CHAMBER OF MINES OF SOUTH AFRICA

RESEARCH ORGANIZATION

OBSERVATIONS AND SUGGESTIONS ARISING OUT OF A VISIT TO THE GOLD MINING INDUSTRY IN SOUTH AFRICA

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C O N T E N T S

PREFACE

In August, 1967, Professor John J. Reed of the Colorado School of Mines, Golden, Colorado, U.S.A., at the invitation of the Chamber, visited the mining industry and the Chamber's Research Organization. Professor Reed subsequently submitted a report consisting of a number of observations and suggestions, on various aspects of mining practice arising out of discussions with mine, group and Chamber personnel.

The observations and suggestions made by Professor Reed are presented by subject in a series of paragraphs, the order in which they are presented not being intended to indicate any order of importance.

Comments by the Directors of the Mining and Collieries Research Laboratories on each observation have been inserted in the text of the report.

/ SYNOPSIS

SYNOPSIS

Following a visit to the South African mining industry and the Chamber's Research Organization, the author has presented a number of observations on various aspects of mining and mining research in the Republic.

These observations relate generally to explosives, drilling, rock reinforcement, raise, tunnel and shaft boring, shaft sinking, rock cutting and longwall mining.

Comments by the Directors of the Mining and Collieries Research Laboratories on the author's observations have been inserted in the text.

EXPLOSIVES

1. In general, it appears advisable to soften the blasting conditions in both stopes and drives. In the stopes, excessive fragmentation may be resulting from the use of high-velocity explosives well coupled, and basically the same conditions exist in the drives, except that the undesirable result there is excessive cracking and weakening of the roof and walls. In the stopes, the high velocity explosives, coupled perhaps with insufficient control of the hole directions, results in bad roof conditions, especially over the gullies. The most direct approach to this problem would be the use of low V.O.D. explosives in long undersize cartridges to attain greater de-coupling, and therefore a softer blasting action. The relative costs of cartridge explosives vs. ammonium nitrate bulk explosives leaves me doubtful as to the ultimate advantages of the change to the latter (ammonium nitrate). Long cartridges of conventional explosives such as 24" lengths, would greatly alleviate the present problems in charging the large number of holes. In addition, the small cartridges could easily provide the desired de-coupling. In contrast, charging ammonium nitrate in bulk necessarily results in the highest possible coupling, and usually over-charging as well. Under the conditions of high vertical stress in the stope face, and probably vertical induced fracturing parallel to the face, it is quite possible that only the heaving action is necessary from the explosive in order to break this relatively pre-fractured material from the face, and the high velocity explosives presently used are simply causing over-fragmentation. When using lower order explosives, good stemming becomes relatively more important.

Comment by Director, Mining Research Laboratory:

Unnecessary damage to the rock around drives and stopes is certainly caused by overcharged and overcoupled holes, although this is only partially responsible for bad hangingwall

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conditions in gullies. The intense fragmentation around a hole can be regarded as useless work and the heave of an explosive, be it due to strain waves or gas pressure, can be regarded as useful work. The ratio of useful to useless work can be improved by using light charges (small diameter or decoupled) and short holes.

DRILL HOLES AND DRILLING

2. In general, smaller diameter drill holes seem to be indicated in order to improve the efficiency of stope drilling, both speed and cost-wise. This is probably especially advisable if bulk-loaded ammonium nitrate is in fact adopted. By using smaller hole diameters and lighter drill steels such as 7/8" Hex, it should be quite feasible to use somewhat smaller size drills and achieve the same penetration rates at much lower cost. A smaller diameter column of AN-FO will detonate at a lower velocity if it still detonates at all.

Comment by Director, Mining Research Laboratory:

Fundamentally, improved drilling efficiencies must be obtainable from narrow diameter holes and smaller machines where hand-held machines are used. ANFEX will detonate over a short length (less than 3 feet) of narrow diameter (25 mm.) hole.

3. In connection with improving drilling efficiency in the stopes, a simple rugged multi-drill carriage which could be dragged up and down the stope face by the scraper ropes seems worth investigating. The design of such a carriage should incorporate the utmost simplicity and rugged dependability, eliminating sophisticated components which are expensive and troublesome to maintain. A simple sled base plus two air cylinders extended against the roof could anchor

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the carriage. Four light rockdrills seem a reasonable number to try. Rather than a slide feed, either chain or screw-driven, which involves a motor and other complications, a simple air cylinder directly on the back of the rockdrill can be considered. Such a drill and feed has been a standard product of the Cleveland Rockdrill people, and hundreds have been in use for many years in the mines of the St. Joseph Lead Company. The air cylinder of this drill is clamped directly to a post, which in this case could be a short stub welded to sled base. The feed length of these machines should be sufficient to drill the desired hole depth with no steel change, and a rigid centralizer should be provided for collaring the holes easily in the desired direction. This carriage or sled could be dragged into position by the scraper ropes, in turn dragging a single large air and water hose behind it, which in turn could be fed off from a reel mounted on a truck in the strike gulley. All four drills on the carriage would remain connected to a manifold on the carriage, and thus only one air and water connection would be required in the strike gulley to put all four drills in operation. It seems quite possible that two men could easily operate such a carriage with its four drills, once in position.

Comment by Director, Mining Research Laboratory:

A simple multiple drill rig is potentially advantageous in regard to drilling rates, drilling pattern accuracy and drill steel life. Professor Reed's suggested design is being investigated.

4. The possibility of stope blasting by means of long holes drilled parallel to the face from the strike gullies poses many problems and these should be investigated. However, in view of the rough terrain conditions in the strike gullies, it would seem unlikely that a trackless wheel-mounted carriage for the long-hole drilling rig would prove practical. A

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simple post and bar-mounted rig on the other hand could be easily moved and mounted in its various components, and by using several posts and long bars along the length of the strike gulley, moving the drill along the bar once mounted should be relatively easy. Of course, as already recognized, keeping such long holes within the reef will be very difficult, except in rather ideal conditions of regularity in the reef itself.

Comment by Director, Mining Research Laboratory:

Long-hole drilling parallel to the face will find limited application because of the irregular nature of most reef and the near impossibility of maintaining reef drives in the region of high stresses ahead of most faces.

ROCK REINFORCEMENT

5. I believe that one of the best possibilities for major improvement in the techniques studied during this visit lies in the area of rock reinforcement as contrasted with present rock support methods. Implicit in this observation is recognition of the significance of active rock reinforcement vs. passive rock support. Inherent in the idea of rock reinforcement is the need to safeguard the inherent strength of the rock to the utmost, and then reinforce it as necessary and as soon as possible after the excavation. These observations apply most specifically to the support of drives, shaft stations, pump chambers, hoist chambers, etc. In reasonably sound rock there is mounting evidence and experience to indicate that sound rock faces treated to reasonable depth with grouted reinforcement will withstand subsequent loading, including blast loading analogous to rockburst conditions, just as well as, if not much better than, cast concrete linings, and at much lower overall cost. I believe the key and secret to the successful application

of this approach is to go all the way once the decision is made to reinforce rather than support, that is to say, plan the entire excavation and reinforcement to be completed immediately, and not try to reinforce the rock later as incipient failure develops and demands attention. Various types of rock reinforcement should be tested and compared, such as fully-grouted, deformed bars, both tensioned and untensioned, plus chain link mesh and straps covering the face, and in turn embedded in gunite or shot-crete. In general, I believe that there should be a trend towards the use of longer bolts than at present, especially in the support of the larger chambers. Even in the smaller drives bolts less than 6 ft. long seem inadvisable, and certainly in large chambers bolts of 8 to 10 ft. and longer are indicated. Recent tests in the United States have shown that relatively large tunnels reinforced as above indicated have shown a decided capability of maintaining passage under severe shock loading conditions analogous to rockbursts.

Comment by Director, Mining Research Laboratory:

Active support can go far to improve strata control in stopes, haulages and chambers. It is important that support be both active but yielding, to accommodate the virtually irresistible movements which take place. Rockbolts should be longer than those generally used up to now and they must be laced with some extensible network - heavy chains and straps are too stiff and tear themselves or the bolts. A good working rule for rockbolting is that the bolt length should be equal to the radius of curvature of the excavation surface or half its span; (relatively longer bolts are often required to supplement the shorter ones for roof support) and should be spaced between 1/3 and 1/2 the bolt length apart. Large diameter mild steel bolts are to be preferred to smaller diameter high-tensile bolts because they are elastically stiffer, can yield far more, and have superior corrosion resistance.

6. Attached to this report is a list of references on the general subject of rock reinforcement, and particular attention is called to the articles by Rabcewicz (25) and Land (11,12). In regard to the latter I would suggest the preparation of some rockbolting models such as described by Lang for demonstration and study purposes by Chamber and Group personnel. I have found such models to be very useful in convincing skeptics of the possibility of creating stable elastic rock structures from fragmented material by means of properly designed and installed bolting systems.

Comment by Director, Mining Research Laboratory:

Rockbolting models are interesting but of doubtful relevance to deep mine conditions.

7. On the general matter of pack supports, it is very important to apply the philosophy of high modulus supports (i.e: low compressibility) and pre-loading wherever possible. These two factors are inherently essential to effective rock reinforcement vs. rock support.

Comment by Director, Mining Research Laboratory:

I am sure Professor Reed must mean high-modulus, that is, rapid-bearing, but ultimately yielding supports. This suggestion is in line with the work on composite packs and pre-loading.

/ RAISE BORING.

RAISE BORING

8. The use of raise boring machines and long hole raises should prove very helpful in many of the conditions observed. The first application of the raise borer, where, in my opinion, success would be virtually assured, would be in the Kimberlite and the Lava formations at Kimberley. With experience there to build on, it seems quite possible to me that the machine's performance could ultimately be built up to where it could cope with the quartzites, although this will be no easy matter. Meanwhile, the development of long hole raise techniques should certainly fill the gap. (Paper by D. Markl, "Mines Magazine", March 1967, p.27).

Comment by Director, Mining Research Laboratory:

Boring machines for quartzites will come.

SLUSHER DRIFTS

9. With further reference to the problems of slusher drift maintenance at Kimberley, it would seem worthwhile considering the possibility of going to direct draw systems by providing more raises, and thereby eliminate the need for other than simple man traffic in the position of the present slusher drifts. Under these conditions, the slusher drift could then become a very small passage, thereby simultaneously greatly increasing the size of the remaining pillar, and such a drift might conceivably be supported by means of rock reinforcement, mesh, and shot-crete, as previously described. This possibility might very well depend entirely on a conversion to raise and tunnel boring techniques for the development of the entire block system, including the access drifts in the Kimberlite.

Comment by Director, Mining Research Laboratory:

I am in complete agreement with this suggestion.

TUNNEL AND SHAFT BORING

10. Considerable discussion has been on the application of tunnelling machines and shaft boring machines with respect to both the mining industry of South Africa and various tunnelling projects. In view of the rapid advance in tunnelling and boring techniques in the past 15 years, I am convinced that the next 10 years will see virtually all tunnels and many shafts driven by these methods. At this point in time, some rocks are obviously too hard for these machines. However, where only small areas of hard rock are interspersed with large areas of rock presently amenable to boring, combined methods should certainly be capable of development. There has been little effort to date to develop such integrated tunnelling systems with the built-in capacity to mine hard rock through or past the boring machine, and also to provide ground support or reinforcement where necessary as the machine advances. However, there is nothing fundamentally so very difficult about the development of such systems, and they should be attacked as simple design problems with existing technology.

Comment by Director, Mining Research Laboratory:

Tunnelling machines capable of handling hard rock are potentially feasible. Karroo dolerite happens to be one of the easiest hard rocks to cut.

/ SHAFT SINKING.

SHAFT SINKING

11. In the matter of shaft sinking it is very encouraging to note the success of the pre-splitting efforts at Winkelhaak No.5 Shaft. In view of the obvious advantages now recognized in this approach, it would seem appropriate to suggest some sort of mounted drilling rig in shafts, at least for the perimeter holes. Such a rig could easily incorporate provision for accurate alignment, and should accomplish the desired precision drilling much easier than trying to provide sufficient supervision on drilling by conventional hand-held methods. A rather simple 4-drill rig was displayed at the exhibition in Moscow recently. This unit had a capability of drilling holes perhaps 12-15 ft. deep in good alignment, and could drill cut and reliever holes as well as perimeter holes. Colored slides of this rig are enclosed. It included provision for changing the curvature of the row of 4 holes to fit the shaft diameter, and could be power tilted in or out from vertical. It also folded up enough to pass through a sinking stage.

Comment by Director, Mining Research Laboratory:

This comment should perhaps be passed on to companies engaged with shaft sinking and those making equipment for that purpose (Cementation Company, Shaft Sinkers, Wright Anderson).

ROCK CUTTING

12. Regarding one of the present Mining Research Laboratory projects, namely Project 301/66, Studies of Cutting Hard Rock From a Face, this appears promising and certainly worth carrying to prototype testing stage. It would obviously represent a major breakthrough if successful. However, a side value of no little significance would be that an extensive test of this approach should provide for the first time, by means of a precise bulk sample over a large fathomage, an

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accurate knowledge of just how much of the gold value is being lost due to extensive fragmentation and incomplete footwall cleaning.

Comment by Director, Mining Research Laboratory:

Professor Reed's intuition seems to have been right on the first score. Maybe the second aspect should also be examined.

LONGWALL MINING

13. With regard to the longwall project at Sigma Colliery, it would seem advisable to induce failure in the Dolerite sill at the completion of the present 300 ft. by 1700 ft. panel, if such failure does not occur on its own, and before proceeding to the development of a new and larger panel. Some knowledge of the mode of failure of this sill seems essential before proceeding further. By virtue of discussions with various individuals who have knowledge of the characteristics of these sills, it seems quite probable that a gradual type of failure may in fact be obtainable, but the uncertainty presently existing, and the possibility of catastrophic sudden failure, certainly indicates a need for clarification before proceeding to a larger panel. I feel the best possibility for induced failure in a more or less gradual manner is by means of hydraulic fracturing through boreholes from surface. If sufficient natural fractures do not exist in the Dolerite to make this effective, small charges in the boreholes in advance of water pressurization should assist. It might also be quite feasible to pre-split a large square of ground, such as 200 ft. on a side, and cause a plug to fail and drop, but I do not think this sort of sudden failure should be encouraged. It certainly is not the sort of continuing gradual failure one should seek.

/ Comment .....

Comment by Director, Mining Research Laboratory:

I think it would be a formidable proposition to put this suggestion into effect.

Comment by Director, Collieries Research Laboratory:

Professor Reed's observation concerning a gradual type of failure of the dolerite sill has now been confirmed to some extent. Recent observations over stooping sections at Durban Navigation Collieries, appear to indicate that the sill is subsiding gradually, layer by layer. These are the most reassuring observations concerning the behaviour of a dolerite bed over areas of total extraction.

GUNITE

14. With reference to the use of shot-crete, or wet-mixed gunite, three manufacturers have been located to date for this type of equipment.

A. True Gun-All Equipment
Eimco Corporation
Salt Lake City, Utah, 84110 U.S.A.

B. Sika Chemical Corporation (Aliva Machine, Swiss Design)
Passaic, New Jersey U.S.A.

C. Air Placo Company
Box 9601
Kansas City, Missouri 64134 U.S.A.

/ SMALL DIAMETER .....

SMALL DIAMETER BLAST HOLES

15. On the subject of drilling smaller diameter blast holes, it would seem worthwhile to experiment with single-use carbide bits with a taper socket connection on 7/8" hexagon or quarter octagon steel drilling a 1-1/4" hole. The steel could be an alloy type with the rubber collars and a taper turned on the lathe and perhaps spiral rolled, but with no use of forging, to eliminate the metallurgical notch. Alternatively, full length carburized rods with forged collars could be obtained from Gardner-Denver or equivalent, and these are undoubtedly the highest quality rods available. The bits are available from Western Rock Bit Company, 552 West 7th South, Salt Lake City, Utah, U.S.A., at about $4.25 each, and should drill about 80-100 ft. in quartzite before discard and without sharpening.

Comment by Driector, Mining Research Laboratory:

Drillsteel costs currently run at about 1 cent per foot. The cost, life and probable bit losses make detachable bits look expensive.

CHARGING AMMONIUM NITRATE BLASTING AGENTS

16. Regarding the use of ammonium nitrate underground, and especially pneumatic charging through long hoses between the placer in the drift and the blast hole in the stope, two references may be cited. One describes work at Inco, by J. McCreedy, and appeared in "Mining Engineering", November 1964, p.56. The second was by H.R. Hammond at Cominco's Sullivan Mine, Kimberly, B.C., and was presented at the AIME Fall Meeting, Salt Lake City, September 1963, but I have no reference to its publication. In addition, the Du Pont Company makes AN-FO placers which can be operated remotely by pneumatic controls by the man at the blast hole. These handle from 75 to 500 pounds of AN-FO.

/ SEALANTS .....

SEALANTS FOR ROCK

17. Regarding surface sealants for the rock, such as some shales, it seems possible that a simple impermeable membrane applied to the surface may prevent the transfer of moisture to or from the ventilating air, and thus prevent deterioration of the shale, which is often simply due to this so-called "air slack".

Some of the manufacturers who produce such surface sealants are:

Mine Safety Appliances Company (Rigiseal)
201 North Braddock Avenue
Pittsburgh 8, Pennsylvania U.S.A.

American Minechem Corporation (AL-1000 Sealant)
Coraopolis, Pennsylvania 15108, U.S.A. (E-771 Sealant)

Stonhard Company (Stontite)
Park Avenue
Maple Shade, New Jersey 08052, U.S.A.

American Cyanamid Company (Aerospray 52 Binder)
Post Office Box 672
Princeton, New Jersey, U.S.A.

Most of these are easily applied by spraying; some are water-base latex compounds.

/ APPENDIX.

APPENDIX

ROCK REINFORCEMENT
(Prof. J. Reed)

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