G+A

CHAMBER OF MINES OF SOUTH AFRICA

WRITTEN EXAMINATION FOR THE CERTIFICATE IN ROCK MECHANICS

METALLIFEROUS OPTION

PART 2 - APPLICATIONS 13 May 1997

EXAMINER: Mr WJ de Maar

MODERATOR: Mr M Roberts

Maximum time allowed 3 hours (09:00 - 12:00)

ANSWER ALL QUESTIONS

A pass mark for this paper is 60 per cent.

References are not permitted.

Hand-held electronic calculators may be used. (No pre-programming).

Put your examination number of the outside cover of each book used, and on any graph paper or other loose sheets handed in.

NB: Your name must not appear on any answer book or loose sheets.

Write on one side of the paper only.

Show all calculations on which your answers are based.

In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.

Graph paper is available from the invigilator.

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 1

(a) Caving is used selectively in certain narrow tabular deposits with considerable success.

i) Describe the caving method commonly used and its associated support. 4 marks

ii) What rock conditions promote caving? 2 marks

iii) What rock mechanics benefits are derived from caving? 3 marks

iv) What practical problems are encountered in cave mining? 3 marks

(b) The management of a gold mine is considering the introduction of face support at a maximum distance of 2 m from the face after the blast. The flat-dipping tabular orebody is at a depth of 2 000 m below surface. The average stoping width is 1,5 m.

As the mine's rock mechanics officer you have been asked to give recommendations. What aspects should you consider in designing stope support, keeping the guidelines for Codes of Practice for support in mind? 13 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 2

(a) A 75° dipping fault was intersected during the development of a 10 m high hoist chamber in quartzitic rock. The fault runs parallel to one of the sidewalls, daylighting 1 m above the floor of the hoist chamber. There is a smooth horizontal bedding plane 1 m from the top of the hoist chamber. Tests on the fault plane gave a cohesion of 1,5 kN and an angle of friction of 40°.

i) Calculate the minimum additional restraining force necessary to stop the wedge from sliding into the hoist chamber. — 3 marks

ii) What is the safety factor for the wedge on the fault plane? What safety factor is regarded as acceptable? — 3 marks

iii) Give an excavation and support sequence for the hoist chamber. — 4 marks

(b) Strike stabilising pillars have been introduced on a number of deep level gold mines. Critically discuss the implementation of strike stabilising pillars taking examples from the mining industry. — 10 marks

(c) i) Calculate the Rock Wall Condition Factor (RCF) for the following parameters:

$\sigma_1 = 40$ MPa $\quad \sigma_3 = 20$ MPa $\quad \sigma_c = 70$ MPa and F = 1,0 — 3 marks

ii) What in your opinion should the recommendation be according to the calculated RCF? — 2 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 3

(a) In an elastic medium the convergence of an underground parallel-sided panel is given by

$$Sz = \frac{2(1-\nu)\,q}{G} \sqrt{l^2 - x^2}$$

where
ν = Poisson's ratio
G = Modulus of rigidity
q = vertical stress
l = half span of panel
x = distance from panel centre
Sz = elastic convergence

Calculate the elastic convergence 20 m from the face of a panel 580 m wide at a depth of 3 100 m below surface. The stoping width is 1,5 m. The modulus of rigidity is 60 GPa and Poisson's ratio is 0,2. 4 marks

(b) A horizontal circular tunnel is bored in quartzite at a depth of 2 800 m below surface. The relative density of the overlying strata is 2,7. The horizontal to vertical stress component is half (k = 0,5).

i) From your practical experience where would you expect fractures to be located and to what depth around the tunnel? Discuss the support requirements for this bord tunnel. 5 marks

ii) Sketch the complete state of stress of the surface of the tunnel. 2 marks

(c) The stability of pillars depends on the pillar itself and the surrounding strata.

i) What are the criteria which determine the stability of a pillar and the surrounding strata? 4 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 3 (Cont.)

ii) Sketch a load deformation curve of a typical yield pillar with a width to height ratio of 2, and name the various stages of the load deformation curve. 3 marks

iii) Indicate with simple sketches what is meant by controlled and uncontrolled pillar failure. 3 marks

(d) Describe what a control pillar is and what purpose it serves. 2 marks

(e) What is pre-splitting and why is it used? 2 marks

TOTAL 25 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 4

(a) The attached plan shows a portion of the "Lucky" Gold Mine. The mine has unpay zones, structural disturbances and high seismicity. A scattered mining method is employed.
Haulages are pre-developed and are situated 25 m below the reef plane. The stoping width is 1 m.

(i) Discuss whether the scattered mining method is appropriate. Give reasons for your answer. 2 marks

(ii) Discuss the location of haulages below the reef plane. What alternative can you suggest? 2 marks

(iii) How would you extract the block of ground below the dyke between the A6 and A7 connections? 2 marks

(b) Pre-conditioning is presently researched in deep level gold mines.

i) Discuss the rock mechanics principles that are involved. 3 marks

ii) Briefly describe the two different methods of pre-conditioning of a stope face. 3 marks

iii) What is the outcome in stopes where pre-conditioning is on trial? 3 marks

(c) A seismic event occurred ahead of a stope face at depth. Damage to the area consisted of large falls of ground in the stope face over approximately 15 m of the length of the panel, and to a height of approximately 1,2 m. The rock in the stope face showed fragmentation of, on average, 3 cm to 5 cm over most of the area, with one large block which fell out on a joint plane-bedding plane combination. The event was located on the mine's seismic system.

i) Give a list of typical parameters which can be obtained from the seismic system. 4 marks

PART 2 - APPLICATIONS - METALLIFEROUS

QUESTION 4 (Cont.)

ii) Explain the significance of the various parameters and how the information can be used to improve the mining layout and support design in order to reduce the damage as a result of seismicity.

6 marks

TOTAL 25 marks

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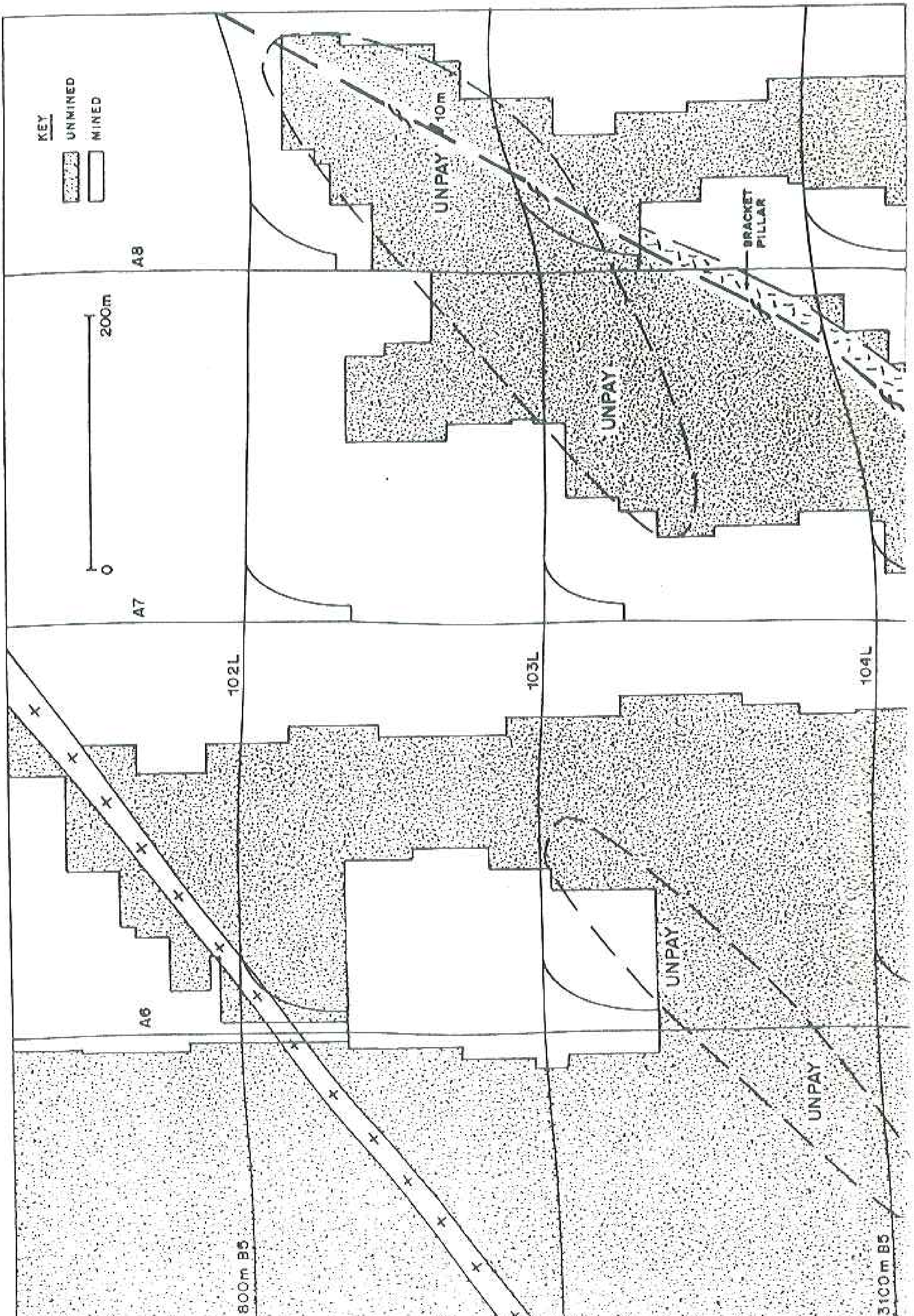
Question 4A


KEY
UNMINED
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200m
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103L
104L
10m
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UNPAY
BRACKET PILLAR
2800m B5
3100m B5

Rm mil P2
May 19

QUESTION 1 - ANSWERS

a)

i)

- weak hangingwall is collapsed 6 - 7m behind the face
- timber sticks and hydraulic props on the face
- hangingwall slot is blasted 10 - 12m behind the face to induce the cave
- timber sticks must be blasted out behind the 3 rows of hydraulic props
- continuous and rapid face advance

ii)

- geology and highly laminated hangingwall strata
- shear movement along bedding planes in the hangingwall
- "plastic" flow of the hangingwall

iii)

- stope support strategy to cater for weak ground condition
- decrease of stress levels on the face
- decrease in level of seismicity
- decrease of stress damage on the face
- more competent hangingwall conditions in the face area

iv)

- the effectiveness of installed support
- containment of blast damage to the hangingwall
- lack of continuous and rapid face advance causing cave overruns and strata control problems on the face
- cave hangups causing increased stress damage on the face and ahead of the face
- very competent hangingwall strata

b) The answer should broadly consider aspects related to the guidelines for Codes of Practice for Support

- 5 year history of rock related accidents
- determine the degree of risk for rockfalls and rockbursts
- determine the specific geological, mining method, people and external hazards
- define strategies to manage the risk
- the strategy to include measures to avoid failures, the overall mining method and sequencing to be followed
- the stope and gully support system design to include: energy absorption capacity of support members (depends on rockburst conditions), spacing of support members, support resistance required by the hangingwall, areal coverage of the support member and the anticipated stope closure.

RM P2 (in) May 1997

QUESTION 2 - ANSWERS

a) (i) Disturbing force parallel to the fault plane

W = density x volume = 231,12kN per metre

D = W Sin 75° = 217,18kN

Resisting forces perpendicular to the fault plane

R = cA + Wcos75° tan 40°

R = 1,5 + 5,0 = 51,69kN

Minimum additional resisting force required is 217,18 - 51,69 = 165,49kN

(ii) Safety Factor is $\dfrac{\text{Resisting force}}{\text{Disturbing force}} = \dfrac{51{,}69}{217{,}18}$

SF = 0,238

A safety factor of 1,5 is regarded as acceptable.

(iii) Mining the top cut first and supporting the hanging wall of the top cut. Then progressing downwards taking 3 cuts in total.

b) Strike Stabilising Pillars (SSP)

- Each stabilising pillar and each underground situation is unique
- Western Deep Levels is the only mine where SSP have proved to be unstable (foundation failure - back area seismicity)
- All other deep level mines employing SSP's have derived benefits
- Pillars at Western Deep Levels appear to bear greater load than other mines at the same depth
- Pillar punching at Western Deep Levels (elastic displacements)
- Average pillar stress not to exceed 600 MPa or 2 x σ_c
- Geological structures should be included in SSP to increase extraction ratios
- SSP impose the disadvantages of mining inflexibility and back area pillar seismicity
- SSP with leads and lags of longwalls on either side result in enhanced levels of seismicity
- Average pillar stress, energy release rate, extraction ratio and width to height ratio are used for strike stability pillar design. These criteria are inadequate as pillars are composed of failed and intact rock.
- SSP usually have a width to height ratio in excess of 20
- Extraction ratio of 85% at 2000m depth to 65% at 4000m depth
- Backfill should complement strike stabilising pillars below 2000m depth.

c) (i) $RCF = \dfrac{3\sigma_1 - \sigma_3}{F\,\sigma_c} = \dfrac{120 - 20}{1{,}0 \times 70} = \dfrac{100}{70} = 1{,}4$

(ii) The level of support must be increased.

Rm P2

QUESTION 3 - ANSWERS

a) $$\frac{2(1-0{,}2)}{60\ 000} \quad \times \quad 83{,}7 \quad \sqrt{290^2 - 270^2}$$

$$= \quad 0{,}236\text{m}$$

b) (i)

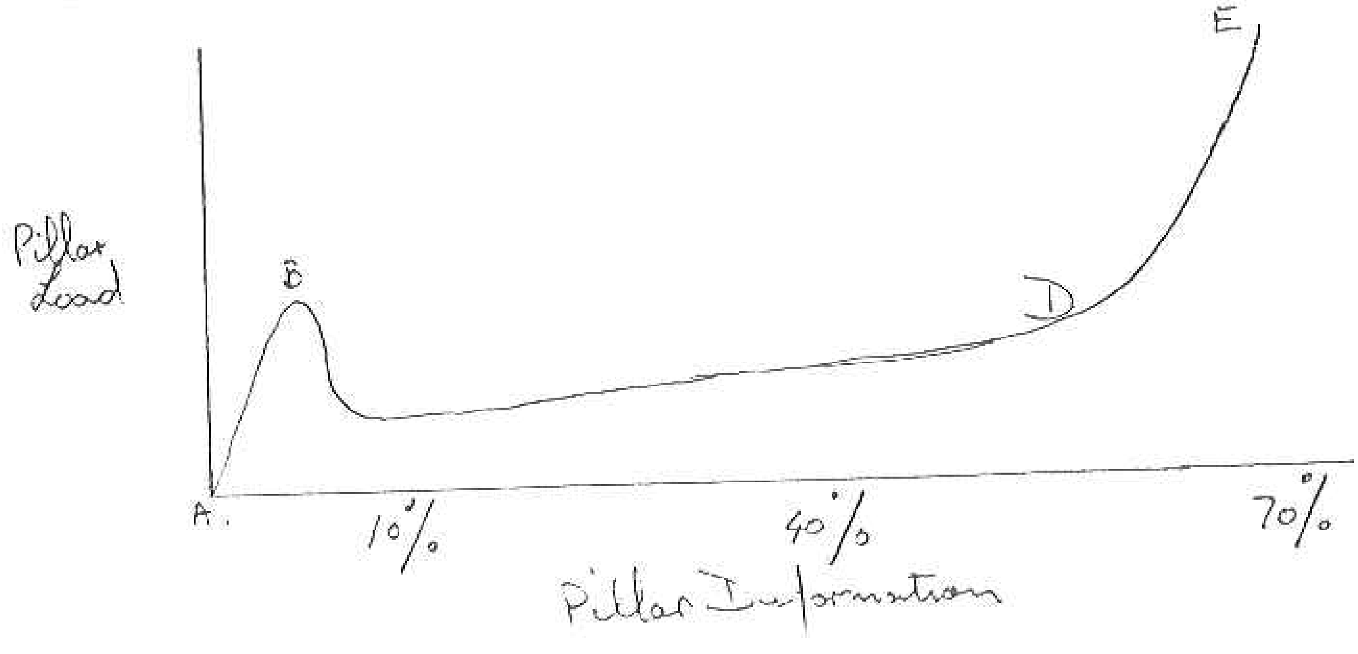
- In the sidewall of the circular tunnel
- Fractures should be slightly curved and parallel to the sidewall of the tunnel
- The fractures extend horizontally to approximately one diameter of the tunnel

(ii) The hangingwall stress drops to approximately 0,5 times the vertical stress and the sidewall stress increases to approximately 2,5 times the vertical stress.

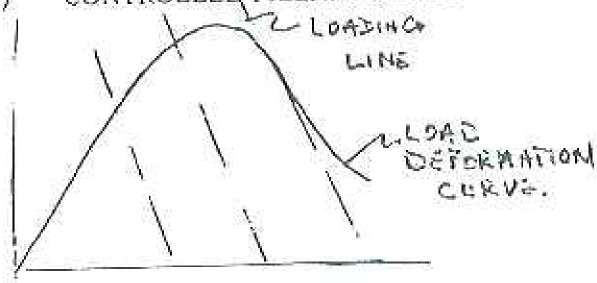
c) (i)

- Material of which the pillar is composed
- The width to height ratio of the pillar
- Discontinuities within the pillar and surrounding strata
- The stiffness of the surrounding strata
- The size of the pillar
- The load on the pillar

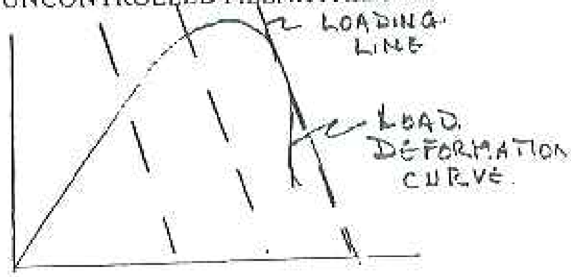
(ii) AB - Pre-peak
BC - Post peak
CD - Residual Strength
DE - Strain Hardening



(iii) CONTROLLED PILLAR FAILURE



UNCONTROLLED PILLAR FAILURE



d)

- Control pillars have w:h ratio in excess of 10
- Control pillars are indestructible
- Used for compartmentalization in shallow mines
- Final line against regional collapse
- Resists surface subsidence

e)

- Pre-splitting involves the creation of a smooth stable face after the blast by drilling holes along the boundary line of the final face
- Holes are lightly charged
- Pre-split holes are fired and connect with cracks prior to the main blast

QUESTION 4 - ANSWERS

(a)

(i) The circumstances dictate that a scattered mining technique is used or possibly sequential mining. The partial extraction of the orebody needs a number of attaking points. To some degree partial extraction assists with minimising ERR and ESS. Leaving strategic pillars between connections will keep stress concentration levels down.

(ii) The pre-developed haulages are unlikely to cope with the high induced stress levels and extreme changes in stress. The orebody does not allow post developed haulages. Consideration should be given to:

- waste mining above haulages to destress them where unpay zones occur
- bolstering the support of haulages to cope with stress changes
- locating haulages deeper into the footwall

(iii) Put up a diagonal raise from the A6 to the A7 connection leaving a substantial bracket pillar on the dyke. History of mining north of the dyke indicates difficult mining conditions.

- Mine downdip from the diagonal.
- The sequencing of this block of ground must be confirmed by numerical modelling.
- As an alternative, A6 and A7 connections to be holed just below 102 level. The block of ground can be updipped leaving a substantial bracket pillar on the dyke. (Mining stops when conditions deteriorate).
- Numerical modelling should confirm the safest way of extracting the block of ground.

b)

(i)

- redistribution of stress away from the working face

- reducing the risk of a face burst
- lower stress ground is able to absorb more energy from distant seismic events
- strain energy release is facilitated by stable sliding of blocks past each other.

(ii) <u>Perpendicular Holes</u>

- short holes drilled perpendicular to the face.
- 3m long holes (38-42mm diameter) spaced 3m apart in the middle of the face.
- ANFO explosives is recommended
- one metre of stemming for hole consisting of clay, bentonite or sand

<u>Parallel Holes</u>

- face parallel holes drilled up to 5,5m from face
- holes are 89mm in diameter and extend the length of the face
- emulsion explosive is recommended
- crushed rock and clay stemming

(iii)

- reduction in the incidence of rockbursts
- the number of severe rockbursts were reduced
- increased drilling and charging up time
- increase in face advance
- improved hangingwall conditions

c)

(i)

- Location of seismic event
- Time of seismic event
- Magnitude of seismic event
- Seismic moment
- Radiated energy
- Source dimension
- Calculation of ESS

c)

(ii)

Location

- Displacement of rock in relation to mining geometry
- Locating "hot spots"
- Locating adverse structure
- Locating problematic mining layout
- Locating area for possible rescue operation

Time

- Frequency of events
- Related to mining activities.

Magnitude

- Relates to mechanism (crush or shear)
- Larger magnitude events produce more potential damage
- Adequacy of support (possible improvement)
- Charge stope layout and support
- Possible withdrawal of personnel

Moment

- The seismogram can indicate direction of movement (if discontinuity is identified).
- Also identifies area where instability occurred.
- Mining layout and support to be changed according to predicted seismicity.

Energy

- Seismogram indicates the potential energy of the event.
- Energy must be related to support resistance (may be changed)

Source

- Identifies the area from where this seismic event took place.
- Identifies potential area of concern. (geology or mining layout)
- Identifies mining and support measures that must be taken to minimise seismicity and damaging effects.

PAPER 1

EXAMINERS COMMENTS

QUESTION 1 Nobody used 3D Hooke equation!

QUESTION 2 Quite well answered

QUESTION 3 —"—

QUESTION 4 Only two candidates got this one!

QUESTION 5 Second part poorly answered.

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL

SIGNATURE

PAPER 2 (MET)

EXAMINERS COMMENTS

QUESTION 1 Disappointing answers, particularly the aspects that relate directly to the Codes of Practice !

QUESTION 2 Poorly answered. It was surprising to see how few candidates knew anything about support design !

QUESTION 3 In general the question was well answered

QUESTION 4 Reasonably answered.

QUESTION 5

QUESTION 6

QUESTION 7

QUESTION 8

QUESTION 9

QUESTION 10

GENERAL

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