MEMORANDUM

SUBJECT: CERTIFICATE IN ROCK MECHANICS: PAPER 2	**EXAMINER:** LJ SCHEEPERS
SUBJECT CODE: COMRME	**MODERATOR:** P GREYLING
EXAMINATION DATE: April 2013	**TOTAL MARKS:** [100] **PASS MARK:** 60%
TIME: 9:00 – 12:00	

NUMBER OF PAGES: 4

SPECIAL REQUIREMENTS:

1. **<u>ALL</u> candidates to answer all 5 questions**
2. References other than those provided are not permitted.
3. Hand-held electronic calculators may be used.
4. Write your examination number on 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.

5. **<u>Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).</u>**
6. Show all calculations on which your answers are based.
7. Illustrate your answers by sketches of diagrams wherever possible.
8. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
9. Answers must be given to an accuracy that is typical of practical conditions.

QUESTION 1 Geotechnical characteristics (20 marks)

Data from a drilling programme on your mine is shown in the table below.
The positions of the drill holes are shown on the accompanying map (Figure 1). Redraw the map with your answers in your answer book (you may use the graph paper in the centre of your answer book).

Position	Height above sea level(m)	Depth of Mineralised layer below collar(m)
A	230	10
B	280	80
C	330	160
D	280	35
E	300	75
F	340	135
I	310	55

1.1. Draw in the contours of the mineralised layer on the plan and calculate the dip. Also show the fault in relation to the mineralised layer. Show the strike of the fault approximately. (10)

1.2 Also shown on the map are two section lines G-H and C-B-I. A fault is indicated at position J on Section G-H.

1.2.1 Draw section G-H and determine the dip of the fault and the throw and heave of the fault along this section. (5)

1.2.2 Draw Section C-B-I with the surface topography and mineralised layer and fault. Calculate the apparent dip of the mineralised layer and the apparent dip of the fault. (5)

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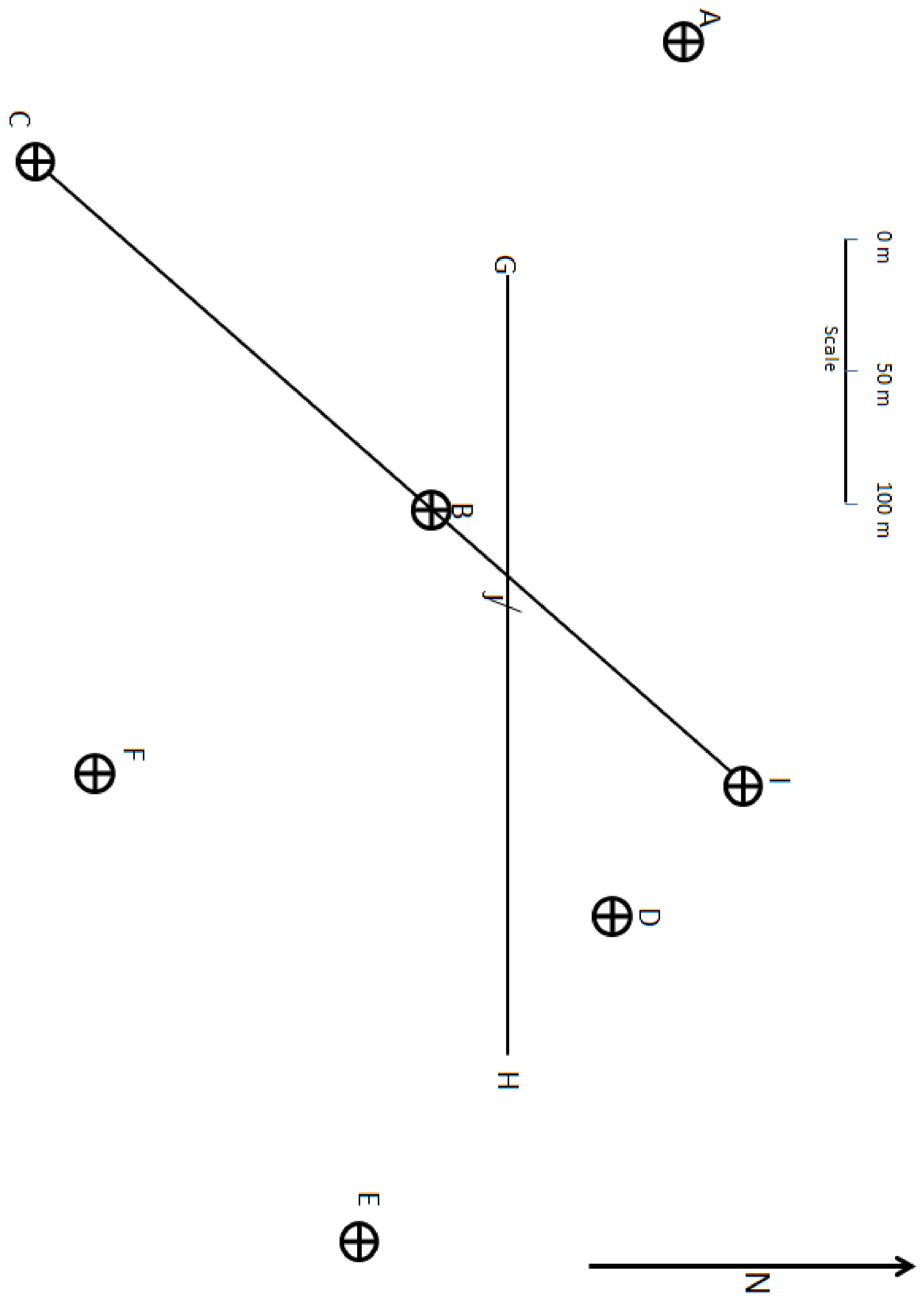
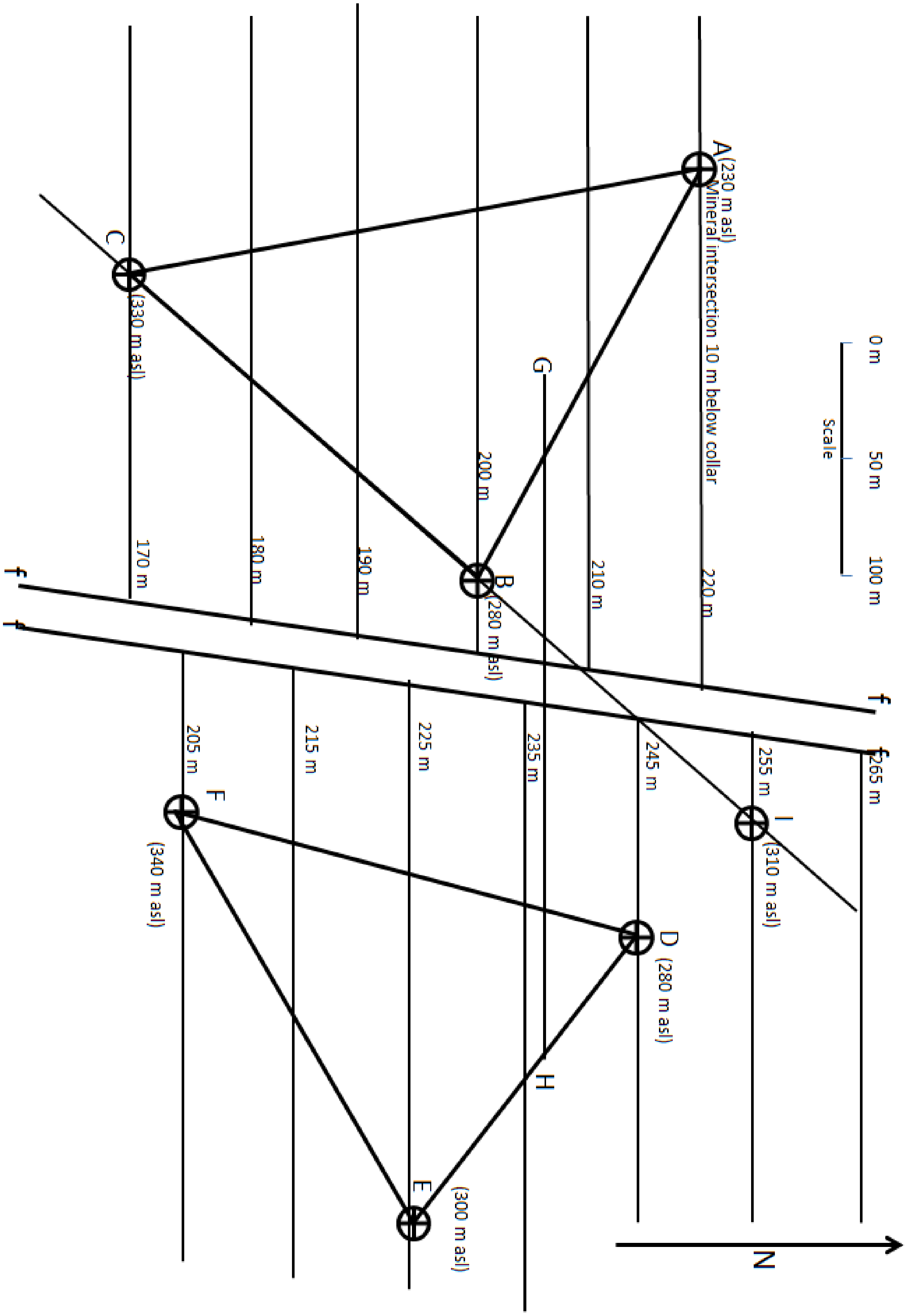
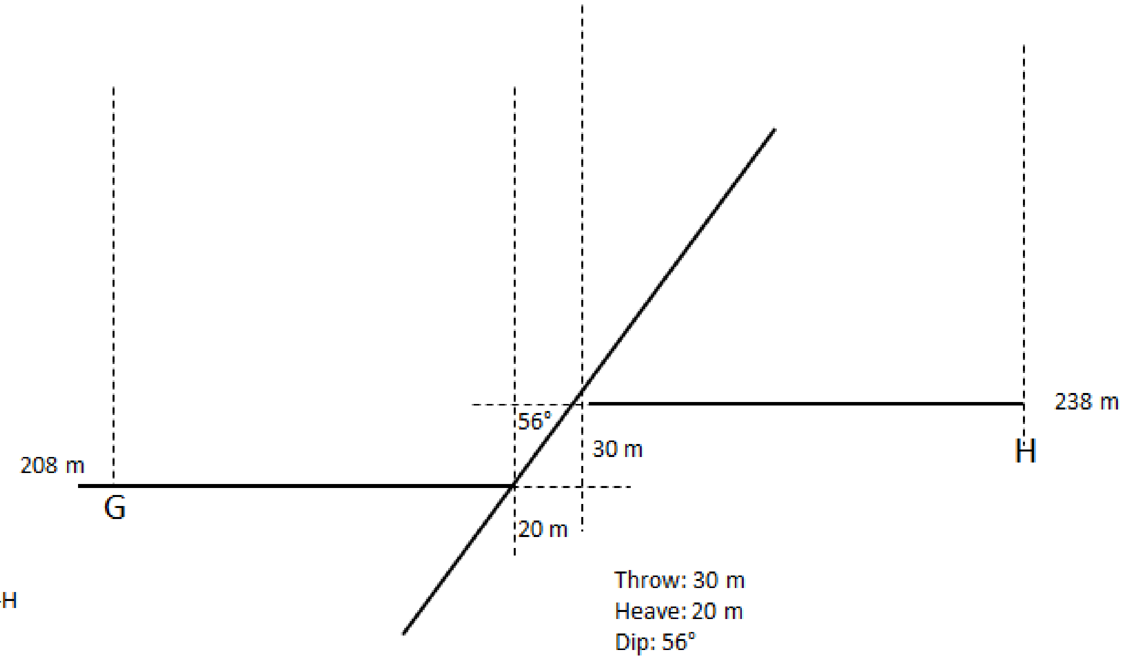


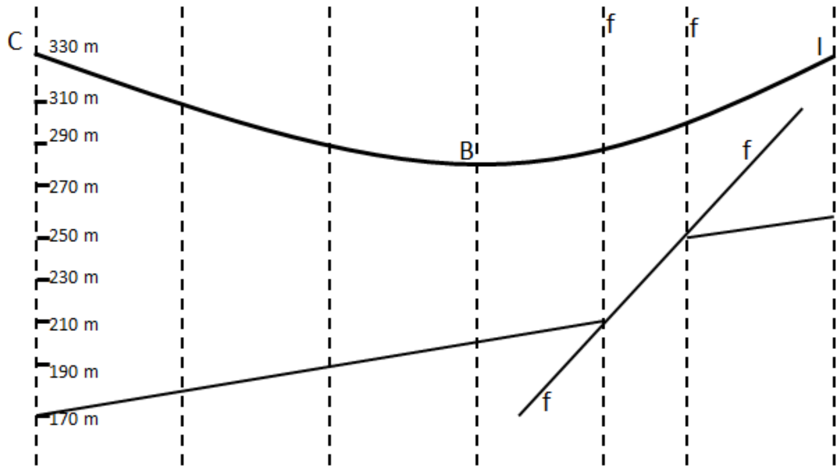
Figure 1 Map of borehole data (Question 1)


A (230 m asl)
Mineral intersection 10 m below collar
B (280 m asl)
C (330 m asl)
D (280 m asl)
E (300 m asl)
F (340 m asl)
G
H
I (310 m asl)
170 m
180 m
190 m
200 m
210 m
220 m
205 m
215 m
225 m
235 m
245 m
255 m
265 m
f
f
f
f
0 m
50 m
100 m
scale
N



Section G-H

Section C-B-I



Dips calculated
Actual dip: $\tan^{-1}(10/50) = 11.3°$
Apparent dip deposit:
$11.3 \cos 42 = 8.4°$
Apparent dip fault:
$56 \cos 42 = 41.6°$

QUESTION 2. Rock and rockmass behavior (20 marks)

You have both deep and shallow development ends on your hard rock mine. Use the geotechnical data below to answer the questions (show all calculations and assumptions).

Density of rockmass: 3000kg/m^3

Gravitational acceleration: 9.81m/s^2

UCS of host rock: 100 MPa

UCS of soft erosion channel: 20 MPa

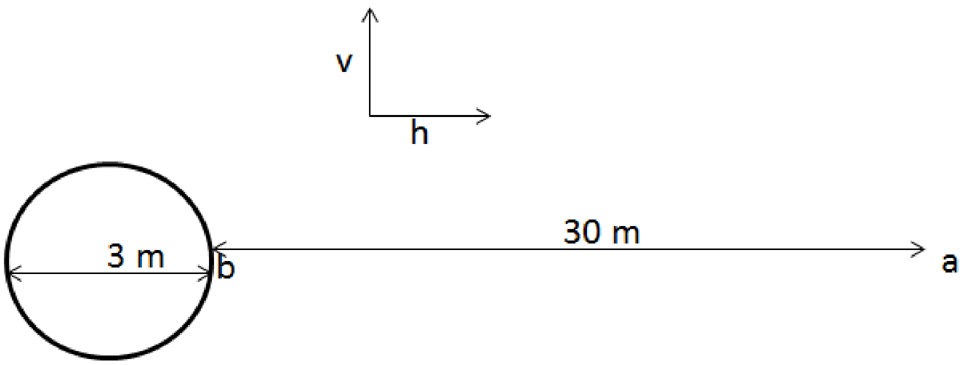
UCS of stiff dyke: 200 MPa

Shallow area depth: 200 m

k-ratio: 2

Deep area depth: 3000 m

k-ratio: 0.5



2.1 For 3m diameter circular tunnels being developed in both the deep and the shallow mining areas, calculate the stress at positions a and b (transfer the table to your answer sheet and complete the empty cells). (8×½=4)

Deep area

$\sigma_v = \rho gh = 3000 \times 9.81 \times 3000 = 88.3$ MPa

$\sigma_h = ½\sigma_v = 44.2$ MPa

shallow area

$\sigma_v = \rho gh = 200 \times 9.81 \times 3000 = 5.9$ MPa

$\sigma_h = 2\sigma_v = 11.8$ MPa

Stress		Position a	Position b
deep	σ_h	44.2	0
	σ_v	88.3	$3\sigma_v$ = 264.9
Shallow	σ_h	11.8	0
	σ_v	5.9	$3\sigma_v$ = 17.7

2.2 Indicate if you expect fracturing to occur in the host rock at positions a and b for shallow and deep development and why (4)

For deep development at position a the stress does not exceed the strength of the rockmass and no fracturing is expected. At position b the vertical stress exceeds the strength of the rockmass and the confining stress is very low and therefore fracturing can be expected.

For shallow mining the stress does not exceed the strength at any position and no fracturing is expected

2.3 For deep development, if position a was located in the soft erosion channel, would you expect fracturing to occur? (2)

Even though the stress exceeds the UCS of the soft erosion channel, due to horizontal confinement the strength is increased and possibly no fracturing will occur.

2.4 For a square tunnel in the deep area, what would the vertical stress (σ_z) at point b be? (1)

$2\sigma_v$ = 176.6 MPa

2.5 Calculate the RCF for a planned circular tunnel in the deep area that will traverse the host rock as well as the erosion channel and the dyke (transfer the table to your answer sheet and complete the empty cells). Assume a rockmass rating of 60%. Show all calculations and assumptions. (6×½=3)

RCF = $(3\sigma_1-\sigma_3)/F\sigma_c$, F=0.6

RCF	Host rock	Soft erosion channel	Stiff dyke
Deep tunnel	3.7	18.4	1.8
Shallow tunnel	0.5	2.5	0.2

2.6 Interpret the RCF values in terms of expected tunnel stability. (4)

The RCF values in the deep tunnel through the host rock and the soft erosion channel are extremely high and indicate potential tunnel instability. The RCF values in the shallow area host rock and dyke are extremely low and indicate stable ground.

2.7 Comment on the applicability of the RCF values for tunnel design and what can be done to ensure correct application of these values in tunnel design. (2)

The RCF values are not necessarily applicable to your mine and should be calibrated through back analysis to ensure applicability.

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QUESTION 3. Mining layouts (20 marks)

View the information in the table and answer questions 3.1 to 3.3 using the information in the table:

Mine	Description	Depth below surface (m)	Average fault spacing (m)
A	Narrow tabular hard rock	4000	500
B	Massive soft rock	100	500

Transfer the answer table to your answer sheet and complete the empty cells

3.1 Describe the most likely mining strategy for mines A and B. In your answers refer to likely mining spans and pillar types and sizes. (6)

3.2 Describe the most likely placement of access development (4)

3.3 List the hazards associated with a fault in the stoping area for mines A and B. Highlight the differences in hazards where applicable. (2)

3.4 List the risk management strategies for stoping associated faults that you will implement at mines A and B. (4)

3.5 List the risk management strategies for access ways associated with faults that you will implement in mines A and B (4)

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	Mine A	Mine B
3.1 mining strategy	Sequential grid or mini-longwall or closely spaced dip pillars Spans controlled through mine design limited to 180m maximum Regional stability pillars (30 to 40 m)	Block caving, cut and fill, open stoping etc Large continuous mining spans Large pillars - Sill pillars, barrier pillars – prevent surface subsidence, separate caves or blocks
3.2 Access development	Haulages (long-term infrastructure) placed remote from mining	Access ways can be placed in the orebody to minimise waste development. Plan major

	abutments, either deep in the footwall or deep in the hangingwall Crosscuts placed directly below raises to ensure overstoping early in extraction sequence or as follow behind ends with longwall mining	excavations away from structure and install tendon support
3.3 Hazard associated with faults	Large seismic events on faults	Localised FOG hazard associated with wedges on weak side
3.4 Risk management strategies	Bracket pillars on structures. Approach angle > 35° if structure approached by a large mining front. Minimise mining in structure Lead panels adjacent to structure	Plan draw points away from structure. Install tendon support at structure

QUESTION 4. Mining support design (20 marks)

4.1 In an ultra-deep level narrow tabular mine using hydraulically placed classified tailings backfill placed in geotextile bags, a large number of bag failures have been reported. Discuss the potential causes that you would investigate to solve this problem. (10)

High percentage of fines – the fines will clog the apertures in the geotextile bags, reducing drainage of water and potentially causing a high hydraulic head – this may result in bag failures. Proper cylconing may fix this problem.

High flow-rate – with a high flow rate, the bag is filled much faster than the rate of water drainage, resulting in a high hydraulic head and potential bag failure. Smaller diameter delivery hoses may fix this problem.

Low RD; i.e. excessive water in the tailings will improve the flow rates but may result in high hydraulic head. The correct mixture of water and slimes is important.

Mismatch between geotextile bag and backfill properties – a range of geotextile bags must be tested with the backfill to choose the optimum bag that will ensure fast drainage without excessive losses of particles. If the apertures are too small, draining will be hampered, resulting in a large hydraulic head and potential bag failure.

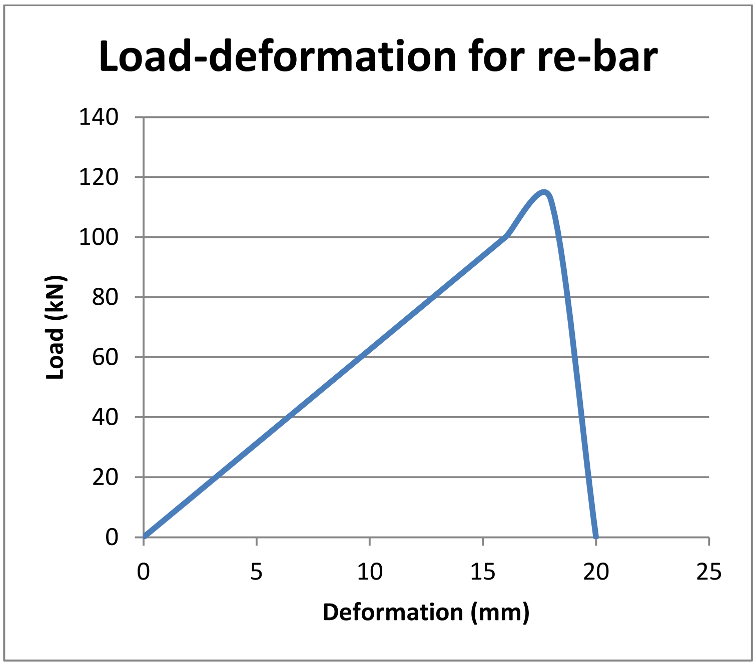
Low quality geotextile bags – follow up on quality control

Insufficient placement of support units (elongates or packs) at the bottom of the panel to create a proper bulk head.

4.2 In a shallow open stoping mine it is decided to use backfill. Describe the most likely fill strategy and fill type and motivate your answers. (5)

The fill is either placed to support the hangingwall (carry the overburden) or to confine the in-stope pillars. If used to confine support pillars, cement additives will not be required to stiffen the support response and hangingwall contact is not critical. If used to support the overburden, then due to low expected closure the fill should be stiffened up with cement additives. Filling does not have to be concurrent with stoping. A stope can be mined to its full extent and then barricaded off and filled. Hydraulically placed fill is probably the most convenient.

4.3 Draw a load-deformation graph for a rebar support unit and describe the conditions where such a support unit will be used and the conditions where this support unit will not be appropriate. (5)



Tunnel support as rockmass reinforcement. It must be full column grouted. It can only be used where little deformation of the rockmass is expected as it has little yielding capability. It is a stiff support type, but passive and can therefore not be used in areas where active support is required (wedge support at a fault) or under seismic loading conditions.

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QUESTION 5. Monitoring, numerical modeling and risk assessment (20 marks)

8.1 A massive mine with a limited ore body in a hard, competent host rock with several intrusions recently expanded from open pit to u/g operation.

8.1.1 What could be the purpose of operating a seismic network on this mine? (3)
slope stability, crown pillar stability, caving process, activity on geological structures

8.1.2 Describe a rough network design to cover the objectives (2)
5 to 7 sensors in the pit walls, 6 to 8 u/g surrounding the cave, 2 of these close to surface

8.1.3 Which type of ground motion sensor would be suitable? (2)
4.5Hz tri-axial geophones for the slope and shallow sites, tri-axial accelerometers for deeper sites (small events in cave hanging-wall, else 14Hz geophone sets)

8.1.4 List the general challenges faced by networks around massive ore bodies? (2)
mixed set of objectives, cave creates a shadow zone, complex wave paths, needs good 3D coverage for location accuracy

8.1.5 List the input parameters / variables related to rock mass that need to be quantified (2)
density, rigidity, elastic wave velocities for P and S, attenuation quality factor Q

8.1.6 For network configuration, in which way could calibration blasts assist and where would they have to take place? (3)
known location to test loc. error, P- and S-velocity determination, some measure of heterogeneity, quantify accuracy of energy release and source size;
On at least two different elevations, eg deep and shallow, and in all main rock types;

8.2 Numerical modelling.

8.2.1 What is the objective / purpose of conducting numerical modelling? (3)

Models are used in engineering for the following objectives:-

- Design – optimisation of an engineering system based on redefined criteria.
- Mechanics – development or improved understanding of an engineering or natural system.

Other sensible objectives will also be accepted. 1 mark per valid comment.

- Verification / Explaining of observed phenomenon
- Back analysis to future predictions
- Risk assessment and relative risk comparisons

8.2.2 Name existing and commonly used numerical modelling codes to conduct the following analyses (3)

a) A detailed assessment of expected fracture patterns in a single pillar in a typical mine

b) An assessment of expected block fallout size in a highly jointed shallow mine.

c) Assessing seismic risk on several sections in a deep level hard rock mine.

a) non-linear or failure models (finite element or distinct element) i.e. FLAC / UDEC / PFC / ELFEN

b) JBLOCK (FLAC / UDEC can also be used)

c) boundary element models like MAP3D / MINSIM / BESOL / TEXAN

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