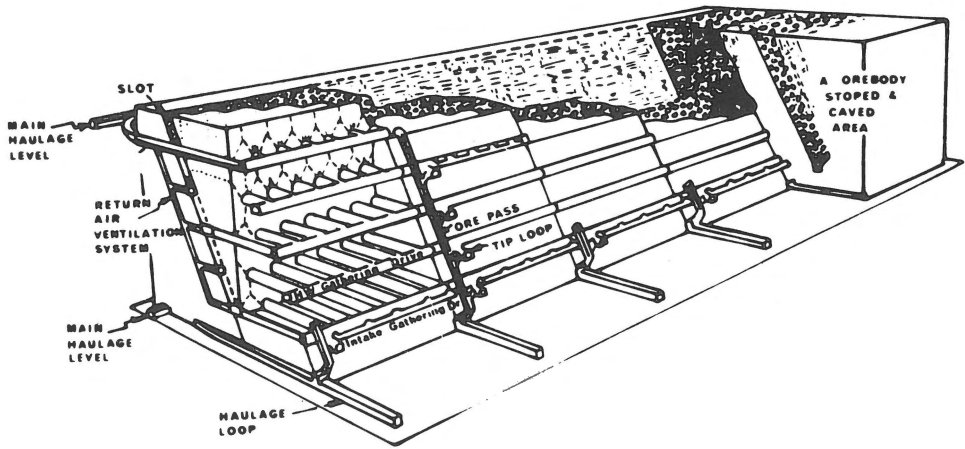
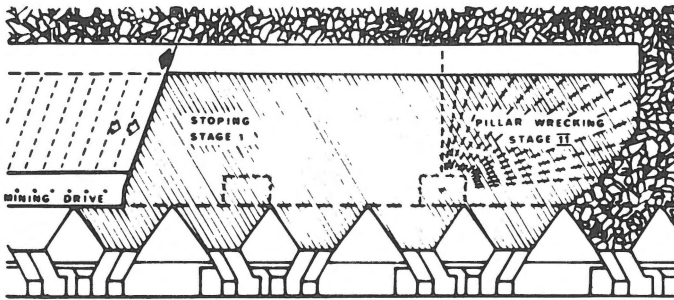
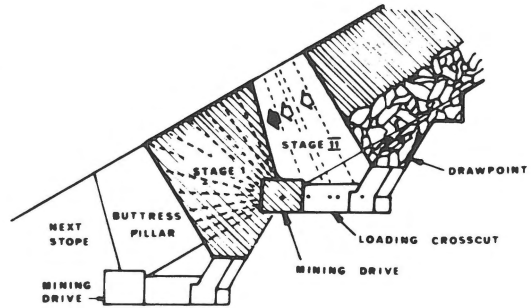


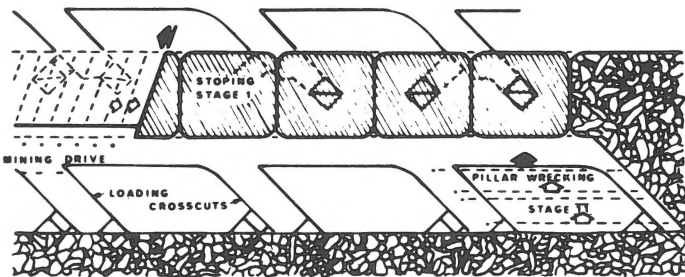
Fig. 3
Block diagram: sublevel caving: Mufulira.



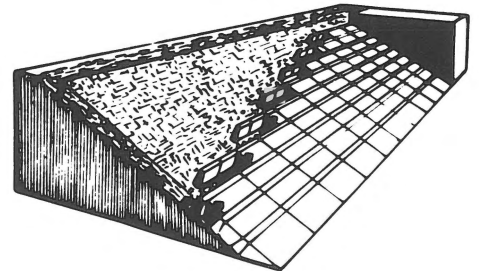
VERTICAL LONGITUDINAL PROJECTION



SECTION DOWN THE DIP



PLAN OF MINING DRIVE



PERSPECTIVE DIAGRAM

Fig. 4
Sections of cascade method: Mufulira

plete mechanisation of the extraction process. It is used in flat orebody areas and eliminates any necessity for stope scraping. The method has been fully described by Airey (1966). In brief, the area of the orebody lying between main haulages is divided into small stopes and associated pillars which make use of gravity by a reduction of stope back lengths and the creation of artificial stoping footwalls. The development headings are of large 4.3 m x 4.3 m, cross sectional area.

Fig. 5 shows mechanised open stoping as used in one of Luanshya's folded areas. At both Luanshya and Mufulira little difficulty was experienced in modifying the conventional sublevel stoping method to either mechanised open stoping or open stoping with mechanised extraction. The only difference between the two methods is that in mechanised open stoping all drives, i.e. drilling, troughing and extraction, are developed using trackless loaders and stope drilling is mechanised whilst with mechanised extraction, as the name implies, it is only the extraction drive development, and extraction that is done with trackless loaders, i.e. a half way step between the old conventional sublevel stoping and mechanised open stoping. At Luanshya extraction drives are 3.8 m x 3.4 m cross section with drawpoints spaced at 12 m centres. Drilling and troughing drives are 2.8 m x 2.8 m cross section. At Mufulira all drives are 4.3 m x 4.3 m cross section and drawpoint spacing is 10 m. Extraction levels are located to suit the dip of the orebody but are generally at 20 m vertical intervals, connected between main haulage levels by inclined roadways in the footwall of the lowest orebody. Tips are spaced from 100 m to 150 m apart depending on the quantity of ore within the area and on required production rates.

Fig. 6 shows longitudinal sublevel caving at Luanshya. This method is used to extract the block of ore between the old grizzly level and the main haulage level in areas where the orebody is steep and narrow and the main haulage was located in the orebody. After removing the tracks from the old main haulage a slot is cut across the orebody and caved ground is allowed to fall in as the ore is extracted. Blast hole rings drilled on 2 m centres from the extraction drive and an upper drilling drive are choke blasted against the caved waste. A complete break through to the old stope above is maintained at all times to provide a cushion for each ring to be blasted against. Pre-

calculated tonnage in stope rings enables a fixed number of scoops to be drawn before waste dilution reduces the grade to sub-economic limits. Close sampling is performed throughout the loading operation to aid draw control. Tips to the main haulage below are spaced at 120 m intervals. Generally two such faces are worked simultaneously so that drilling can take place at one face whilst blasting and loading takes place at the other face.

MECHANISED MINING EQUIPMENT

It has been recognised that the greatest cost benefits of mechanisation come from the loading, hauling, drilling, raising and ground support operations.

Loaders

The first large rocker shovel loaders were track-mounted Eimco 40H and Atlas Copco LM 250's introduced in the late 1950's. Many LM 250's are currently in use for major development cleaning and ore extraction using the tracked drawpoint loading method. Whilst these were used, many combinations of loaders and trucks were tried out on an experimental basis.

At Mufulira a crawler mounted loader in conjunction with electric shuttle cars for cleaning large development headings off shafts that were being sunk, was tried. In 1963 these were followed by a Joy Transloader used both as a lashing and production unit. Because of the possibility of major ventilation problems with large numbers of diesel units, experiments were conducted with a large electric rocker shovel mounted on crawlers, the Eimco 115E, with 8 tonne rear dump trucks as haul units. However, growing experience with the Transloader indicated that rubber tyred, diesel, load-haul-dump (LHD) vehicles would best satisfy mechanisation programme requirements provided ventilation problems could be overcome. After exhaustive tests of the then available LHD vehicles Mufulira decided to standardise on Caterpillar front end loaders as the development and extraction units. The stated advantages were:

- a. they were highly manoeuvrable and easy to operate;
- b. they were capable of moving the required 300 tonnes ore per shift;

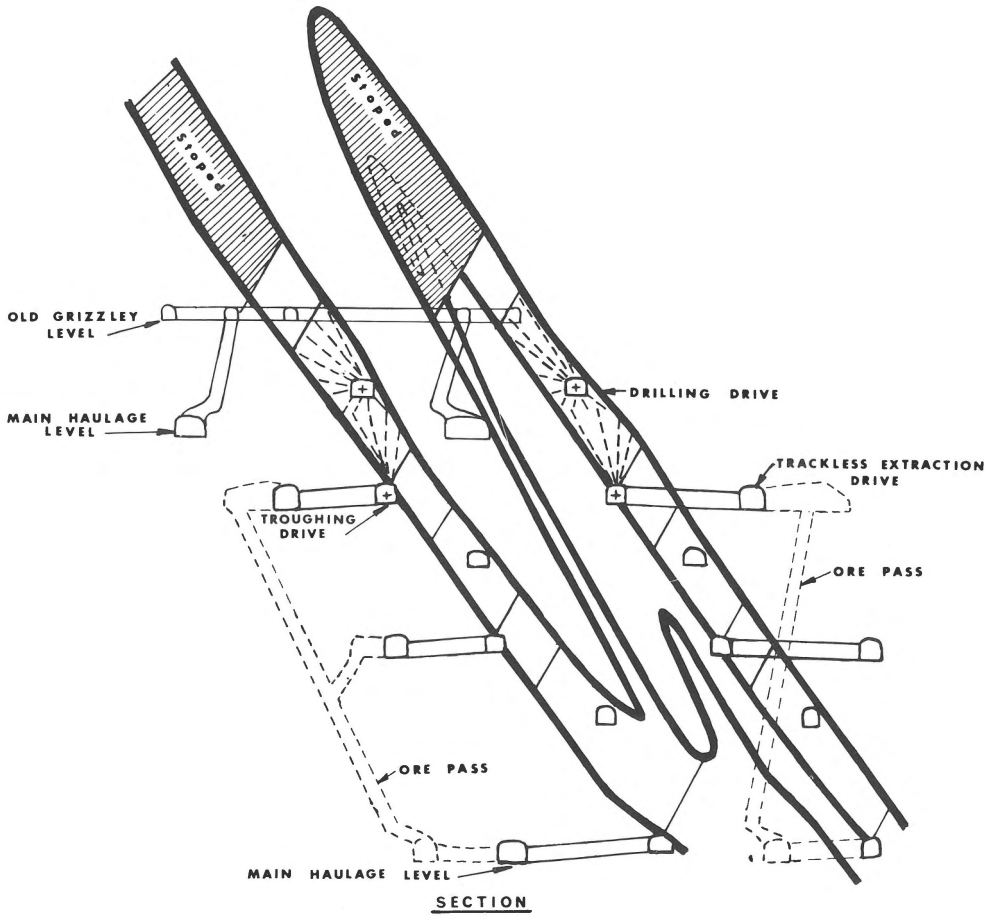


Fig. 5
Mechanised Open Stopping: Luanshya.

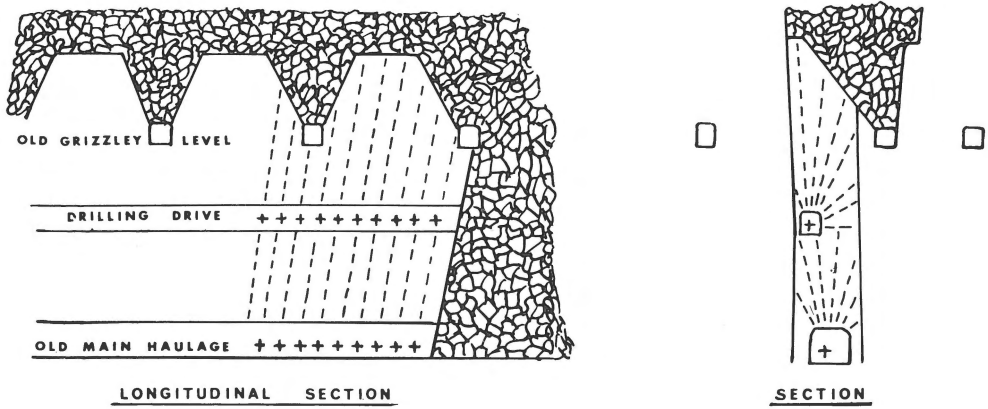


Fig. 6
Longitudinal Sublevel Caving: Luanshya.

- c. they could be used for both development and extraction;
- d. they were standard, well-proven vehicles backed by an efficient after-sales service.

Mufulira currently has 26 Caterpillar 950 loaders and 36 of the larger Caterpillar 966C loaders. Four of this fleet are used full time for training activities.

Luanshya embarked on its trackless loader programme in 1966. In the wake of Mufulira's exhaustive testwork, the Caterpillar 950 was the obvious choice for initial access development between main levels and extraction drives. About this time, however, large capacity, low profile, specifically for underground, LHD loaders of the Wagner ST5A and Eimco 916 type were coming onto the market. This, coupled with the necessity for timbering out after development in Luanshya's poorer ground conditions and the consequent hazards of using the high profile, Caterpillar 950's, in timbered extraction drives, prompted tests between three types of loader, the Cat. 950, the Wagner ST5A and the Eimco 916.

A low profile, high capacity, loader was deemed necessary in the timbered areas and the Eimco 916 was standardised upon as the production loader. As the model was a relatively untried machine a considerable number of modifications had to be made in conjunction with the manufacturers. The Eimco 916 is a 4.2 cu.m. capacity loader which will operate in headings of 2.7 m x 3.3 m. Recently several models have been adapted to take the 915H bucket of conventional one-piece design in place of the clamshell type bucket normally fitted to the Eimco 916, and the eight double acting hydraulic cylinders reduced to four by eliminating those on the boom and those used to open the bucket. The hoist and breakout cylinders have been increased in size and better positioned. As cylinders were the largest single cause of failures, machine availability and production capacity have both been increased by this move. There are 25 Eimco 916's at Luanshya.

Because of its speed, reliability and low costs the Caterpillar 950 has been retained as the major development loader and it is also used as a standby production machine. Its main disadvantage in Luanshya's conditions is its high profile with the machine itself standing 3.1 m high, i.e. 1.2 m higher than the Eimco 916. There are 25 Caterpillar 950's at Luanshya.

Luanshya has sought to keep the size of its drilling and troughing drives down to 2.7 m x 2.7 m, the minimum size for a Gardner Denver CH 123 drifter with 1 m rods. This has required the use of a third, smaller sized loader. Many suitable sized loaders have been tried out but only three types have met with any success. Of these the Wagner ST2B has been chosen. There are 12 ST2B's at Luanshya and 9 on order for Luanshya/Baluba.

At Luanshya three Atlas Copco 510 air powered, rubber tyred, loaders with hoppers have proved a success for large excavations such as pump stations and crusher stations and for medium sized development headings where the tipping distance does not exceed 60 metres. They have proved reliable and cheap but lack manoeuvrability between development areas.

Overall loader availability at Luanshya averages 80% and utilisation 50%. Loader availability has suffered from the lack of a ready supply of spare parts and this has become a major consideration in the choice of any new type of machine. Availability and utilisation are defined as available hours and running hours respectively, both expressed as percentage of shifhours.

At Mufulira extensive use has been made of the Atlas Copco 310 loader for the development of small drives over short distances such as ventilation drives and pillar access drives. In addition successful use has been made of the Cavo 520 machine in circumstances where the type of operation or duration of the operation has warranted neither the use of a Caterpillar loader nor the laying of tracks for an LM 250 loader. Mufulira's overall loader availability is 88% and utilisation 54%. Losses of availability are generally due to staff shortages.

Trucking

The maximum economic travelling distance of LHD loaders is generally taken to be about 300 m; beyond this distance it becomes more economic to use a combination of front end loader and dump trucks. There are two areas at Luanshya/Baluba where it has been decided to use this technique. The application at Luanshya is that of using long trucking/service ramps to mine 4 million tonnes of ore in the bottom of a trough, instead of using conventional tramming which would require a crusher station



Photo 1
An Eimco T20 truck on the Baluba main service incline.

currently located above the trough to be relocated near the bottom of the trough.

At Baluba an 8° , concrete lined, roadway connects the top three lines of stopes on the 80 m, 100 m and 120 m levels to surface. When development of this roadway using LHD front end loaders only became uneconomic, the loaders were used in conjunction with two Eimco T20, 17 tonne, rear dump, trucks. When stope development is ready it is planned to establish the top stope retreat faces by mining and trucking the ore to surface up the concrete roadway at a rate of 800 to 1 000 tonnes per 3 shift day.

Following an investigation in 1970 into suitable

makes of trucks, Wagner MTT 420's were chosen, 5 of which are currently in use and 3 more are on order. The Wagner MTT 420 is a diesel, rubber tyred, four wheel drive, truck with a telescopic body. It was chosen for its 18 tonne capacity, 2 m only height, its telescopic loading and dumping action which does not require any extra height, and because it can be readily loaded by all the front end, rubber tyred loaders currently in use. Its speed, loaded, on an upgrade of 8° is 5.6 km per hour. With the correct number of trucks, loading could be almost continuous.



Photo 2
A Gardner Denver stope drifter, skid drill rig.

Drilling

It has been found necessary to introduce mechanisation of drilling operations in stages.

For development headings the drilling for many years has been done by jackhammer-jackleg combination, with a timber platform being erected on pipe frame supports to enable the crews to drill the top half of the round. This method required considerable preparation and dismantling. As a halfway stage, meccano type supports and platforms carried in on the front end loaders were used and at Mufulira mobile drilling platforms were tried (flat steel drilling platforms on the backs of 8 tonne diesel dumpers).

Several types of large, self propelled, hydraulic drilling jumbos are currently being tried. A three boom Atlas Copco "Boomer" rig has proved successful at Luanshya, but too large. As any drill jumbo purchased must be able to drill all sizes of development to be economic, a smaller, Secoma, two boom rig is to be tried next. It is envisaged that, to be economic, drill jumbos will need to be operated on a three shift basis with fully mechanised support in scaling, charging and other ancillary operations.

At the new Chambishi underground mine, mechanisation of as many underground operations as possible is planned. The large size development headings required for trackless mining are being developed using the Tamrock MJM-21 three boom, self-propelled drilling jumbo. This rig is equipped with a cutboom and two RP 625 rotabooms. The outstanding feature of the rotaboom is its ability to drill parallel holes. Parallelism is obtained with a patented hydraulic system. As the boom moves up or down, a proportioning cylinder in closed circuit with the feed tilting cylinder, moves the feed to keep it parallel. No lining up is required once the first hole has been drilled.

Other units planned for use at Chambishi are self-propelled stope drilling rigs and automatic rock-bolting units. Cleaning of development headings and stope extraction is done with Eimco 915 LHD units.

Stope drilling is another field of operations which lends itself to further mechanisation. At Mufulira blast-holes are drilled with 114 mm bore Gardner Denver CH 123 drifters mounted on rigs arranged to slide on tracks. The machine cradles have provision for 2 m rod changes and are equipped with pneumatic rod support and coupling clamp which enables the

drilling to be done by one operator. These powerful drifters are capable of drilling up to 67 m per shift in the hard quartzites under ideal test conditions, but under normal operating conditions the figure is lower, the present average per machine shift being 48 m. A mobile hydraulic drilling rig equipped with two drifters mounted on 2 m cradles has been tried with limited success. The unit was propelled by an air motor.

At Luanshya, the further mechanisation of stope drilling has been slower than at Mufulira, but the future has been determined. The majority of the drills are 102 mm bore Gardner Denver CF 99 drifters. These are being phased out in favour of the larger 114 mm bore CF 123 and CH 123 drifters. As the number of drifters totals 250, this is a gradual process. Most of the drifters are bar mounted but successful experiments have been carried out using a CH 123 drifter fitted onto an old loader chassis with air powered crawler tracks to provide mobility. All new stope drills are to be locally put together and will consist of a CH 123 drifter gear-mounted on a bar, rigidly welded onto a steel platform on twin air-trac air powered crawler tracks. Twenty-five of these are being specially manufactured. The main advantages of this machine are that it can be quickly moved from hole to hole and from ring to ring by one man with a potential of 70 m per man shift.

Raiseboring

Standard methods of developing raises have always presented serious problems of safety, speed and cost. Mechanisation has shown enormous benefits in this area. Limited use was made at both mines of the Alimak raise climber, which increased efficiency and safety. Cage raising was used extensively until it was overtaken by raiseboring, although it is still employed for many openings in excess of 3 m diameter.

Raiseborers were introduced at both Luanshya and Mufulira in mid-1967, since when their usage has grown enormously. Today there are 3 Robbins 61R and 2 Robbins 41R machines in use and one further 61R on order. It is planned to phase the 41R models out in favour of 61R models. The 41R machines raise bore holes of 1.2 m diameter and the 61R machines holes of 1.8 m diameter. Many articles have been written on the subject of raiseboring. This

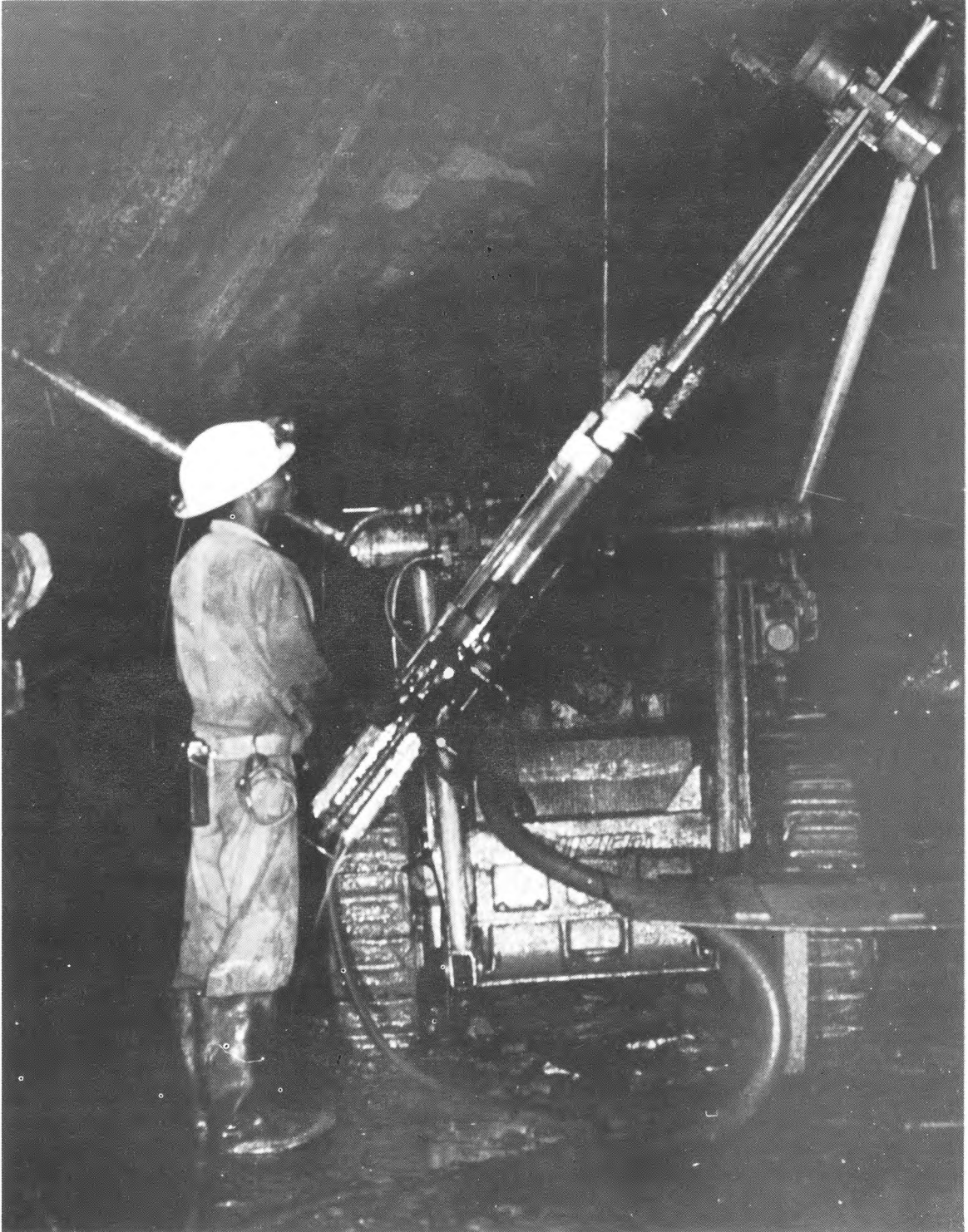


Photo 3
A Gardner Denver CH 123 stope drifter mounted on an Eimco 630 chassis.

article therefore has been limited to RCM experience only.

It has been found that both models will operate readily in ground of uniaxial compressive strengths up to 2461 kg/sq.cm. (35,000 psi). Drilling rates average 3.0 m/hour at Luanshya (2.5 m/hour at Mufulira) and reaming rates 0.6 to 0.8 m/hour at both mines. Because cutter costs represent some 40-50% of the stores costs and to minimise deflections during drilling it has proved beneficial to use Geograph recorders. These record continuously bit pressure, penetration rate, rpm and torque amps. The average hole length is 80 m and the longest hole drilled 184 m. It is now normal practice to raisebore most holes in excess of 25 m. Raiseborers have been used for:

- a. service, drainage and ventilation raises;
- b. internal rockpasses of 1.8 m diameter;
- c. main shaft rockpass systems developed subsized, requiring slipping;
- d. opening up new blocks of ground between main levels (group of 3 raises for use as ventilation raise, ore and waste passes) and to facilitate development of footwall service spiral;
- e. shaft deepening;
- f. submersible pump installations during a critical pumping period; and
- g. stope slotting out raises in near vertical, long backed stopes.

The following advantages have been proven:

- a. there is a vast saving in development time, raiseboring taking a third of the time of other raising methods;
- b. because of this time saving new areas can be opened much more quickly than before;
- c. incalculable savings resulting from increased safety;
- d. smaller cross sectional openings are required because of the circular shape and smooth finish;
- e. future raiseboring costs will compare more favourably with conventional raising costs, as labour costs inevitably increase.

Ground Support

Almost all of this section applies to Luanshya only with its poor ground conditions and complicated ore-body and not to Mufulira which requires very little

ground support. At Luanshya, ground conditions limit the size of openings, limit development and ore extraction rates, and consume a significant proportion of the labour force.

A rock mechanics section was formed in 1967 and the use of rock mechanics has progressed from the stage of being a specialist subject to being part of all stoping designs in the same way as geology and ventilation are. One of the first conclusions reached by this section was that too little use was made of rockbolts and too much use was made of timber as a means of support. This situation was reserved so that rockbolts now have wide scale usage and timber is installed only in very weak ground that is not self supporting and cannot be adequately supported by rockbolts. Special mobile rockbolting jumbos are planned which will have a drill and a rockbolt tensioner mounted on them. The drill will have a high rate of penetration and the bolt tensioner will be hydraulically controlled. Where conventional rockbolt anchors cannot be used, the polyester resin, Rocloc, which solidifies rapidly to bond the strata, is used in addition.

Shotcreting is meeting with increasing interest and there are now thirteen Eimco GH-17 machines in use. A large scale study was commenced in June 1969 to determine the most efficient shotcreting methods which were best suited to Luanshya conditions and to compare their costs and effectiveness with those of conventional methods of support. Shotcreting is the name given to the air spraying of a mixture of a fine aggregate, cement and water onto rock surfaces in varying thickness but usually 25 to 70 mm; the thickness depending on ground conditions. The conclusions of the study were: (a) shotcrete is a very effective support medium except in ground that is making water; (b) it is particularly effective with weathering and decomposed ground; (c) it is cheaper and quicker than timber support.

The attractiveness of shotcrete is that it offers greater opportunity for mechanisation than rockbolting, timber or steel support in that it can be a continuous support process compared to the cyclic nature of all the other support operations.

VENTILATION

The operations of heavy diesel powered equipment aggravates the normal mining problems of heat, dust

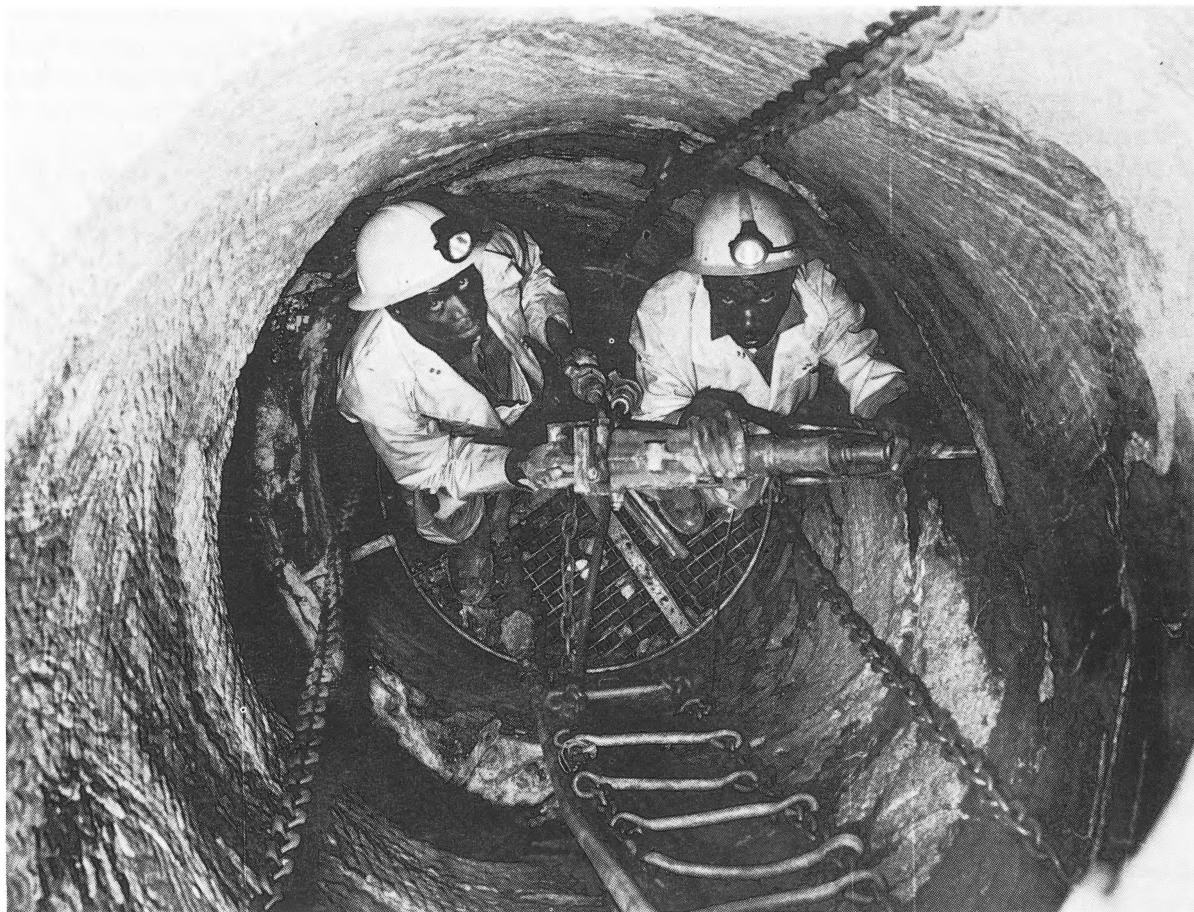


Photo 4
Collaring an intermediate station from a 1.2 m raisebored hole.

and gas control making an effective ventilation system a vital part of any mechanisation programme using this type of equipment. Conversely one important advantage stemming from the introduction of large scale mechanisation is that high tonnages can now be extracted from fewer mining faces, i.e. concentrated mining operations. This means an immediate improvement in air distribution, giving closer control and less air loss due to leakage.

Recommended standards of ventilation for diesel equipment underground vary considerably. Observations in the RCM mines have shown that the best criterion is air velocity with brisk air movement essential to avoid accumulations of gas, to control heat and to ensure a satisfactory environment. Minimum standards include 30 m per minute velocity in large deve-

lopments headings and a volume of 570 cubic m per loader. In all cases intake air is obtained from the inclined roadways or ladderway access raises and the emphasis is on the circulation of large volumes of air and brisk movement. Whilst large diameter auxiliary fans are used, ducting is minimised because of the ease of damage from blasting or the movement of loaders. In most of the mining methods used at Luanshya no special ventilation raises are required and foul air is returned through broken ground in the stopes to a main return airway situated adjacent to the upper main haulage level. In most of Mufulira's mining methods however, ventilation raises are installed at intervals along strike dependent on the method. All diesel machines underground are gasted regularly for carbon dioxide, carbon monoxide, nitrogen oxides and aldehydes, and special precautions are taken to render these gases harmless.

UNDERGROUND MAINTENANCE AND TYRES

At Mufulira eight workshops have been established underground whilst at Luanshya there is an underground workshop at the bottom of each major trackless mining area. These are located on the lower main haulage level adjacent to the inclined service roadway. Each workshop handles 6 to 10 vehicles. Workshops are provided with washing, servicing and repair bays and are fully equipped to handle all repair jobs except major overhauls which are done on surface. The main function of the underground workshops is to provide the maximum availability of machines and most repairs consist of the replacement of small parts or sub-assemblies. Sub-assemblies requiring repair are sent to surface. A few smaller workshops have been provided in areas where the vehicle population is less than five. A feature of all workshops is good ventilation and lighting. At Baluba one large seven-bay workshop has been provided on surface adjacent to the entrance portal of the main inclined roadway. It is planned that this one workshop will provide all facilities for the first few years of operations, including all features of the underground and surface workshops previously mentioned.

Many ad hoc studies have been made to improve machine availability and utilisation and thereby reduce costs. At the end of 1970 a special diesel team was introduced for this purpose at Luanshya. Its terms of reference were to:

- a. plan the maintenance of all diesel equipment;
- b. order spares, set and update stock levels, control and distribute tyres;
- c. lay down standards and standardise on modifications;
- d. analyse breakdowns and troubleshoot major failure areas;
- e. advise on layouts and maintenance facilities;
- f. advise on training and improve and maintain communications; and
- g. obtain, analyse and reduce costs.

As the largest single operating costs is that of tyres, considerable attention has been given to them. The yearly cost of tyres of RCM is 500 000 kwacha*

and at any one time there are 700 tyres in stock and a similar number on order. In the early days of trackless equipment tyre life averaged 300 hours; today it is three times this figure. The following conclusions have been drawn at Luanshya:

- a. continuous use of the correct tyre pressure is vital;
- b. tubeless tyres are preferred;
- c. the use of tyre chains is uneconomic;
- d. 12 ply tyres are preferred to 32 ply tyres;
- e. whilst smooth treaded tyres are preferred to obtain long life, super extra deep lugged tyres are necessary with wet and muddy ground conditions.

TRAINING

The introduction of mechanised mining has meant an extensive training programme for heavy equipment drivers, artisans, mechanics, junior and senior officials. This programme has been achieved over a period of three years and has involved the familiarisation of more than 300 officials and artisans and the training of more than 300 heavy equipment drivers and mechanics.

Following aptitude and physical fitness testing, trainee drivers undergo initial training on surface to familiarise themselves with the controls of the units and to achieve manoeuvrability of them in confined spaces. As the training areas are located on waste rock dumps, instruction is also received on loading techniques. The initial surface training period of two weeks is followed by four weeks' intensive training underground where experience of the confined environment is gained. Mechanic training takes the form of three months' lectures followed by three months of on-the-job training under the supervision of a qualified artisan. The same form of training is followed for progressions to higher grades of mechanics, there being four such grades. The introduction of mechanics underground has relieved skilled, mostly expatriate, artisans of the more simple aspects of their trade and enabled them to concentrate on the more technical work.

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* 1 kwacha = U.S. \$ 1.40.

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