Paper 3.1. May 2011 Answers

Question 1

Important to note from the Question

- Deep mining - thus failure is stress driven
- **Closely spaced bedding planes (dipping to the South) – makes N-S long axis orientation preferable.** (Examiner was strict here deducting marks if students didn't pick this up.)
- 40m middling has been given – this information should be used in some way (for the 45° rule – NONE of the students did this though)
- The dyke (both strata control and **seismic risk**)

1.1)

- **The chamber developed in elevated stress** **(2 marks)**
  - Chamber is below the shaft pillar (elevated stress)
  - Chamber is close to the abutment (very high abutment stress)
  - The result is increased stress driven failure and vulnerability to ground motions from seismic events.
  - Always preferable to develop important excavations in a de-stressed environment.
- **The chamber is located in the path of the dyke** **(2 marks)**
  - Chamber intersected by dyke. This increases the chance of nearby seismicity and also the vulnerability of the chamber. Students could also refer to localized weakness due to sympathetic jointing and localized weaknesses.
- **The long axis of the chamber is not ideal** **(2 marks)**
  - The long axis is roughly orientated E-W. This is parallel to the strike of the bedding planes (which are reported as being closely spaced). From a stability point of view it is better to orientate the chamber N-S reducing the span over which individual joint planes traverse.

Other sensible answers also accepted like,

1.2) Refer to drawing …

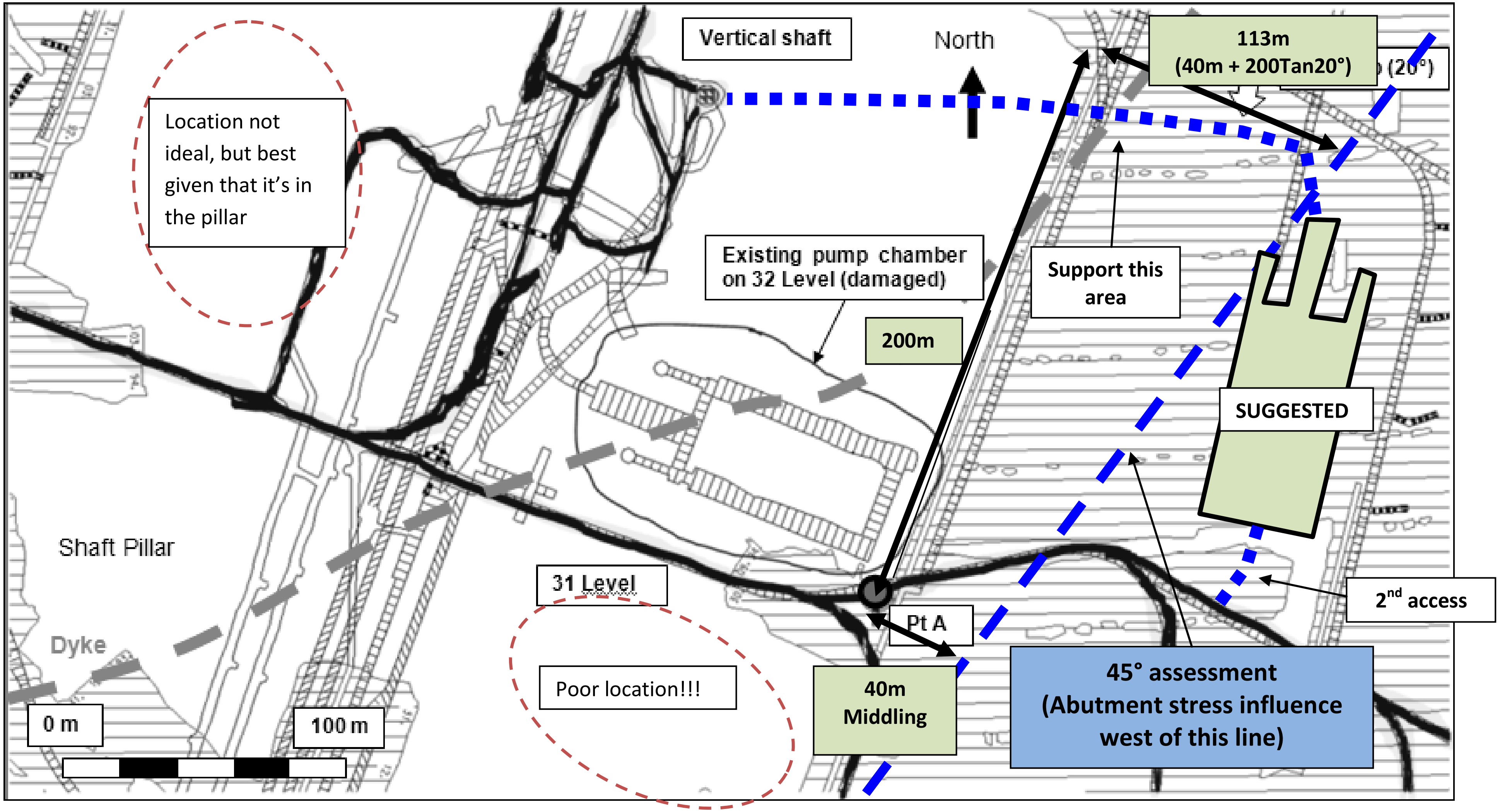
Main points are **(3 marks)**

- move the chamber outside of the stressed area (below the mined out area). Only a few students got this logic right.
- Orientate the long axis N-S
- Apply the 45 degree rule to ensure you are out of the abutment stress
- Note that the smaller pillars are not a problem at this middling!
- Students may mention risk due to the access passing through the dyke and that it should be supported.
- Second access way could also be suggested.

Additional 1 mark for accompanying and sensible comments **(1 mark)**

Notes on mark allocations

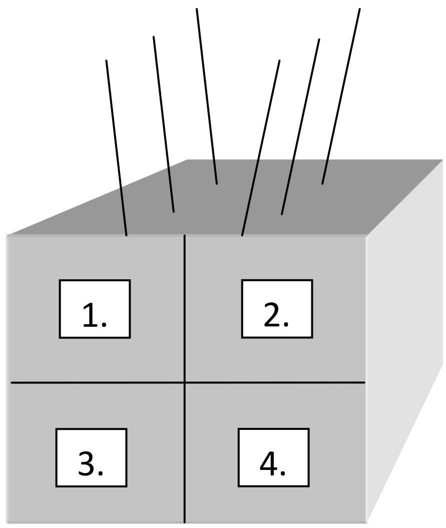
Typically if a student left the chamber below the shaft pillar, minus 1 mark immediately. Marks allocated / deducted on merit. i.e. if the new location is suggested in the pillar (which it shouldn't be), then it should AT THE VERY LEAST be located to the north (north west corner). This is to remove it from the dyke and to ***maximize the middling*** *as much as possible.*


Vertical shaft
North
113m
(40m + 200Tan20°)
(20°)
Location not ideal, but best given that it's in the pillar
Existing pump chamber on 32 Level (damaged)
Support this area
200m
SUGGESTED
Shaft Pillar
31 Level
Pt A
2nd access
Dyke
Poor location!!!
40m Middling
45° assessment (Abutment stress influence west of this line)
0 m
100 m

1.3)

1.3.1. Any sensible approach will be accepted. Main points are (**5 marks**)

- Break larger excavation into smaller sections i.e. 5m x 5m
- Start with a top 5m cut and install support as you advance (1)
- BEST to install long anchor support (6m) now else later at *
- Develop the second top cut opening the span to 10m.
- (*) Install remaining 6m long anchor support in the hangingwall and tendon support in the sidewalls
- Develop the lower cuts and install sidewall support as you progress. (3 and 4)



1.3.2.

Temporary support **(1 mark)**

- Top cuts – Typical camlok jacks on a suitable 1.5m x 1.5m spacing. Nets should be used for friable ground.
- Bottom cuts – Not necessary – permanent support in place. Barring of sidewalls is to be done and/or sidewall nets used.

Permanent support

- Will depend on local ground conditions but should include a combination of
- Shorter tendons (H wall) can be designed for the 5m span (cut 1). (**1 mark)**
    - SR = p g h (where h = ½ span = 2.5m) = 2.7*10*2.5 = 67.5 kN/m2
    - Assume 1 tendon gives 10 tons = 100 kN and 2m advance
    - Spacing = 100/67.5 = 1.48m2 per bolt.
    - Spacing = 1.0m x 1.5m (**1/2 mark** for some form of calculation)
- In poor ground conditions, areal coverage should be provided. Wire mesh and lace using installed tendons or fibre reinforced shot crete. WM&L preferable for highly seismic areas. **(1 mark)**
- Longer tendons (H/Wall) designed for the final 10m span (after cut 2). Length should be > ½ span i.e. 6m in length minimum. **(1 mark)**
    - SR = p g h (where h = ½ span = 5m) = 2.7*10*5 = 135 kN/m2
    - Assume 1 Anchor gives 38 tons = 380 kN and 2m advance
    - Spacing = 380/135 = 2.8m2 per bolt.
    - Spacing = 2.0m x 1.4m (**1/2 mark** for some form of calculation)
- Sidewall tendons typically ½ x height in length.

Question 2

2.1) Chapter 5 = General Information

5.1 Locality

A brief description and locality map to indicate the location of the mine in relation to towns, existing infrastructure and any other relevant features such as mines sharing a common boundary, dams, rivers and any other topographical features which could influence the strategies adopted.

5.2 Geological Setting

Geological structures, such as faults and dykes and stratigraphy, around individual orebodies or seams must be described and any hazardous conditions highlighted. A typical geological section of the mine must also be included. A detailed geological assessment may not be necessary but a map showing major geological features in relation to mining outlines and shafts must be included.

5.3 Mining environment

The mining environment describes major subdivisions of an orebody, which dictates specific fundamental extraction strategies and occurs on a regional scale thus crossing mine boundaries.

5.4 Ground Control Districts

The location and extent of ground control districts must clearly be described in the COP. The nature of the virgin stress field in which mining is to take place, as well as the occurrence of significant pore water and any other local geological features, must be included here. All ground control districts must be indicated on a Ground Control District Plan

5.5 Mine Rock Fall and Rock Burst Incident Analysis

The COP must contain a tabulation of the mine's five year history of rock-related casualties (fatals, reportables and disabling incidents) and non-casualty incidents (where available), categorised according to rock bursts and rock falls per 1000 employees at work for both surface and underground operations. From this information the risk associated with each hazard can be established. These statistics should be normalised with respect to production tonnage in the different ground control districts.

Students to correctly name and briefly discuss at least 2 of the above. Marks deducted if no discussion (Read the question) (4).

2.2.1)a) The terms ***hazard*** and ***risk*** are defined in section 102 of the Mine Health and Safety Act **(1)**

Hazard - Means a source of or exposure to danger.
*(Alternatively, a **HAZARD is something that has the potential to cause HARM.** This includes substances, machines, methods of work or other aspects of work Organisation; (The term danger is not defined in the Act))*

Risk - Means the likelihood that occupational injury or harm to persons will occur.
*(Alternatively, RISK **is the LIKELIHOOD that the harm from a particular hazard will occur**; The extent of the risk depends on not only the severity of the harm to a person but also the number of people who will be harmed. Risk therefore reflects both the likelihood that the harm will occur and its severity in terms of the degree of harm and the number of people harmed).*

2.2.1)b) **(1)**

Existing controls - Means those controls (physical, managerial or procedural etc) that are currently in place specifically to reduce the likelihood of harm due to a given hazard.

Additional controls - Means those controls (physical, managerial or procedural etc) deemed to be necessary (following the conducted hazard identification and risk assess (HIRA) process) and being in addition to those controls that are already in place, aimed at further reducing the risk to a more acceptable level.

2.2.2)a) **(2)**

Mine management to involve representatives from all applicable departments. Most important is

- Safety rep (of U/G crews) **and representatives of the general work force NB!.**
    - NB! This is essential to ensure chosen controls are practical, acceptable and achievable. **(Mark deducted if workforce not mentioned)**
- Mine management (Mine manager and upper level management)
    - NB! This is essential to ensure chosen controls are practical, acceptable and achievable.
- Rock Engineer
- Safety Manager / Officer and other relevant persons

2.2.2.)b) **(2)**

- The team is to identify and assess all rock related hazards. This is often best done by classing hazards according to the various mining operations (drilling, blasting etc.)
- A Risk Matrix type approach is often used whereby those who are carrying out the risk assessment categorise the **consequence**s of the hazard, and its **likelihood** separately and then combine them on a matrix to produce a priority based on a Risk Rating.
- Each hazard is assigned a Risk Rating (RR) where

$$\textbf{RR} = \underbrace{\textbf{Probability (P)} \times \textbf{Exposure (E)}}_{\boxed{\text{Frequency / Likelihood}}} \times \underbrace{\textbf{Consequence (C)}}_{\boxed{\text{Consequence}}}$$

Probability = Can/will the hazardous situation occur?

Exposure = Will people / machinery be exposed?

Consequence = Assuming a hazard causes harm to men or machinery, how severe will this harm be?

2.2.2.)c) **(2)**

The objective is to **classify and rank rock related hazards in terms of risk** i.e. to identify those hazards that currently pose the highest risk to the operation. Furthermore the purpose is to :-

- Determine all necessary control measures necessary to either **eliminate, control at the source or minimise** the risk; and insofar as the risk remains, provide for personal protective equipment; and institute a programme to monitor the risk to which employees may be exposed.

2.3)a) **(4)**

As per the DME guidelines (2002), A COP must set out a description of the design methodology to avoid uncontrolled collapses of the mine or portion/s thereof, and the effects of the mining methods employed on surface structures and topography. This is typically achieved through different pillar types as detailed below.

Type	**Role**	**Design guidelines**
Barrier pillars	Legal requirement. Separates different mines. Provides mine compartmentalisation (fire/ flooding).	Legal Width > 18m W:H > 15:1
Stabilising pillars	Provide regional stability. Support overburden weight to surface.	W:H > 5:1 Use squat pillar formula. FOS ~ 1.5

		or 1.6 or 2.0 in some cases Check foundation failure with APS criteria (APS < 2.5 UCS)
Instope pillars	Support the tensile zone between stabilising pillars (if stabilising pillars are used) ELSE must support overburden weight to surface. Crush pillars may also be used purely to stabilise poor ground (re-establishing)	W:H<4.5 but is typically not less than 1.5 to 2.0 Use Hedley-Grant pillar formulation. FOS can either be ~0.7 (crush pillars) ~1.0 (yield pillars) or >1.6 (Non yield pillars).

To get 4 marks students to at least show that they understand that

- ***the entire weight to surface must be supported (either through regional pillars or through non yield instope pillars)***
- ***The mine needs to be compartmentalised against fire/floods***
- ***Students must make some sensible reference to pillar formulation, FOS and W:H ratios.***

2.3)b) **(4)**

Typical Sequential grid mining layout / geometry. (main points) **(2 marks)**

- Top down (underhand configuration) – over hand or "c" shape acceptable in some situations (as long as it promotes other rules)
- Reduce spans (20-30m wide dip pillars spaced 180-200m apart between sequential grids)
- Mine towards solid
- Approach angle to structures > 30°
- Mine away from structures
- Face shapes / Leadlags and sidings
- Pre conditioning
- Etc.

Reference to at least 2 of the above (or other applicable discussions) for 2 marks

Instope support requirements **(2 marks)**

Type	Role	Pros	Cons
Packs	Long term – back area support. Provide high load bearing capacity	Provide high load bearing capacity Durable / resilient Energy absorption (cement based packs)	Less stiff (not active) Can't be installed close to the face. Time consuming construct
Elongates	Immediate and active support in the short term	Active /immediate support. Pre-stressed	Limited life / limited deformation Blast damage
Tendons	Immediate support (closer to the face than elongates)	Can be installed close to the face Don't hamper scraping operations	Limited in terms of length / zone of influence. Lack of durability (if not grouted)

For 2 marks ,

- ***Reference to at least 2 of the above (in terms of pro's and cons)***
- ***Reference to the terms "Support Resistance" and "Energy Absorption" in support design***

OR

- ***Reference to “active but short term” vs “passive but durable” interms of elongates v.s packs***

Question 3

3.1) Any 2 of the following (or other applicable) **(2 marks)**

- The elongateis splitting down the middle (crack development) **AND**
- The elongate's yielding mechanism (profiled end) is not brushing / yielding as designed
- Elongate splitting instead of "walking"
- Other

3.2.) Possibilities include **(4 marks)**

- Manufacturing design fault (yielding mechanism)
- **Dry timber / low moisture content due to exposure to the sun/ elements (this is the most likely / obvious reason)**
  - Delays in the manufacture process
  - Delays in surface storage / transportation
  - Poor logistics management
- Confined yielding mechanism ?? (see photo on the right). Confined by either PSU or by stoff.
- Timber excessively cracked prior to installation (failure of Quality Control system)
- Blast damage??? Possible, but unlikely based on the photograph provided!
- Incorrect installation (point loading, not 90° etc.)
- Lack of strengthening wires around the elongate stem
- Other

Must give 4 sensible possibilities.

3.3.) **(14 marks)**

Students to make reference to at least the follow stages in the life cycle of a timber elongate

1. **Manufacturing**
   a. Has the **design (yielding mechanism) changed**?
   b. Production line fault?
   c. Suppliers **QC system**
      i. Is it in place
      ii. Is it followed?
      iii. Has it failed?
2. **Procurement** (acceptance by shaft)
   a. Did the mine accept poor quality product?
   b. Mines QC system
      i. Is it in place
      ii. Is it followed?
      iii. Has it failed?
3. **Surface storage**

a. Is exposure to the sun / elements minimised by
   i. **FIFO (first-in-first-out) loading**
   ii. **Elongates wrapped in plastic** / under cover
b. **Are batches marked with dates**? This is important for management of bundles fit for dispatch into the shaft and those that need to be discarded
c. Routine checking of quality (**Stock yard QC**) based on
   i. Crack width, density and length.
   ii. General condition
      1. Rust (if steel components exist)
      2. Profile shape / condition of yielding mechanism (profiled end)

4. Routine testing

a. Routine testing of random elongates to be conducted by BOTH the supplier and by the mine. **Load-deformation testing**.

5. Installation

a. 90° to strata??

b. Over inflated prestress units?

c. Cutting of yielding device etc (incorrect installation practices)

<u>Possible Strategy:-</u>

1. Conduct additional testing of representative samples.
2. Investigate the life cycle process and systems as described above to identify areas of system failure.
3. Rectify problems, develop systems and conduct necessary training.
4. Monitor progress and improvement.

Above is a guideline only. Marks given for each applicable and sensible discussion point. Marks deducted if key points above not mentioned at all. Repetition / rewording not marked. Students must show a logical approach to problem solving that covers the above cycle.

Question 4

4.1) Objectives (As per Jaeger and Ryder pg 289). **(5 marks)**

1. **Location**
   Inform management of event locations / provide assistance in possible rescue operations
2. **Prevention**
   Allows for the confirmation of design assumptions and parameters. I.e. allows for real time monitoring of the performance of the design during mining preventing prolonged exposure to higher than expected seismic risk.
3. **Control**
   To monitor and detect spatio-temporal changes in seismic parameters. Activity rate, Time of day distribution, Energy, Moment, Apparent Volume, Apparent stress etc.
4. **Warnings**
   Large or sudden changes in seismic trends can be used as a warning system in the management of workers to seismic risk.
5. **Back analysis**
   Use of seismic data to conduct detailed modeling and back analysis case studies to improve forward predictions of seismic risk.

NB!!!!Marks deducted if no discussion provided (as asked in the question – STUDENTS DON'T READ THE QUESTION).

4.2) **(3 marks)**

Event plot is "Pipe" shaped and is elongated at right angles to the reef. This is due to poor location accuracy in this orientation. The reasons for this lies in the typical layout of a seismic system in a narrow tabular reef mine.

- All stations are installed close to reef (typically not more than 50-100m from the reef plane)
- For good location accuracy, seismic stations should be distributed evenly around the source. This can be done in X and Y (on the reef plane) but is not easily achieved in Z (in depth).
- The i**mplications** are that event location predictions can be assumed accurate when looking normal to the reef plane but their location in depth must be considered with due care.

4.3) **(2 marks)**

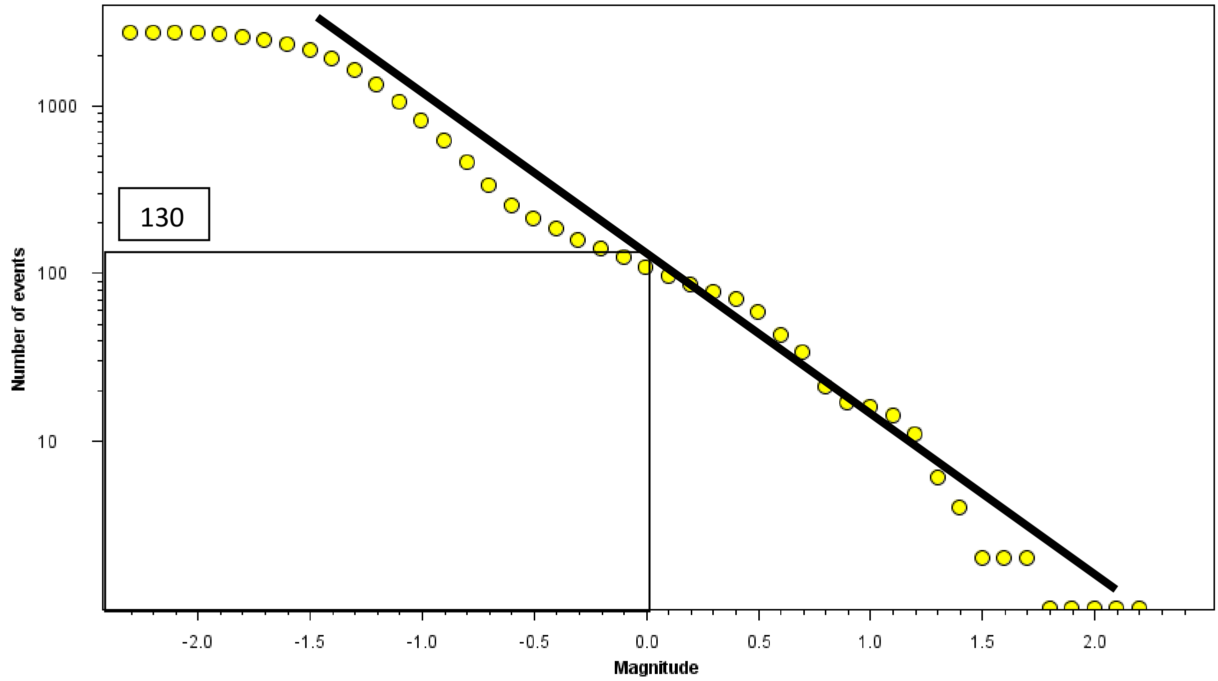
4.3.1.) GR = Gutenberg-Richter relationship (1)

The GR relationship defines the seismic response of a given polygon by representing the distribution of recorded seismic event magnitudes in the form of a histogram.

- It can be used to determine the network sensitivity (M min)
- It can be used to determine the Max expected size of event (M max)
- Other system properties like system stiffness can be deduced. (1)

4.3.2.) No. Larger events are over estimated by the fit. The larger events are the important ones that cause damage.` (1 mark)

4.3.3) The fit is up to the student but must be focused on a best fit to day of M > 0.0. This ensure a more realistic prediction of larger damaging events. (1)



1 mark for sensible fit (i.e. above), 2 marks for calculation of GR relation.

GR fit (y=mx+c) or LOG(Number of events) = A x (Magnitude) + B

NB. Note that the y axis is a log scale.

Where

A = log(Number of events having magnitude > 0).

A = log 130 = 2.114 ***note that log is used – the y axis is a LOG scale*** ***(1)***

B = slope of GR fit line.

B = Δy / Δx = (0 – 2.114) / (2.2 - 0) = -0.91 (**NB slope is NEGATIVE**) **(1)**

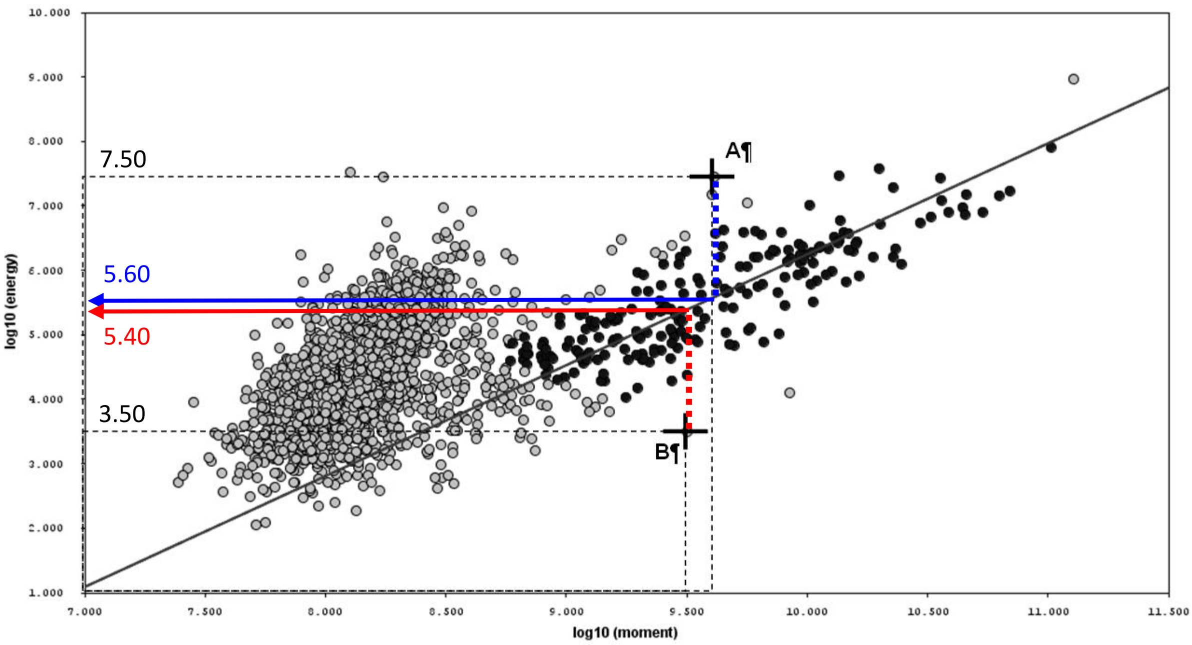
Log(N(M))	**= -0.91 x (Mag) + 2.114**
Number of events(N(M))	**= 10^(-0.91 x (Mag) + 2.114)**

4.4)

4.4.1.) Clustering referred to as **"a-type"** events or **"blast"** events. These events (1)

- Represent the physical recording of the actual blast by the seismic system
- Are different to normal seismic events in that they are higher in energy for the same moment.
- Lie at the lower end of the magnitude scale
- Are typically removed from the seismic database to prevent biased information. (2)

4.4.2.) (3 marks)



Events marked "A" – top and "B" – bottom. Read the Energy values off EM plot

EI (A) = log E $_{(\text{event a})}$ / log E $_{(\text{line fit})}$ = 7.5/5.6 = 1.34 > 1.0 (1)

EI (B) = log E $_{(\text{event b})}$ / log E $_{(\text{line fit})}$ = 3.5/5.4 = 0.65 < 1.0 (1)

EI > 1.0 refers to a high energy "burst" type event. EI < 1 refers to a high moment "slip" type (structurally related) seismic event. (1)

Question 5

5.1.1)

Any of the following. Numerical modeling can be used for **(2 marks)**

1. Design verification
2. Verification / Explaining of observed phenomenon
3. Comparative analysis and studies (to select the best possible option out of several options)
4. Back analysis of past experience to calibrate modelled results in predicting future reactions
5. Back analysis for research and development and improved understanding

OR As per Jaeger and Ryder pg 331, Models are used for two different purposes

1. **Design** – optimization of an engineering system based on redefined criteria
2. **Mechanics** – development of improved understanding of an engineering or natural system.

5.1.2) **(8 marks)**

Discussion along the lines of that in Jaeger and Ryder pg 344-345…

1. Identify problem areas and **clearly define the objectives** (what do I want to achieve?)
2. Design a **number of potential mining strategies** to alleviate the problems and to reach the objectives
3. **Define relevant design criteria**
4. Develop a model of appropriate detail to assess the mining strategies in terms of the design criteria (**Apply Occum's Razor**!)
5. **Choose a relevant tool / tools** to test the proposed mining strategies based on the model. It is important to use the correct modeling package for what is wanted!
6. **Perform simulations on each strategy** using the model and the specified design criteria.
7. **Analyse and compare** the results **based on the chosen design criteria**
8. **Select the most appropriate strategy** based on the analysis taking all other factors (cost and practicality included) into consideration.

5.1.3) ***(only half marks given if terms not briefly described – READ the question!)*** ***(3 marks)***

ERR = Energy Release Rate. Used to assess seismic risk due to face stresses. Applicable in deep level mines to assess the possibility of face related seismicity. ERR measured in MJ/m2.

ESS = Excess Shear Stress. Used to assess stability of structures (faults) by modelling the amount of excess shear stress acting across their surfaces. Applicable in deep level mines to assess the possibility of structure related seismicity. ESS measured in MPa.

RCF = Rockwall Condition Factor. Used to assess tunnel stability where failure is driven by mining induced stress. Measures the ratio of tangential sidewall stress to the strength of the rock in which the tunnel is situated. RCF is a unitless factor ranging between 0 and > 2.0

5.2.1) Refer to pg 316 of Jaeger and Ryder. **(2 marks)**

Accuracy refers to the difference between an instruments reading for a parameter and a known value of the same parameter. I.e. how accurately can the instrument report the parameter?

Precision refers to the extent by which the instrument can reproduce the same reading for the same input. I.e. how variable is the instrument's reported value?

Resolution refers to the smallest division on the instrument's readout scale. I.e. how much detail does the instrument report?

Sensitivity refers to the smallest unit of measurement detectable by the instrument. I.e. how much detail can the instrument actually measure? – this is fundamentally different to the term ***resolution*** above.

5.2.2) Discussion along the lines of the following … **(5 marks)**

Pillar stability (in terms of a non-yield pillar) implies no or minimal movement

- The pillar sidewall should not converge
- The hanginwall between pillars should not move (no closure or hangingwall convergence should occur)

The first point is a **direct measure** of the pillar's stability whilst the second is a secondary measure (i.e. the pillar sidewall must converge before hangingwall movement is recorded). The first option is thus a better one.

Focusing on sidewall stability then, the following instruments are possible

Instrument	Measures	Pro's	Cons
Simply apply some form of skin i.e. white wash the pillar sidewalls.	Nothing (Visual aid only). If the sidewalls are failing scaled material will clearly be visible.	Cheap and easy. Visually effective	No measurement is taken. It simply indicates whether the sidewall is scaling or not. Poor sensitivity – may not indicate small movements.
Borehole camera **(Probably a very suitable solution based on cost, practicality ease of use and benefits)**	Can assess the development of fracturing in the pillar	Cheap, easy and reliable. Allows one to look inside the pillar (can see early signs of failure through crack development)	Low sensitivity / resolution. You can see that cracks are forming but don't know by how much the sidewall has converged.
Sidewall installed Wire extensometers with analogue or tape read outs	Sidewall deformation relative to a fixed point.	Sensitivity is reasonable (in the order of a millimetre or less)	More difficult installation Resolution limited. Measurements are not continuous.
Sidewall installed ground motion monitors with digital logging and read out	Sidewall deformation relative to a fixed point.	High resolution and sensitivity Measurements are continuously logged.	More expensive Intricate – can be subject to electronic related problems (temperature, flat batteries, incorrect calibration etc.)
Geophones / Accelerometers	Micro seismicity (rock fracturing)	Will indicate early stages of pillar failure – i.e. will give early warning	Expensive Requires seismic network hardware/software
Closure loggers (i.e. Rock watch)	Hangingwall movement / closure	Simple, cost effective and easy to use	Measure a secondary effect. The hangingwall moving down is a secondary effect of the sidewall cracking and deforming.