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MINING IN THE 21ST CENTURY

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ABSTRACT

The rate of advancement since World War II, in the field of electronics and microbiology (genetics) been exponential. The quantum leap experienced in the field of electronics caused by the, now-relatively-simple-to-understand device - the transistor, has changed the whole materialistic life of people. The impact of this development is so great on human life that there is no field left which does not have an electronic device. The sophistication achieved by this advancement is mind-boggling.

Although, mining is a late comer to this assault, the strides made in its application to equipment design is catching up with other commercial fields. It is not that mining engineers are slow to understand, or are very conservative, but mining by its nature is not so prone for adaptation. Mining has got inherent problems which do not allow the ready application of this sophisticated technology. Despite these drawbacks, tomorrows mines will not be recognizable to to-days mining engineers.

The concept of having a mine without a miner underground might seem far-fetched, but tomorrows mines will come close to that concept. A very high degree of automation of development machines, material handling and transport systems, environmental monitoring and control, mining methods requiring a minimal amount of ground control, mineral processing and total waste rock handling underground, fully instrumented mine to give full managerial support and even automated decision making using knowledge based systems will virtually eliminate middle management. Record keeping using paper and pencil will be obsolete. Electronic portable key pads or voice recorder will give direct input to interpreting machines eliminating manual data entry to computers. The whole mine will be displayed on large electronic screens to give underground superintendents up to the minute status of the mine. It will also form the communications centre for the whole mine.

If the present day mine engineers, mine operators, Government and university research organizations, mining associations, hi-tech companies and mine equipment manufacturers set such an objective, it is within the reach of Canadians to have such a mine.

Keywords: Future mining, hi-tech in mining, mine automation.

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L'EXPLOITATION MINIÈRE AU 21e SIÈCLE

J. Pathak*

RÉSUMÉ

Depuis la Seconde Guerre mondiale, le rythme de développement des nouvelles techniques électroniques et microbiologiques (génétique), a été fabuleux. L'évolution extraordinaire des connaissances dans le domaine de l'électronique repose sur la découverte du transistor, dispositif qui ne recèle plus de secret aujourd'hui, mais qui toutefois, a modifié de façon radicale le contexte matériel de la vie quotidienne. L'impact de cette découverte sur le mode de vie des êtres humains a été d'une importance telle que ces dispositifs électroniques ont envahi tous les domaines. Le degré d'évolution que cette réalisation a permis d'atteindre dépasse l'entendement humain.

Bien que la modernisation des techniques minières n'en soit qu'à ses débuts, l'application des nouvelles techniques à la conception de l'équipement a progressé à pas de géant et permis à l'industrie minière d'évoluer au même rythme que les autres industries. Les ingénieurs des mines possèdent le savoir-faire requis et la connaissance des techniques de pointe mais l'adaptation de ces dernières à l'industrie minière est ardue et lente en raison de problèmes qui découlent de la nature même de l'industrie et qui préviennent l'application rapide des techniques modernes. En dépit de ces difficultés, les ingénieurs qui oeuvrent dans les mines à l'heure actuelle auront peine à reconnaître les mines de demain.

Il est difficile de concevoir une mine souterraine d'où le mineur serait absent, mais ce concept est sous-jacent aux mines de l'avenir. La mine de demain sera dotée d'un équipement d'exploitation, de manutention des matériaux, et de systèmes de transport, de surveillance et de protection de l'environnement qui exigeront un contrôle minimal. Il en sera de même pour ce qui est des techniques de traitement des minéraux et de manutention des stériles dans les mines souterraines. Les mines seront dotées d'un équipement de soutien complet afin de simplifier la tâche des gestionnaires, et d'appareils automatisés secondés par des systèmes de bases de connaissances qui remplaceront les cadres moyens. Le maintien de dossiers au

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Mots-clé : exploitation minière dans l'avenir, techniques minières avancées, opérations minières assistées par ordinateur.

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moyen de crayons et de papier deviendra désuet. Des claviers numériques électroniques portables et des appareils d'enregistrement fourniront directement les données aux décodeurs éliminant ainsi l'entrée manuelle des données dans l'ordinateur. La configuration de l'ensemble du site de la mine souterraine apparaîtra sur de vastes écrans électroniques qui renseigneront les chefs de service sur la situation de la mine en tout temps. Ce centre automatisé deviendra le centre de communication de l'ensemble des secteurs de la mine.

La modernisation des techniques minières que cherchent à promouvoir les ingénieurs et les exploitants des mines, les organismes de recherche du gouvernement et des universités, les associations minières, les sociétés de technologie avancée et les fabricants d'équipement minier, est la pierre angulaire de la mine moderne canadienne de demain.

MINING IN THE 21ST CENTURY

Introduction

The number of technical advances made in the field of electronics and micro biology since the Second World War would seem to be increasing exponentially with time. The discovery of the transistor has had a profound effect on the materialistic aspect and aspirations of human race. No field of human endeavor has not been effected by the discovery of the device and subsequent solid state progeny. Home and leisure environments are now as greatly effected by advances made in electronics as are in industrial scientific aspects of most world societies. Today genetic engineering has reached the point where its possible impact on society is as worrying as it is profound.

Although mining is a relatively new comer to the use of high technology, considerable strides are being made in its use with respect to mine planning and new equipment design. The slowness with which high technology has entered the mining field should not be interpreted as an unawareness of the potential advantages of its introduction by mining engineers. Rather, it is mere realization of the difficulties associated with its effective applications. Despite the difficulties of its introduction, high technology is increasingly being used in mining operations and will make mining operations in the future unrecognizable in terms of todays operations.

In terms of the present level of mining technology, the concept of an underground mine without underground staff seems to be far fetched. It is possible that miners of the 21st century will approach that concept with very few underground workers. This will be made possible through a very high degree of automation of development machine, material handling and transport systems; environmental monitoring and control; the use of mining methods requiring a minimal amount of ground control, mineral processing and total waste rock handling underground and the instrumentation of mines in operational control based on knowledge based systems which virtually eliminate middle management. Paper record systems will be obsolete. Electronic portable key pads or voice recorders will be used to enter or receive data from computers data banks. Total mine operations will be displayed on large electronic screens to give and provide up-to-the minute status reports to underground superintendents. The display rooms will be the communications centre for the mine. The same information will be relayed and displayed on-line at the head or corporate office, which could be located on another continent.

However, in order that the Canadian mining industry can play a leading role in the development of the automated mine of the 21st century, present day mining engineers, mine operators, Government and university research organizations, mining associations, high technology companies and mine equipment manufacturers must establish the industries specific requirements and the potential ways they can be met.

The worlds future mining industry will be shaped by an economic curve of the type shown in the Fig. 1, (3). Whether, as an example, 1 kg of nickel is supplied to a customer by a 3rd world country using primitive mining technology or an advanced country using advanced mining and processing technologies will depend on their competitive ability to meet specifications and price (Fig. 2).

In May 1979, a futuristic series of articles on mining by mining engineers appeared in the Canadian Mining Journal. The mining of moon and asteroids were given consideration as well as ocean floor mining (4,5). Consideration was given to the possible development by the year 2000 of an open pit mine that could produce, handle, process and distribute 300 million tons of ore per year (Pilbara Mine 1). What has happened to some of these concepts which were so exciting in 1979, but on which little if any progress has been made. An economic curve of the type shown in Fig. 1 has dictated that they be put on hold until world economic conditions permit their pursuit.

By 1979, concepts were quite advanced on how the ocean floor could be mined by the end of the century. Mineral rights, jurisdictions and ownership of the ocean floor and their mineral deposits were subject of lively international discussion. The United Nations organized a Conference on Law of the Sea, (UNLOS) to tackle these problems and Canada was an active participant and signatory to documents resulting from the conference. By 1979, 5 consortia involving 24 companies located on 5 continents were engaged in research and development related to ocean mining. Sudbury, as a mining community highly dependent on nickel mining felt threatened by the activities of these consortia. One of the many articles on the subject in the journal was entitled : "Will Sudbury survive the impact of ocean mining?" (5). Today we know that the economic health of Sudbury and its mining industry is not so threatened by ocean mining as by the general market situation for base metals and competition for markets from the third world countries.

The author believes, the concept of ocean mining of mineral deposits will be reactivated towards the end of the century using the new concepts outlined in Figures 3 and 4. As an underground hard rock miner, the author would like to concentrate his talk on future concepts for underground mines as shown in Figure 4.

The Multi-activity Cycle in Mining.

Before treating the principal subject of this section of the talk, the author thinks it is important to characterize the attitude of the mining engineer to the introduction and use of new technology. The commonly held view is that he is ultra conservative and takes few risks with respect to innovative mining technology. The best is to this view is a quote from Hickson et al (1):

"Mining is a practical art that generally responds to, if not initiates, technological development in its quest to win metal profitably. However, an obsession with 'things that work', driven by the need to minimize the unknown in an already high risk business, tends to limit the miners' technological advancement to incremental or evolutionary steps."

While the above statement is an accurate statement of the general situation, there are companies taking bold steps to advance mining technology in a non-evolutionary way. The companies involved are firmly convinced that major (quantum) technology advances are essential to the industry's survival.

Many mining companies would agree that drill and blast operations, despite the age of the technology involved, are far from attaining their technological limit. Most can see that technological advances can still be made to equipment, man-power practices and design procedures. Most improvements envisaged would tend towards increasing the scale of operations, and or therefore producing bigger muck volumes to be moved. The author is of the opinion that as long as developing and stoping is a part of a cyclical operation involving drilling and blasting, the complete automation of mining operations will not be possible despite the use of continuous loader, portable hard rock crushers and conveyors. The drill-and-blast cycle is the most restrictive operation in mining and presents the toughest problem to solve. Unless a suitable substitute can be found, there will be no fully automated underground mines, and mines will have to forego the attendant advantages of reduction in operating personnel. In this sense, underground mining technology has reached a dead-end. A radical new technology for rock breaking is required.

There has been several attempts made to develop mechanical excavation machines for use in underground hardrock mines. None of these attempts have resulted in a machine that can compete with drill-and-blast operations. Tunnel boring machines were developed as early as 1865 (6) and have been under constant development ever since. Robbins has produced a mobile miner which is presently in or at underground trials at Mt. Isa Mines in Australia. The mining community is still awaiting the results from the trials. The author is not confident that a high-pressure water jet used in conjunction with a mechanical cutting tool will provide the means to bore hardrock openings. He is of the opinion, however, that prefacturing or preconditioning of the rock ahead of mechanical cutters would dramatically improve rock cutability. The author is aware of a few proposals based on the exploitation of this concept for hard rock continuous mining machines.

<u>Automated Explosives Handling and Loading, and Wire-less Blasting</u>

Explosives loading in underground mines is almost a manual operation although bulk mining blasts of more than 50,000 tonnes ore are not uncommon. Quasi-manual explosives loading of large blasts is a very slow operation. This is particularly true in the case of VCR blasts where rope-held plugs must be inserted to support explosives, decking, stemming and accessories. All aspects of explosives loading related to bulk mining underground need to be improved to achieve economies, handling, transportation and loading.

Blast operations procedures have remained practically the same from the early days of rock breaking by explosives. Improvements have been mainly in the areas of explosive chemistry, method and accessories but the 'way of the operation' has not seen large technical changes.

It is this area that the author believes greater research effort is required and which has considerable potential for robotics application. A systems approach should be used to design an explosives placement system for use with bulk mining. It would be difficult to design suitable equipment around existing explosives packaging and detonating systems for the new system. Explosives handling and placement in the hole should be an integral part of the same system. Explosives manufacturers, mining companies and governmental regulatory agencies should be involved in the design of such placement systems.

The detonation of an explosive charge has not changed so far, although it might have become safer to do. Still we have a physical connection between an energy supplying device (an exploder), and a cap, (detonator). This arrangement is extremely time consuming and fully manual. It does not lend itself for mechanization and automation of the operation. It is difficult, if not impossible to fully automate or robotize the explosive handling, loading and blasting operations. With the present-day hi-tech application, it should be possible to do away with it. The detonation charge with a booster should have its own receiver, power supply, safety and coded delays which could be fired by a remote transmitter avoiding the physical connection between the explosive and the exploder. If such a system is devised, it could not only be mechanized but automated. Explosive loading will become simpler - only it will have to be put in the hole and no connections to be made. If mass produced, it should be cost competitive with the present system. (A computer chip is now available for less than 50 cents - a detonating chip could be similarly produced cheaper on the basis of volume production. The whole operation will be cheaper because of the time saved in making the connection for blasting (6)). See Figures 4 and 5 for automated loading and blast initiation system.

New stemming techniques will be required which are compatible with any newly developed explosives placement system. Probably, it should be either a self-locking mechanical plate type or a chemical plug system which could be machine loaded.

Reduced and/or Restricted Ventilation and All-electric Mines

It is evident that, underground mines in the 21st century will have fewer underground production workers if any at all. Underground service personnel to maintain equipment will always be required. If there are no operating personnel then what are the ventilation requirements for? It is most likely that the 21st century will have replaced diesel power completely in underground mines and the main requirement for oxygen (ventilation). The ventilation needs of workers going underground can probably be more economically met by isolated enclosed chambers with air where equipment must be serviced and self-contained suits underground between such chambers (check)-Figure 5. The technology will come from the aerospace industry which has built space suits for NASA. There is every possibility for the successful transfer of technology to underground mines when it is required. The use of space suits would obviate the need for a mine ventilation system. The use of space suits in uranium mines would additionally reduce the radiation hazard risk for workers in uranium mines. Additional cost saving in northern mines of Canada will come from a reduction in heating ventilation air and energy saved in moving large amounts of air required for diesel equipment and men.

Automated Ore Sorting Underground

A move towards ore sorting underground is seen for mining in the 21st century. There are definite advantages to be gained from reduced transportation costs associated with hauling waste materials; releasing of hoisting capacity for transportation concentrated ore; utilization of some of the waste rock available underground as back fill material and accelerated placement of backfill to achieve better ground support. There are, therefore, a number of technical and economic incentives to redesign old mines and design new ones so that waste rock can be disposed of underground rather than in surface dumps. There should also be a parallel trend to process ore underground and produce the backfill material required. Such a processing facility need not be located at the bottom of the mine but at the optimal level for gravity feeding of backfill material to the stopes. There would probably be a slight additional cost incurred in hoisting ore to the processing facility. It is based on a backfilling system designed by Falconbridge Mines staff in the early 1980s. However, it only permits the partial utilization of available waste rock and does not process ore to provide a complete fill material.

It is envisaged that future technological breaks in highly automated manufacturing processes and micro processor applications, particularly in the areas of sensor development, vision systems and application in handling of material of variable characteristics will be an impetus to the software, which will provide a tremendous impetus for the development of sophisticated, reliable and accurate underground ore sorting machines. They will significantly improve the economics of mines using them by reducing waste and backfill materials handling costs.

The Role of Different Professions in Mining

Historically, mining has been the nearly exclusive domain of geologists, mining and metallurgical engineers. Other discipline such as mechanical and electrical engineering characteristically had a support role. There has been significant changes in the situation in the last decade. In additional to the traditional professional disciplines, mines staff can also include specialists in the following areas: Computer Scientists, Electronics/Automation Engineers, Communications Engineers, Geostatisticians and even Public Relations Experts. Many years ago, prospecting was mainly the exclusive domain of geologists, professional or self trained. Field trips, with exploration sites based on this geological understanding were the basis of discovering new ore bodies. With the advent of geophysical prospecting, the geologists began to share this role of picking test site areas for ground exploration with the practitioners of this new technology. More recently, geochemical prospecting has come to the aid of geologists in selecting and assessing test sites for ore potential. The exploration geologists is about to receive the added assistance of satellite imagery in detecting potential deposits; the detection of mineral resources by satellite imagery and its analysis is a rapidly developing technology. It is anticipated that as the technology develops, it will be able to pin point the location and the depth of an ore body and through subsequent data analysis information on its physical dimensions, ore grade and metals content etc.

In the 21st century, the technology should also be available to estimate the 'near-geology' around mine excavations and developments. This should permit the precise guiding of automated mining machines so that drilling waste rock or missing ore is avoided. This same technology should also permit the detection of dangerous ground conditions such as badly faulted ground, water inclusions etc. sufficiently early to take corrective action.

Automation of Surveying and Surveying Functions

It is envisaged that an automated survey will replace the present two man teams. Cavities being surveyed will be fully described in digital form. The surveying machines carrying out the survey will be located on mining and drifting machines or lowered down a hole as conditions require. The computer processed data will be used to provide 3-D projections in any orientation desired and sections as required. Manual mapping and layout planning will be things of the past. Plans and sections will be printed out on demand or displayed on CRT screens in local as well as in head or corporate offices for officials to make decisions. Survey data as it is developed will be directly led into the mines CAD systems.

Borehole Mining and Leaching

In situ mining of ore by using bacterial leaching of the metallic recovery process would possibly see much wider use in future years. There are a few operations where underground leaching is being used for metal recovery. In 1985, CANMET financially supported a contract awarded to Noranda Research Centre to investigate the feasibility of using leaching on a complex Au-Cu ore mined in one of their mines. One of the study conclusions (7) was that, 'the state-of-the-art of bacterially-assisted in situ leaching of ore (sulfide copper) is not yet sufficiently advanced to be economically feasible'. For the process to become feasible, technological advances in the process must be made in the following areas:

- faster rate of ore (copper) leaching;
- least expensive method of muck development and rubblization, and
- reduction or elimination of the cost of pumping the dilute leach to the surface.

It is the author's opinion that in the 21st century, in situ leaching will become a major mining method because of its low man power requirement, its unsophisticated equipment requirements and the advances that can be expected to be made in microbiology and genetics pertinent to leaching. New more productive and selective bacteria should be available as a result of research in the latter two areas.

Robots and Mining

If we define a robot as a machine having mobility and capable of handling several variable tasks after programming, then robots have a future in underground hard rock mines. By these definitions remote controlled out-of-site (OSRC) units such as scooptram does not qualify as a robot as it does not operate independently with preprogramming. However, OSRC developed technology can contribute to the development of true robots. Additional break through in the areas of artificial vision, anti-collision devices etc. are required before robots will become part of hard rock mining equipment in the 21st century. As well, advances in such areas as artificial vision will permit in the future the remote operation of mining equipment from surface using advanced telemetry systems. The location of equipment and the operator will become immaterial.

Conclusion

It can be confidently concluded that in the 21st century, there will be a few to none operating personnel in mines and the majority of the equipment will function without operators. However, there will be a substantial increase in highly trained specialists, to maintain the very complex mine equipment being used. Some of the mines using leaching will have no underground personnel at all. Successful development of hardrock miners, which will provide predictable fragmentation of products will result in hydraulic lifts replacing skip hoists. Improved and readily available communications systems will permit the transfer of all information within the mine management system back to head or corporate offices as it is developed. This combined with instantaneous communication to the few underground operators could result in major changes in the operating responsibility of head office and mine staffs.

References

1. Anonymous, 'Australian research aimed at jumbo ore trains safety'. Canadian Mining Journal, May 1979, pp 115.

2. Hickson, P.W., McMohan, D.W. and Schapper, M.A., 'The Shape of Hard Rock Mining in the 21st Century'. Automation for Mineral Resource Development, IFAC Proceedings Series, 1986, Number 1, pp13.

3. Pathak, J., 'Potential Application of Advanced Technology in Underground Hardrock Mining'. Proceedings of 12th World Mining Congress, New Delhi, India, November 19 - 23, 1984.

4. Strangway, D.W., 'Moon and asteroid mines will supply raw material for space exploration'. Canadian Mining Journal, May 1979, pp 44.

5. Cundiff, W.E., 'Will Sudbury survive the impact of ocean mining?' Canadian Mining Journal, May 1979, pp 56.

6. Robbins, R.J., 'Future of Mechanical Excavation in Underground Mining'. Mining Engineering, June 1984, pp 617.

7. Pathak, J., 'An overview of current major research and trends in Canadian mining technology'. Paper delivered at the First Symposium on Innovative Mining Systems at Massachusetts Institute of Technology, Cambridge, USA, November 4 - 5, 1985.

8. Smith, B.J., Seleken, L., Rockel Ed., 'GPEX: Geophysical Expert System', Interact R & D Corp., Victoria, B.C., Canada. Direct correspondence with the Company and Authors.

9. A pre-feasibility analysis of bacterially-assisted underground leaching of a Canadian copper sulphide deposit. A CANMET Contract report no. 23440-4-9071 by Noranda Research Centre, Pointe Claire, Quebec, Canada.

NICKEL

PRICE	PRICE
$3.30/kg.	$5.00/kg.
.PRODUCED BY:	.PRODUCED BY:
.CONVENTIONAL MINING .PRIMITIVE MINING (IN THE THIRD WORLD)	.FULLY AUTOMATED 'UNTOUCHED BY HUMAN HANDS' MINE

WHICH ONE WILL YOU BUY ?

FUTURE MINES

.OCEAN MINING
.SEA WATER (MINERALS / SALTS) MINING
.ASTEROID MINING

.OPEN PIT MINING
(VERY HIGH CAPACITY MINES
300 MIL TONNES / YR MINING, PROCESSING,
CONCENTRATING AND DISTRIBUTION)
(PILBARA REF. CMJ MAY 1979)

.UNDERGROUND MINING
(SEE NEXT FIGURE)

FUTURE MINES (CONTD.)

.UNDERGROUND MINES

-MINIMUM OR NO OPERATING PERSONNEL
(WITH MAINTENANCE PERSONNEL)
-REMOTE OUT-OF-SITE OR FULLY AUTOMATED
-WITHOUT OR WITH MINIMUM EXPLOSIVES USE
-ALL ELECTRIC MINES
-NO OR MINIMUM SELECTIVE VENTILATION
-CONTINUOUS DEVELOPMENT AND MINING
-ALL WASTE ROCK STAYS U/G (FILL)
-ORE SORTING U/G
-MINERAL PROCESSING & CONCENTRATION U/G
-MOSTLY HYDRAULIC HOISTING
-MINE OPERATING PARAMETERS
ON-LINE TO SURFACE/HEAD/CORPORATE
OFFICES
-AUTOMATED REPORT WRITING ON DEMAND
-MACHINE HEALTH SENSORS
-NO PAPER/PENCIL USE FOR DATA COLLECTION
-AUTOMATED 'NEAR-GEOLOGY' EXPLICIT MAPPIN
(FOR MACHINE CONTROL)
-
-
-
-
-ROBOTS

THE MULTI-ACTIVITY CYCLE IN MINING

- MOST RESTRICTIVE FOR AUTOMATION, THEREFORE OPERATING MANPOWER CANNOT BE TAKEN OUT;
- FRAGMENTATION UNPREDICTABLE CREATING PROBLEM FOR MACHINE DESIGN;
- GEOMETRY UNCONTROLLABLE

DESIRABLE

- NON-EXPLOSIVE BASED TECHNOLOGY;
- WOULD GIVE A QUANTUM LEAP;
- CONTINUOUS MINING MACHINES;
  - TUNNEL BORING MACHINES (1885)
  - MOBILE MINER (1985/86)
  - WATER JET/CAVITATION/MECHANICAL BREAKERS

ALL-ELECTRIC MINES AND REDUCED AND/OR RESTRICTED VENTILATION

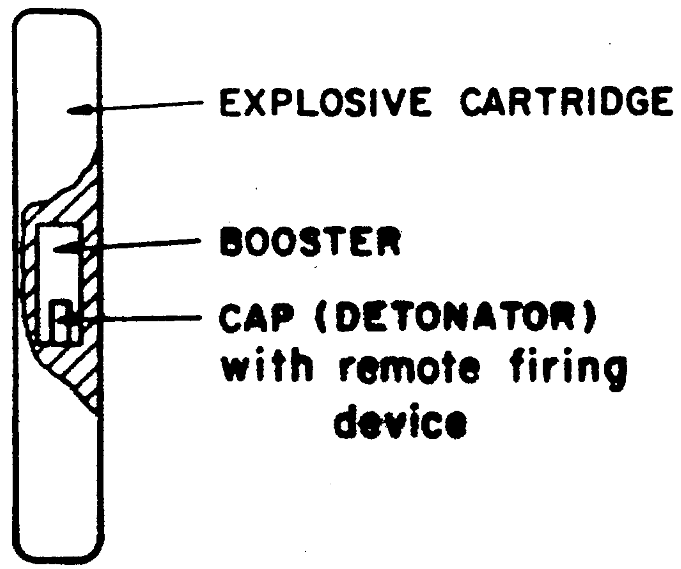
- DIESEL EQUIPMENT OUT
- ELECTRIC OR ELECTRO-HYDRAULIC EQUIPMENT ONLY
- BETTER FOR AUTOMATION/ROBOTI-ZATION
- REDUCED OR NO VENTILATION (BECAU-SE NO OPERATORS)
- SAVINGS IN AIR MOVING AND HEATING AND ACCESSORIES
- SELF CONTAINED SUITS FOR TRAVELLING AND REPAIRS
- VENTILATION ONLY IN REPAIR SHOPS AND CONTROL ROOMS

AUTOMATED EXPLOSIVES HANDLING & LOADING AND WIRE-LESS BLASTING

- \+ 50,000 TONNES BLASTING COMMON
- MULTI-ACTIVITY OPERATION, THEREFORE DIFFICULT TO AUTOMATE AND REMOVE MAN
- PHYSICAL CONNECTION BETWEEN EXPLODER & CAP REQUIRED
- MANUAL STEMMING

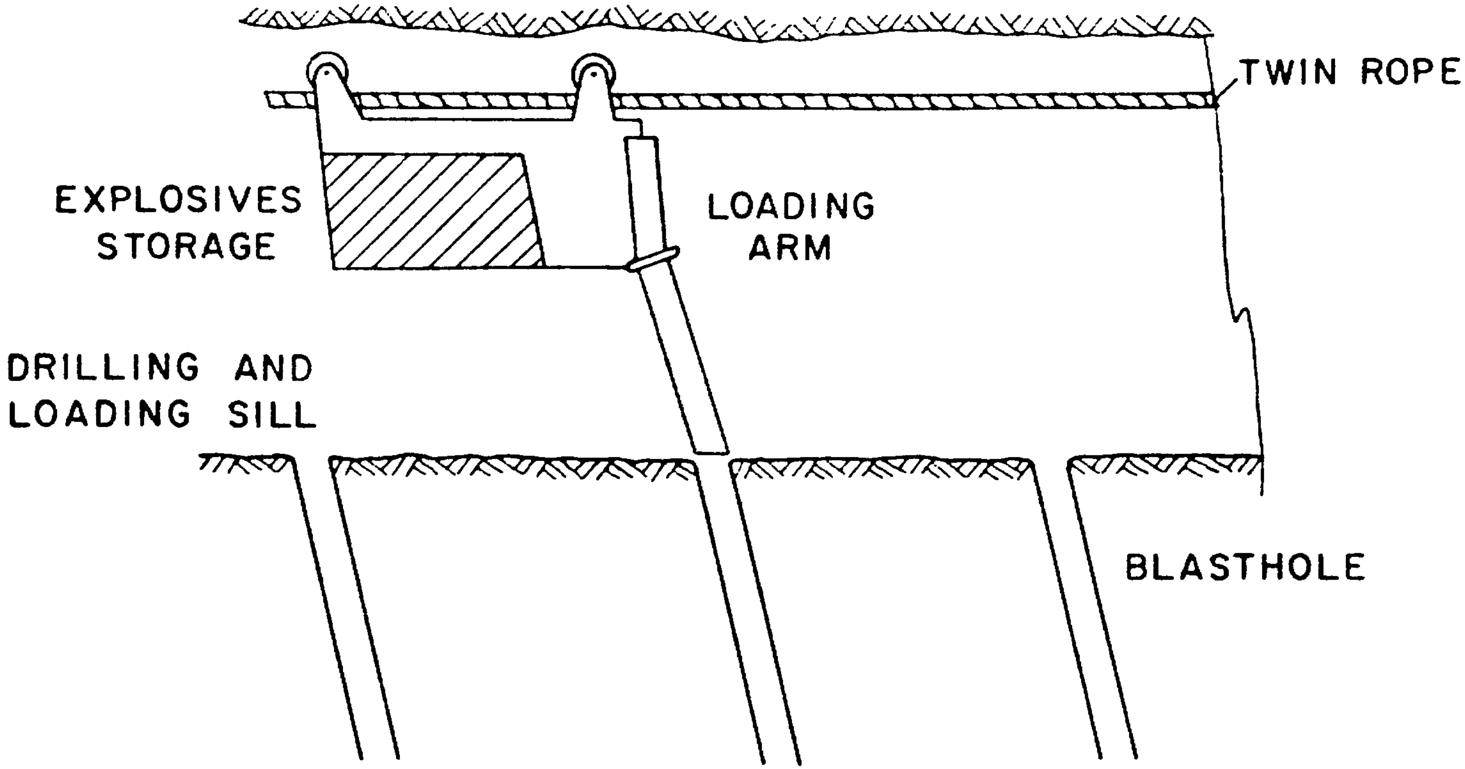
DESIRED (IF EXPLOSIVES TO BE USED)

- IMPROVED PACKING FOR AUTOMATED LOADING
- WIRE-LESS DETONATION
- CAPS HAVING RECEIVERS, POWERPACK AND DELAY CODES
- MECHANICAL OR CHEMICAL PLUGS FOR M/C AUTOMATED STEMMING



- MULTIPLE CODE, SEQUENTIAL TRIGGERED CAP
- ALL CAPS SIMULTANEOUSLY TRIGGERED, BUT
- DELAYS ELECTRONICALLY CONTROLLED
- ALL FUNCTIONS PREPROGRAMMED
- FULLY PREPACKAGED

WIRELESS, REMOTE, DETONATED EXPLOSIVES



- HOLE PARAMETER DETECTOR (LOCATION, INCLINATION, AZIMUTH ETC.)
- PLUGS (STEMMING) - MECHANICAL, CHEMICAL OR FREE FLOWING
- DETONATORS (CAPS)/ BOOSTERS WITH NO WIRING
- ALL PREPROGRAMMED AND PREPACKAGED

AUTOMATED EXPLOSIVES LOADING FOR BULK MINING (A ROBOT ?)

AUTOMATED ORE SORTING UNDERGROUND

- FAST COMPUTERS, AI APPLICATION AND SPECILIZED SENSORS FOR DISCRIMINATING ORE/WASTE

- ORE SORTING U/G

- AUTOMATED HYDRAULIC TRANSPORT FOR ORE

- ORE DRESSING U/G

- WASTE FOR BACKFILL/GROUND CONTROL

AUTOMATION OF SURVEYING AND SURVEY FUNCTIONS

- TWO-MAN SURVEY TEAM OUT
- CAVITY/RAISE/SHAFT SURVEY BY SUSPENDED SURVEY INSTRUMENTS
- EQUIPMENT MOUNTED SURVEY INSTRUMENT
- ALL DATA DIGITIZED
- RETRIVABLE AS 3-D GRAPHIC ON CRT
- DIRECT PLOTTING IN ANY ORIENTATION OR SECTION
- DIRECT INTERACTION WITH COMPUTERIZED MINE PLANNING SYSTEM
- REPORT WRITING AND DOCUMENTATION ON DEMAND

BOREHOLE MINING AND LEACHING

- INCREASE IN LEACHING FOR METAL RECOVERY:
    - SIMPLER EQUIPMENT
    - INEXPENSIVE
    - NOT MUCH DEVELOPMENT REQUIRED
    - NO MANPOWER UNDERGROUND
- DEPENDS UPON:
    - FASTER RATE OF ORE LEACHING
    - BETTER RUBBLELIZATION TECHNIQUE
    - REDUCTION OR ELIMINATION OF PUMPING OF LEACHATE TO SURFACE
- CUSTOM DESIGN OF BACTERIA FOR VARIETY OF METALS (GENETIC ENGINEERING)

THE ROLE OF DIFFERENT PROFESSIONS IN MINING

- HISTORICALLY EXCLUSIVE DOMAIN OF:
  - GEOLOGISTS
  - MINING ENGINEERS
  - METALLURGICAL ENGINEERS
- SUPPORT ROLE:
  - MECHANICAL ENGINEERS
  - ELECTRICAL ENGINEERS
  - GEOCHEMISTS
  - GEOPHYSICISTS

(Continued)

THE ROLE OF DIFFERENT PROFESSIONS IN MINING (continued)

FUTURE:

- COMPUTER EXPERTS (GRAPICS, AI, EXPERT SYSTEMS)
- COMMUNICATIONS/AUTOMATION ENGINEERS
- ELECTRICAL/MECHANICAL ENGINEERS
- ROBOTIC EXPERTS
- GENETIC ENGINEERS

  - SATELLITE IMAGERY
  - GRAPHIC DISPLAYS (INTERCONTINENTAL)
  - INTELLIGENT ANALYSIS OF NUMEROUS DATA
  - 'NEAR-GEOLOGY' INTERPRETATION
  - 3-D MINEGRAPHIC FOR PLANNING

ROBOTS AND MINING

- OUT-OF-SITE REMOTE CONTROL (OSRC) WILL BECOME COMMON
- ONE MAN OPERATING SEVERAL EQUIPMENT FROM ONE CONTROL CENTRE
- ARTIFICIAL VISION FOR MINING SYSTEMS
- ANTI-COLLISION DEVICES FOR MAN-LESS OPERATION OF MOBILE EQUIPMENT

LEADING TO:

- POSSIBILITY OF ROBOTIZATION OF INDIVIDUAL OPERATION