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Rock-Related Accidents, Investigations and Inquiries in South African Mines

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ABSTRACT: South Africa's mineral industry is supported by an extensive and diversified resource base. It has a mird or more of the world's reserves of alumino-silicates, chromium, gold, manganese, platinum-group metals, vanadium and vermiculate. This large reserve base allows it to play an important role in the world in respect of the production and export of many minerals and processed mineral products. Rock-related accidents have been a major problem in the South African mining industry for many years. According to 1999 statistics, 312 workers died in mines, in which 43% of the accidents were rockfall and rockburst related (rock-related). Although there has been a steady decline in accidents in the industry, rock-related accident rates are still far from being satisfactory. The author conducted 25 rock-related accident investigations and inquiries in various deep-level gold mines. The conclusions of the accident investigations and inquiries revealed that most of the accidents occurred as a result of a lack of support units in the working face area, poor mining practice, lack of hazard identification, poorly designed mining and support layouts and lack of strata control training for workers. The main objectives of this study are firstly to describe the importance of the mining industry for the South African economy and secondly to determine the causes of rock-related fatalities in gold mines.

1. INTRODUCTION

South Africa's mineral industry is an important contributor to the country's economy. In 1998, mining and quarrying contributed $6.6 billion, or 6.6% of the Gross Domestic Product (GDP), and $1.7 billion, or 8.6% of the Gross Domestic Fixed Investment (GDFT). The industry also contributed about 1.2% of state revenue. In 1998, South Africa's total primary sales were valued at about $12.8 billion, of which earnings from exports contributed 76.6%, while gold accounted for 44.2% of exports. Although primary minerals contributed some 37.2% of the country's foreign exchange earnings, the addition of processed mineral products would raise that figure to well above 50%.

2. STRUCTURE OF THE SOUTH AFRICAN MINING INDUSTRY

For more than a century, South Africa's mineral industry, largely supported by gold, diamond, coal and platinum production, has made an important contribution to the national economy. Furthermore, it has provided the impetus for the development of an extensive and efficient physical infrastructure, and has also contributed greatly to the establishment of the country's secondary industry.

The mineral industry is a well-established and resourceful sector of the economy. It has a high degree of technical expertise and the ability to mobilize capital for new development. It is recognized worldwide as a leading and reliable supplier of a large variety of minerals and mineral products of a consistently high quality. In 1998, some 55 different minerals were produced from 691 mines and quarries, of which 53 produced gold, 62 coal and 58 diamonds. Mineral commodities were exported to 80 countries. According to recent statistics, 470,372 people are employed in the mining industry.

The government's economic policies are based-on principles of private enterprise and a free-market mechanism. The system has enabled the mineral industry to develop without undue state influence, thereby allowing market forces to dictate the pattern of its development. The Department of Minerals and Energy Affairs (DMEA) is responsible for the administration of the Minerals Act, 1991 and Mine Health and Safety Act, 1996, which regulate the prospecting for, and optimal exploration, processing and utilization of minerals, and safety and health in the mining industry respectively. The DMEA's mission is to provide effective management of the mineral and energy industries for economic growth and development, thereby improving the quality of life of the people of South Africa.

The Chamber of Mines of South Africa is a private sector employers' organization with voluntary membership, founded in 1889, three years after gold was discovered on the Witwatersrand. The chamber is an association of mining finance companies and mines operating in the gold, coal, diamond, platinum, asbestos, lead, iron ore, antimony and copper mining sector.

The National Union of Mine Workers (NUM) is the biggest union in South Africa, and was formed in December 1982. The NUM is the largest recognized collective bargaining agent representing workers İn the mining and electrical energy sectors.

Table 1. South Africa's mineral industry reserves, 1998.

Commodity	World reserve %	World ranking
Alumino-silicate	37.4	1
Chrome ore	68.3	1
Gold	35.0	1
Manganese	80.0	1
Coal	10.6	5
Phosphate	7.2	3
Platinum	55.7	1

Table 2. South Africa's role in world mineral exports, 1998.

Commodity	World production %	World ranking
Alumino-sihcate	49.8	1
Chrome ore	28.9	!
Coal	11.9	3
Manganese	28.5	I
Vanadium	69.0	I
Zirconium	32.3	2

Table 3. Contribution of mining & quarrying to Gross Domestic Product (GDP), Gross Domestic Fixed Investment (GDFl) and state revenue of mining industry in RSA, 1995-98.

Year	GDP %	GDFI %	Total state revenue %
1997	6.5	8.7	1.4
1998	6.6	9.2	i.1

Table 4. Employment in the South African mining industry, i 998.

SECTOR	EMPLOYEES		£ Remuneration	
	Number	%	Rm	%
Gold	258815	55.0	9205	47.2
Platinum	89905	19.1	3474	17.8
Coal	60469	12.9	3532	18.1
Diamonds	14531	3.1	887	4.6
Other minerals	46652	9.9	2393	12.3
TOTAL	470372	100	19490	100

3. MINE HEALTH AND SAFETY ACT, 1996 (ACT NO 29 of 1996).

3.1 *Background to the Mine Health and Safety Act, 1996*

The unacceptably high number of fatalities and serious injuries in the South African Mining Industry was of grave concern to the government and subsequently, after a tripartite mining summit, the cabinet in 1993 approved the appointment of a commission of inquiry into health and safety in the mining industry. The commission recommended that the Mine Health and Safety Act, dedicated to regulating health and safety in the mines, be drafted. During 1995, the Parliamentary Mineral and Energy Affairs Portfolio Committee supported this recommendation and the cabinet approved the implementation of the recommendation.

3.2 *Nature and content of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996)*

The act is dedicated solely to health and safety within the mining industry, which was not the case with the amended Minerals Act. The main objectives of the act are; -

- to provide for employee participation in matters of health and safety;
- to protect health and safety of persons at mines;
- to provide effective monitoring of health and safety conditions at mines;
- to provide for investigations and inquiries to improve health and safety at mines; and
- to require employers and employees to identify hazards and eliminate, control and minimize the risks relating to health and safety at mines.

Some of the important sections of the act are as follows; -

1. Health and safety İn mines concerning employer's duty.
2. Codes of practices.
3. Risk management.
4. Record of medical surveillance.

5. Health and safety representatives and committees.
6. Tripartite institutions.
7. Establishment of inspectorate.
8. Minister's power.
9. Legal proceedings and offences.

4 ACCIDENTS IN SOUTH AFRICAN MINES

The South African mining industry has for the past years been trying to reduce expenditure on all major and minor costs in an attempt to either keep profits up to acceptable levels, or in many cases, to prevent the mine from making a loss. Great pressure in the field of heath, and safety has also been exerted by unions, employers and state in order to bring about a significant reduction İn the fatality and injury frequency rates. Although there has been a steady decline in accidents in the South African mining industry, both in fatality rates and injury per thousand workers, the health and safety situation is still far from being satisfactory.

Table 5 Type of accidents ui South African mines, 1999

Type of accident	Fatality	Injury	Total accidents
Rock-related	137	1517	1529
Machinery	11	294	303
Transport	62	1103	1158
Electricity	8	37	41
Fires	0	3	3
Explosives	5	26	28
Subsidence /caving	0	1	1
Heal sickness	2	8	10
Gas/fumes	28	54	39
Conveyance	8	43	43
General	45	2402	2443
Rate	0.77	13 42	
Total	315	5488	5598

General, miscellaneous, occupational diseases, diving sickness, inundation, struck by objects etc

Table 6. Total accidents in South African mines

	1995	1996	1997	1998	1999
FATAL	533	463	415	371	315
INJURY	7717	7426	7095	6064	5466

Table 7. Total accidents in specific mines, 1999.

Year	1997	1997	1998	1998	1999	1999
	I	F	I	F	I	F
Gold	5707	277	4650	252	4202	213
Coal	270	40	257	42	207	28
Platin	755	53	785	44	766	39
Other	363	45	372	28	291	35
Total	7095	415	6064	366	5466	315

Table 8. All mines rock-related accidents, 1999

	1995	1996	1997	1998	1999
Fatal	222	247	192	181	137
Injury	2102	2184	2012	1819	1517

As it can be seen m Table 5, the most significant problem in the mining industry is rock-related accidents such as roekburst and fails of ground. Table 7 also shows that most of the accidents occur in gold mines.

In this research, most attention will be focused on the South African gold mines, which not only has higher total casualties than other hard rock mines, but also experiences more severe hazards, notably a high incidence of roekburst in deep-level gold mines. The author conducted 25 rock-related roekburst and fall of ground accident investigations and inquiries in order to determine the causes of these accidents.

4.1 *South African Gold Mining Industry*

Gold is synonymous with South Africa. Approximately 31% of the world's gold has been mined in the country over the past decade. Today, the gold fields form a discontinuous arc 430 km long, extending through the Gauteag, the North-west, the Mpumalanga and the Free State provinces. In 1999, 475 t of gold (at 5-6 g/t average grade) was produced by primary gold mines, tailings re-treatment operations and as a by-product of the production of other metais.

Gold mining m South Africa, from its humble beginnings in the first recorded mine in Eesterling in the Northern Province in 1871 to its pre-eminence as the largest gold mining industry in the world, has played a significant role in the economic development of the country over the past 120 years Through gold minmg, many towns and cities have come into being. One notable example is Johannesburg. Much of the İnfrastructural development of roads, electricity generation, water reticulation, telecommunications, housing and the development of industry to provide input for the gold mining industry have resulted directly from gold mining.

Most gold mining companies exploit more than one reef-vein in the Witwatersrand Supergroup. Further exploration, although at a reduced level, is expected to ensure that recent production levels are maintained for at least the near future. Precise age estimation in the Witwatersrand Basin is difficult since the rocks were deposited by sedimentation approximately 2700 million years ago, before the age of fossils. Experts believe that a great inland sea existed in what are now the Highveld and the Free State plains. Successive layers of conglomerate containing pebbles and gold were washed down into the sea and spread over the bottom by wave action. The gold particulars subsequently settled in successive layers of pebbles along the shoreline of this sea, which later silted up.

4.2 *Mining gold m South Africa*

South Africa's thin but extensive gold reefs often lie several kilometers beneath the earth's surface and usually slope through the ground at up to 25°. The country's gold mining industry has to sink the deepest mine shafts in the world, sometimes close to 4 km in depth, in order that miners can reach and extract these reefs. The mining method in deep gold mines is the 'longwalT mining method and the mining operation is carried out in hard brittle quartzitic rock, often at extreme depth. The great bulk of this rock mass behaves elastically, but stress concentrations around the excavations cause stable as well as sometimes unstable fracturing to take place. The vertical component of the virgin stress in South African mines tends to increase with depth approximately 0.027h(MPa) rock density 2.75 t/m^3 in each meter. The rock temperature can reach up to 50 C°, and this necessitates the use of ice and refrigeration facilities.

Today, with the tremendous pressure on profit margins in the gold mining industry, which is mining steadily declining grades at ever-greater depths, there is more emphasis on mechanization then ever before. Among the many aspects of mechanization, which are the focus of ongoing research, are technologies like trackless mining, backfill, non-explostve breaking and hydropower.

On average, only 5 ppm of every ton of ore mined is actually gold. It is, therefore, necessary to separate the precious metal from more than 100 million tons of ore milled each year in South Africa. The carbon-in pulp (CIP) method, which is increasingly widely used, makes use of the tremendous physical affinity "activated" carbon has for gold, which it readily attracts to its surface in cyanide solution. After smelting, which takes place in individual mines, bullion bars containing about 85% gold are then taken to the Rand Refinery near Johannesburg and processed to either 99.5% purity or 99.9% purity to meet specialized demands from certain industries.

Despite the fact that the gold industry's contribution to mining and the economy has declined, it remains a vital sector in the South African economy. Gold mines provided 211,200 direct job opportunities in 1999. Moreover, through its links to the domestic economy, about 220,000 additional jobs are also maintained in the rest of die economy. The direct contribution in terms of salaries and wages amounted to $1.4 billion during 1999.

Table 9 clearly indicates that South African is a pioneer in world gold production and the country will remain a world-class gold producer in the 21^{s}' century.

Table 9. Annual world gold production by country and region, 1996-1998 - m metne ions.

Country /Repon	1996	1997	1998
South Africa	494.6	492.5	464 4
USA	329.3	359.0	364 4
Canada	1639	168.3	164
Oceania	305 6	329 2	325 0
China	144.6	153 0	161.0
Russia	132.8	138.0	127 3
Peru	64.8	74 8	89 2
Brazil	64.2	59.1	55.4
Chile	56.4	52.9	46.7
Other Asia	229.7	246 0	258.7
Other America	188.4	126.3	144.6
Other Africa	129 1	144.5	169.4
Other Europe	300	32.9	33 6

Table 10. Total labour force in South African mines.

MINE	1997	1998	1999
GOLD	292 HO	235940	211200
COAL	55297	57585	54820
DIAMOND	14274	14903	14537
PLATTN	80164	81734	85921
OTHERS	56193	55775	56919

4.3 *Accidents in South African Gold Mines*

In 1999, 213 fatalities occurred in gold mines in which 43% of these fatalities were rock related.

Accident statistics in South African gold mines cannot be compared with those of other countries for die following reasons:

1. Most of the gold mines are currently working 2500 km below the surface.
2. Deep mines are subject to very high states of rock stress, causing seismicity and rockbursting.
3. In all deep mines, the exposed rockwalls are highly fractured, which results in fall of ground accidents.
4. The heavy faulting encountered in many deep gold mines generates strata control problems and seismicity.
5. Gold mines in South Africa are the largest employers in the industry and employ more than 210000 workers.

Table 11. Number of rock-related fatalities in South African gold mines.

ACCIDENTS	YEAR			
	96	97	98	99
GRAVITY	125	73	81	68
ROCKBURST	65	80	62	41
TOTAL	190	153	143	109

In South Africa, rock-related accidents are classified in two groups. - Firstly, *gravity accidents* are accidents which occur mainly when an unsupported rock or portion of fractured rock falls in the working environment. Secondly, *rockburst* accidents occur as a result of stress-strain build up in the rock face or geological discontinuities such as faults or dykes, sometimes causing fatality and/or damage to underground workings.

In gold mines, rockfall and rockburst accidents represent the most significant cause of all fatal accidents. An important finding of the investigations here was that 72% of all rock-related accidents were seismic, and 28% of them were gravity-related accidents. In 25 accidents, the total deaüı toll was 38. The most important finding of these investigations was that all gravity-related accidents could have been prevented if the support had been installed prior to the accidents. Accident investigations and inquiries also revealed that most of the damage mechanism of the seismic-related accidents could also been minimized if the design of the mining layout and support had been adhered to by the production staff. Another important finding of these investigations was that most of the seismic-related fatalities occurred between the support units due to seismic shakedown.

5 ACCIDENT INVESTIGATIONS IN MINES

5.1 *Accidents to be reported*

Whenever an accident results in the death of any person or an injury to any person likely to be fatal as a result of rockfall or rockburst, the manager of the mine shall give notice thereof to the inspector of the DMEA without delay.

When an accident causes the immediate death of any person(s) as a result of rockfall or rockburst, the place where the accident occurred cannot, without the consent of the inspector of the DMEA, be disturbed or altered before such place has been inspected by an inspector, unless such disturbances or alteration İs unavoidable to prevent further accidents, to remove corpses and injured persons or to rescue persons " from danger, or unless me discontinuance of work at such place would seriously impede the working of the mine or works: provided that should an inspector assigned by the Chief Inspector fail to attend within three days after notice of the accident has been given, work may be resumed at the working place concerned.

5.2 *Accidents to be investigated*

In terms of the Mine Health and Safety Act, 1996, (Act No. 29 of 1996) the Chief Inspector of Mines of the DMEA instructs an inspector to investigate any accident or occurrence at a mine that results in any death, serious injury, any occurrence, practice or condition concerning the safety of person(s) or any actual or suspected contravention of, or failure to comply with, any provision of the acf.

5.3 *Initiating accident investigation*

The purpose of carrying out investigations is often poorly understood by all the parties concerned. As a result, they can degenerate into finger-pointing, blame-fixing and fault-finding exercises, which seldom determine the actual causes of the accidents. When the purpose is poorly defined, investigations are often poorly done. The purpose of the accident investigation should be:

- to determine what actually happened in order to prevent conflict,
- to determine the real causes jn order to develop corrective/remedial actions,
- to demonstrate concern in order to show the importance of the employees in mines.

All rock-related accidents must be investigated by an inspector of the DMEA, who is a specialist in the field of rock mechanics." Only a specialist and well-trained inspector can determine the real cause of the accident. An incompetent inspector always causes conflict during an accident investigation or inquiry. The inspector must also be well acquainted with all die legal aspects of the Mine Health and Safety Act and Regulations.

When a rock-related accident occurs in a mine, the responsible manager reports the accident to the DMEA for in-loco inspection (accident investigation). It is the responsibility of the inspector to obtain all me details concerning the accident prior to me accident investigation. The information that is obtained form the mines must also be reported to the Chief Inspector immediately. It is always good practice to conduct in-loco inspection on the same or next day, as the working place may be under die influence of potential instabilities such as seismic activity.

All the responsible mine staff and trade union representatives should accompany the inspector of the DMEA during the accident investigation. The investigating officer should also inform people of the purpose of the in-loco investigation prior to the investigation.

The following methodology is recommended for the investigating officers for an effective investigation: -

1. Establish a small leading group. •
2. Take many photos at the accident scene.
3. First determine the location of the injured or deceased.
4. Measure support distances, size and excavation height at the accident scene as well as non-damaged area.
5. Determine the damage mechanism of the event in the excavation and on the support units.
6. Take some rock samples.
7. Determine the geological discontinuities around the accident scene.
8. Observe fracturing at the accident scene.
9. Continuously question all the witnesses and responsible persons.
10. Do mt allow anybody at the accident scene due to danger.
11. Discuss all sub-standard acts and conditions with die manager and request remedial actions.
12. Thank all people concerned for their valuable contributions.

After completing the in-loco inspection, the responsible inspector must also issue a notice of instruction concerning the accident scene and determine a date for an inquiry.

5.4 *Accident inquiries*

The Mine Health and Safety Act, 1996 makes provision for the conduct of an inquiry into any accident or occurrence at a mine that results in die deam of any person. The Act also provides uSat a person questioned at such an inquiry has die right to be protected against self-incrimination and die right to be represented.

The purpose of the inquiry must be the following:

- To develop control and make recommendations in order to prevent the recurrence of a similar accident.
- To define risk in order to determine frequency and consequences.
- To enable the Attorney General to decide whether a prosecution should be instituted.

In terms of me Act, all inquiries must be held in public. The person .presiding at an inquiry may of that people's own accord or at the request of a witness exclude members of the public from attending the proceedings. The people entitied to participate are:

- Any person who has a material interest in die inquiry.
- A representative of any registered umon with members at the mine.
- Any health and safety representative responsible for the working place.

The person presiding at die inquiry may -

- instruct or summon any person to appear at any specified time and place,
- question any person under oath or affirmation,
- instruct any person to produce a book, plan, record or other document or item necessary for the purpose of the inquiry.

Witnesses and persons called to produce documents or other items have the same rights as they would have in a' court of law. Witnesses may therefore refuse to answer any incriminating questions. The presiding officer should always advice a witness of his/her right to so refuse.

It is recommended that the following documentation should be taken by me presiding officer at all times:

1. Statements from all the legally appointed individuals.
2. Details of the mine and accident place.
3. Plan of the accident area.
4. Particulars of the people present at die inquiry.
5. Particulars of the deceased.
6. Training record of the deceased.
7. Post mortem report.
8. Related codes of practices.
9. All rock-related risk assessment modules.
10. Safety statistics of the mine.
11. Logbooks of the responsible production staff.
12. Seismic history of the accident area.
13. All numerical modeling works concerning the accident area.
14. Minutes of all production and seismic review meetings concerning the accident area.

5.5 Inquiry reports

A person presiding at an inquiry must -

- record the evidence given at the inquiry;
- at the conclusion of the inquiry, prepare a written report of the findings, recommendations and any remedial steps;
- submit a copy of the report and the record of the inquiry to the Chief Inspector of Mines;
- supply a copy of the report and the record of the inquiry to the employer, Attorney General and on request to any person who has a material interest in the inquiry.

6 SOME STATEMENTS *WHICH* WERE TAKEN IN ACCIDENT INQUIRIES

Many pathetic statements have been taken from witnesses and responsible persons during inquiry proceedings. Here are some examples: -

Need 1 : All code of practices for stope layout design should be properly and clearly defined. It should be based on rock mechanics principles. Production and rock mechanics matters should be separated.

From a mine's code of practice:

"Standard size for up-dip mining to be 11.2m at all times, but wider up-dips only to be established as per section manager's discretion. "

Need 2: Supervisors often have a workload that is too heavy and cannot properly supervise their working places. The supervisors need very close contact with the crews under their care.

Question: "How many working places were you in charge of prior to the accident? "

Answer: "3 Panels in Level 31, 3 Development ends in Level 32 and 3 Panels in Level 33. "

Need 2: Do not pass the buck. Stop blaming others.

Section Manager:

Question: "Why was the bracket pillar mined out prior to the accident? "

Answer: "I really do not know The rock mechanics officer would be the best person to answer this question. "

Need 3: Think before talking. Don't escape from the fact. Seisimicity in deep-level mines is a reality.

Rock Mechanics Officer:

Question: "Did you consider that this working place was in a seismogenic region? "

Answer: "No, I did not. "

Question: "During the past 3 months, how many seismic events occurred in the area where the fatality occurred?

Answer: "I486events."

Need 4: Everyone needs training.

Team Leader:

Question: "Did you ever think that you needed to be trained in the field of strata control? "

Answer. "No, I never requested training. I am a big man. "

Need 5: The training officer's duty is to train the workers in the mine. The identification of job-related hazards is his/her main responsibility.

Senior Training Officer:

Question: "Didyou train the in-stope team members in mechanical prop installation and removal procedures?"

Answer: "They normally learn it by themselves. "

Need 6: All mines need outside consultation for the safe operation of the mine. Consulting companies should not regard safety matters as money-making business. They are also responsible for the safe design of the works.

Question: "Did the consulting firm ever visit the area for the applicability of their work? "

Answer: "No, they did not. They sent us a quotation. "

Need 7: Inspectors must be impartial during the investigations and inquires. (Please note that this statement was observed during another inspector's inquiry).

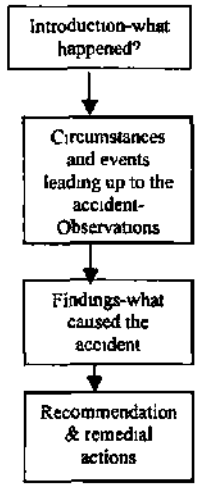
Question by manager to inspector for clarification:

Question- "Can you tell us the purpose of leaving crush pillars along the old working area? "

Answer: "I think you and I must discuss this matter outside. "

All these quotations above, taken from witnesses following falls of ground and rockburst accidents clearly indicate inadequate human response to strata control needs.

Proposed Accident Investigation Report



7. SE1SMICITY AND ROCKBURST IN SOUTH AFRICAN MINES

The • term "rockburst" first received official recognition in 1924, with appointment by the government of safety inspectors. The terms of reference were "to investigate and report upon the occurrence and control of rockburst in mines and the safety measures to be adopted to prevent accidents and loss of life resulting therefore".

Rockburst can be defined as "a seismic event which involves brief, violent movements of the rock mass and which causes fatality and noticeable damage to an excavation. "

Mining excavations induce elastic and then inelastic deformation within the surrounding rock mass. The elastic strain energy accumulated in a portion of the rock mass may be gradually unloaded due to,,the passage of mining, or it may be released gradually or suddenly during the process of inelastic deformation. Therefore, *seismic event is a "sudden inelastic deformation (release of the strain energy stored in the rock mass) within a given volume of rocks, i.e., seismic source that radiates detectable seismic waves. "*

Table 12. Rock-related accidents, death and injuries in all mines, 1999

	Accidents	KilledB	Injured
Gravity	1185	94	1138
Rockburst	344	43	379
TOTAL	1529	137	1517

Rockburst has been a matter of concern in South African Mines, especially in deep-level gold mines, for many years. Whilst the total number of injuries and fatalities has been dropping steadily, the rates have remained essentially constant for many years. Table 12 shows that the number of fatalities resulting from rockburst is 31% of all rock-related accidents. Table II also indicates that 109 rock-related fatalities took place in gold mines, which is almost 80% of all rock-related fatalities that took place in all South African mines. Table 11 also shows that 38% of all rock-related accidents that took place in gold mines were rockburst related. Mines in South Africa are planning to extract ore at depths of 4.5 km and deeper m the next 10 years, and it is clear that serious measures are needed to minimize the risks implicit in mining at such great depth. In essence, the safety of the underground workers is paramount.

7.1 *Seismic monitoring in gold mines*

Most of the seismicity in the South Africa mining region is mining induced. Most of the seismic events are categorized as being face-driven, geological-driven (local) and regional-driven. That is why most of the African deep-level gold mines are equipped with a seismic network system for warning, prevention and design purposes.

The recognition of the hazards posed by seismicity can be quantified through seismic observation, i.e., experience over time in a particular environment. That is, by obtaining seismic information from a particular environment for a period of time. The hazard of large events associated with major geological discontinuities can also be inferred by knowledge of the structure and the mine layout. It can be recognized without having had prior seismic information, which then implies that it can be estimated even before mining starts in an area, i.e., 'non-monitor' recognition of hazard. Substantial investment in research is being made in South Africa in order to understand the physical processes, development and evaluation of the early warning concept.

7.2 *Seismic emission and rockburst control in gold mines*

Mines must adopt all reasonable procedures and techniques to prevent or reduce seismic emissions. These can be achieved by implementing stabilizing or bracket pillars, backfilling, proper mining configuration and sequencing, limitation of excess shear stress (ESS) on the geological feature, mining of dykes, face shapes, limitation of energy release

%

rate (ERR), face advance rate, remnant removal, mining of dykes, mining away from structures, hydraulic props, seismic monitoring for prediction, or any other preventive procedures.

8 ROCK-RELATED RISK MANAGEMENT IN MINES

The Mine Health and Safety Act, 1996 requires that every employer must:

identify the hazards to health and safety to which employees may be exposed while they are at work;

assess the risk to health and safety to which employees may be exposed while they are at work;

record the significant hazards identified and risk assessed; and

make those records available for inspection by employees.

Rock-related risk management is an ongoing and necessary process that must be implemented to address hangingwall hazards, support installation, seismicity etc.

Before risk management can be implemented, it must be folly understood by all people concerned. All risk assessment works should be based on a tripartite approach because employees and workers especially are joint owners of the risk management process. Employers wanting successful results form their rock-related risk management processes are advised to consult workers from the outset.

8.1 Rock-related risk assessment process (İRAP)

Nobody comes to work to be injured. The mine management therefore has a moral obligation to provide workers with the tools and knowledge to enable them to work in a safe manner, avoiding accident and injury; risk assessment facilitates this. The causes of rockburst and fall of ground accidents as experienced in deep-level gold mines in South Africa are controlled by a variety of factors, such as the magnitude of the seismic event, rock mass conditions, geological features, mining layout, support effectiveness, and safety and management strategies. Rock-related risk assessment could be greatly enhanced by analyses of accidents and incidents. This type of approach helps the mine management to determine *"hot spots "* and *"critical job tasks "*.

The guidelines issued in terms of the Mine Health and Safety Act, 1996 by the Chief Inspector for compilation of a mandatory code of practice to combat rockfall and rockburst accidents in metalliferous mines also require managers to identify and describe rock-related hazards which are likely to arise from the mining of each gee-technical area identified. This information and information arising from the above accident analysis will enable the manager to develop strategies.

The rock-related risk assessment process provides the basis for decision making and enables management to create a safer environment. Therefore, roçk-related risk assessment process in a work place must be carried out continuously and not be regarded as once-off exercises- There are three types of rock-related nsk assessment techniques namely; -

1. *Base Line Risk Assessment*

This must be done to identify major risk for future risk control. (Analysis of historical data, rock-related accident reports, inspections and information-sharing between mines, etc.).

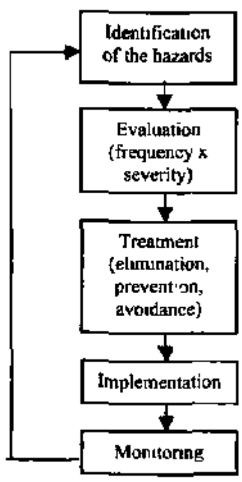
2. *Issue-Based Risk Assessment*

As circumstances and needs arise, separate risk assessment studies will need to be conducted. (Introduction of a new support after an accident, process or technique introduced to the underground environment, etc.).

3. *Continuous Risk Assessment*

This is the most important form of risk assessment, which should.take place continuously, as an integral part of day-to-day management. It may not use the more sophisticated hazard identification and risk assessment tools. It will mainly be used by frontline supervisors (audits, strata control checklists, etc.). Checklists can also provide input to an ongoing working area risk classification process mat will monitor ground conditions, control of conditions and serve to highlight any detenotion that requires remedial action.

<u>*Risk Assessment Model for Mines*</u>



Many mines, especially deep-level gold mines, in South Africa develop their own rock-related risk management system according to their needs. Many parameters such as seismicity, mining layout, sloping width, ERR, ESS, face shapes, support, gully shape, ground condition, drilling & blasting, etc. are taken into account in the design of a rock-related risk management process.

9 EXPECTATION FROM ALL CONCERNED

What I strongly believe is that rock-related safety in mines should be everybody's concern and responsibility. Each employee, all employee representative unions, all levels of management and the inspectorate are required to be committed to rock-related safety, to acting safely at all times and to promoting safety. The accident investigations and inquiries that I conducted in deep-level gold mines revealed that if the following responsibilities were carried out by all concerned, Aère would not be any problems in managing rock-related issues in mines.

What we should expect from employers.

- define practical and adaptable rock-related safety objectives;
- define rules and rock-related safety standards;
- define realistic rock-related safety training and hazard identification so that all employees can perform assigned duties safely;
- consult and discuss rock-related safety matters with workers and state at all times;
- encourage safe behavior by disciplining unsafe behavior,
- appoint all rock mechanics officers to prevent conflicts between production section and rock mechanics department.

What we should expect from employees:

- participate İn the continuous improvement of the safety process of the company;
- comply with safety regulations and safe work procedures;
- identify and initiate action to correct unsafe work practices and conditions;
- challenge work procedures, practices or behaviors that you believe to be inappropriate;
- take reasonable care to protect your safety as well as that of other people.

What we should expect from unions:

- proper participation and involvement in accident investigations and inquiries;
- properly trained union representatives concerning rock mechanics issues.

What we should expect from rock mechanics officers:

- properly qualified and trained staff;
- properly equipped service department;
- safe, economic design of mine workings and support systems;
- identification *of* potentially dangerous situations (seismic monitoring) or recommendation of remedial action before workers are injured or working place damaged;
- develop a strategy to reduce the incidence of as well as ameliorating the effects of rockburst;
- routine monitoring and investigations;
- quality control of support units;
- provide basic strata control training for production personnel;

What we should expect from the state:

- continuous participation and co-operation concerning rock-related issues at all times;
- enforcement of regulations in mines;
- drafting and implementing more rock-related safety regulations for die Act;
- properly trained and qualified inspectors.

10. CONCLUSIONS

Over the years, the South African rock mining industry sustained, and continues to sustain, a high level of rock-related accidents, and the resulting rate of human casualties (injuries and fatalities) has been, in worldwide terms, unacceptably high. Of these accidents, 43% of all accidents have been rock-related, that is, the result of rockfalls or rockbursts. In gold mines rockfall and rockburst accidents also constitute the most significant cause of all fatalities. In 1999, 68% of all fatalities took place in gold mines, of which 51% of all accidents that occurred in gold mines were rock-related.

The author conducted 25 rock-related accident investigations and inquiries in order to determine the actual cause of 38 fatalities. The investigations and inquiries revealed that most of the fatalities and seismic damage mechanism occurring in deep-level gold mines could have been minimized if the following points had been in order: -

1. Installation of the support as per standards.
2. Additional support installation and areal coverage
3. Proper removal of the support units.
4. Non-adherence to designed mining layout & sequences-poor mining practice.

5. Hazard identification & training.
6. Appreciation to seismic monitoring and prevention in mines.

It is my considered opinion that the amount of seismicity and rock-related fatalities in mines can only be reduced if the following are taken in to account. -

- keeping or introducing *backfill support* in all deep-level gold mines in terms of strata control, regional support, environmental control, ERR control, etc. This conclusion is based on my routine underground inspection and accidents investigations.
- rock engineering services can make great contributions to the rock-related safety of the mine. All rock mechanics personnel should be legally appointed so that they can speak and express themselves in management language in order to get their rightful recognition.
- rock-related risk management should be integral to the management system of the mine to reduce accidents.
- rock-related accidents can be reduced significantly by training the workers in strata control and support issues.
- in-stope face support systems must be closed to the face as much as possible and die support should have sufficient areal coverage.
- adherence to layout design and extraction principals of the mine's rock mechanics department.
- the concepts and tools for seismic prediction in South African mine have been developed, and the results are appreciated and valid in a more holistic approach towards the assessment and management of seismic risk.

The mining industry in South Africa, especially deep-level gold mines, has no choice other than to radically improve its safety and productivity records. If the gold mines are to be in a position to enjoy continued long-term success, they must utilize the most advanced technology available to reduce rock-related fatalities and injuries.

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