Chamber of Mines of South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES CERTIFICATE IN ROCK MECHANICS: PAPER 2 **SUBJECT CODE:** COMRMC **EXAMINATION DATE: May 2016** **TIME:** 09h00	**EXAMINER:** B VAN DER KEVIE **MODERATOR:** P GREYLING **TOTAL MARKS:** [100] **PASS MARK:** 60%

NUMBER OF PAGES: 9 (including answer sheet)

SPECIAL REQUIREMENTS:

1. Answer all questions.
2. Write your **answers for Question 1 on the answer sheet provided** at the back of the question paper and submit this with your script.
3. **Only 1 (one) correct answer for all questions in Question 1.**
4. References other than those provided are not permitted.
5. Hand-held electronic calculators may be used.
6. 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.

7. **Write in ink on the RIGHT HAND SIDE of the paper only (only the right hand pages will be marked).**
8. Show all calculations on which your answers are based.
9. Illustrate your answers by sketches of diagrams wherever possible.
10. In answering these questions, full advantage should be taken wherever necessary of your practical experience as well as of the data given.
11. Answers must be given to an accuracy that is typical of practical conditions.
12. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

TICK THE CORRECT ANSWER ON THE ATTACHED SHEET PROVIDED AND HAND IN WITH YOUR EXAM BOOK. ENSURE ID NUMBER IS ON THE SHEET.

Only 1 (one) correct answer for all questions in Question 1. If more than one is ticked no marks will be given

1.1 Which **one** of the following statements is **correct**?

a) Foliation is a structure (or texture) due to the parallel disposition in layers (or lines) of one or more conspicuous mineral. The most common rock exhibiting foliation is shale.
b) Erosion channels are methamorfic-filled channels or stream that are cut into pre-existing layers of rock during deposition
c) A fold is a bend in a surface or layer of rock, and can occur only in igneous rock formations.
d) An unconformity represents a period in geological history during which new strata were deposited in layers. The strata already formed before this deposition may be uplifted or tilted by earth movements. (4)

1.2 Which **one** of the following statements is **incorrect**?

a) The Witwatersrand basin's precise age is difficult to determine since rocks were deposited by sedimentation approximately 2700 million years ago. Before the age of fossils.
b) The Bushveld complex was formed by various igneous activity like a basic volcanic phase, sill phase, acidic volcanic phase, plutonic phase and acid plutonic phase.
c) The Vaal reef, "C" reef, Ventersdorp Contact Reef (VCR) and Elsburg reefs are all part of the Klerksdorp Goldfields.
d) The West-Wits or Carletonville Goldfields comprises of the Basal Reef, Kimberly Reef, Carbon Leader Reef, Middelvlei Reef and Ventersdorp Contact Reef (VCR) (4)

1.3 Which **one** of the following statements is **correct**?

a) There also appears to be some correlation between the size of a fault (expressed in terms of its throw, though probably also including its areal extent) and the maximum size seismic event that can be generated by the fault. Van der Heever (1983) showed empirically that in the Carletonville goldfield the likely maximum sized event on a fault with a throw of 15 m has a magnitude of 3, and on fault with a throw of 280 m a magnitude of 5. He expressed this relationship by

Mmax ≈ 1.8 $\log_{10}$ D + 1.6 (where D is throw in m)

b) A seismic event is a sudden elastic deformation within a given volume of rock whereby a source radiates detectable seismic waves. The amplitude and frequency of the radiated waves depend, in general, on the size of the source, and on the magnitude and the rate at which the stress in the rock is relaxed during the fracturing process.

c) On the analysis of seismicity in time, the slope of the ΣV_2 (Cumulative Apparent Volume) reflect changes in the strain rate

d) When a seismic event is plotted on the plan, the point where it originated is referred to as the hypocenter (4)

1.4 Which **one** of the following statements is in**correct?**

a) The simple yet insightful concept of Energy Release Rate ('ERR', expressed in MJ/m2), introduced in the 1960s by workers including Cook et al (1966) and Salamon (1984), remains to this day the most accessible measure of severity of conditions in deep mining situations. The average level of ERR pertaining at a given set of mining faces appropriately takes into account the effects of depth, mining span, stoping width, rock mass modulus, presence of backfill or pillars, and influences of neighbouring mining. It is related to the extent of volumetric convergence taking place, or being permitted to take place, in the back areas of a given stope.

b) If a weak plane in the rock mass is subjected to a sufficiently high level of shear stress,

slip (ride) on the plane will occur. The extent to which this is possible, and the severity of any resulting seismic event, are governed by the cohesion properties of the plane. Two states have to be considered: the static (pre-slip) shear strength , and the dynamic strength once slip has been fully mobilised

c) Comminuted or milled waste backfill (CMW) is prepared from underground waste rock using a dedicated crushing and milling plant sited underground. A well-graded material is produced with a maximum size of approximately 5 mm and a fines content of which only 10 – 15 % passes the 38 micron mesh size. The material has optimum and placement porosities of 15 % and 36 % respectively, and can be pumped to stopes at a relative density of 2.1 (Gürtunca et al 1989).

d) Classified or de-slimed tailings backfill (CCT) is produced by the cycloning of run-of mine tailings to reduce from 50 % to 10 % the particle size fraction passing 0.038 mm mesh size. This material, which has optimum and placement porosities of 40 % and 52 % respectively, is usually gravity fed to the underground filling sites at a slurry relative density of between 1.65 and 1.75 (Gürtunca et al 1989). (4)

1.5 Which **one** of the following statements is in**correct**?

a) Boundary Element ((BE) models are efficient numerical models for the solution of arbitrarily shaped tabular voids (stopes, planes of weakness, cracks) in an inelastic material are popularly based on the so-called displacement discontinuity method which exploits known BE kernels to formulate

b) The finite element method provides a general framework for the analysis of the mechanical behaviour of arbitrarily shaped bodies containing arbitrary inhomogenities ,and can be adapted to solve problems involving large geometrical strains and nonlinear material behaviour.

c) Finite difference methods represent some of the earliest attempts to generate numerical solutions to solid mechanics problems described by analytically intractable systems of differential equations. In this form of analysis the problem region is covered by a number of regularly spaced points (nodes) and the derivative terms in the describing

equations are approximated by suitable difference formulae which depend on the values of the key variables at the nodes surrounding the node of interest.

d) Distinct element models models were pioneered mainly by Cundall (1971). The modelling paradigm provides a framework for tracking the motion of distinct polygonal or polyhedral blocks as a function of time. The blocks interact through their common interfaces and may themselves be deformed elastically or can undergo plastic deformations. In principle, the models are fully dynamic and can undergo arbitrary large strain deformations (4)

Total: 20

Question 2 (Mine Design)

2.1 Describe and explain 2 (two) methods of drilling? (4)

Percussion drilling: drill machine uses compressed air and a button bit to break rock.

Diamond drilling: Hydraulic machine uses diamond cutting bits to cut the rock and pull core if necessary.

2.2 With regard to the following 3 numerical modeling techniques. Describe and explain the principles of these modeling techniques and secondly for which typical Rock Engineering applications they are used.

a) Finite Element method

The FEM requires the entire problem domain to be covered by a mesh of contiguous 'elements'. The variation of each component of the displacement field within each element is controlled by an assigned number of independent nodes within each element. Each displacement component is then assigned a fixed variation in relation to each node. Using virtual work arguments, it is possible to determine the force components that will arise at any node in an element due to a specific component of incremental displacement applied at any other node.

The finite element method provides a general framework for the analysis of the mechanical behaviour of arbitrarily shaped bodies containing arbitrary inhomogeneities, and can be adapted to solve problems involving large geometrical strains and non linear material behaviour.

b) Boundary element

Efficient numerical models for the solution of arbitrarily shaped tabular voids (stopes, planes of weakness, cracks) in an elastic material are popularly based on the so-called displacement discontinuity method which exploits known BE kernels to formulate integral equations of the convergence and ride distributions.

Used to model narrow seam orebodies and the accompanied off reef development stress field

c) Distinct Element Method

The modelling paradigm provides a framework for tracking the motion of distinct polygonal or polyhedral blocks as a function of time. The blocks interact through their common interfaces and may themselves be deformed elastically or can undergo plastic deformations. In principle, the models are fully dynamic and can undergo arbitrary large strain deformations.

Able to model the interaction of support units such as tendons and grouted ropes with adjacent blocks. (6)

2.3 Describe and explain a process of geotechnical hazard and risk evaluation on a typical shallow mine in the Bushveld.

For this question student must describe and explqain any sort of panel rating system used on his or her mine e.g.

Monthly a panel rating report is compiled for each shaft. There are 6 Risk areas that are scrutinized from the stope sheets after measuring. These risks are weighted individually to determine a final panel rating for each shaft. They are is classified Low, Meduim, or High risks. It must be noted that this panel rating is **not a percentage compliance to risks.** Some of the risks are cosidered very high and is thus weighted such that it will classify that panel high risk even if all the other risks are found low and in order.

Working Place	2W6		Panel	6W	Month Planned	December
			Recommendations			
Stoping width	Actual SW > 10cm < 20cm of Best SW	2	SW between 10 and 20cm more than best cut. Reduce stoping width to best cut. Drilling and blasting into the hangingwall will increse FOG risk and decrease stability of the panel .			
Face shape	Overhand/ Underhand/Irregular etc	2	Overhand or underhand face shapes create support installation difficulties i.e incomplete support lines and thus excessive un-supported spans .			
Pillar Robbing	No Pillar robbing	1	Maintain good pillar cutting .			
Water intersections	No water intersections	1	No water present in panel .			
Mining Towards, Through or stripping along a Dip Geological Structure	No Major Geology	1	No major geology present .			
Potholes	No Pothole	1	No potholes present .			
Face length	≤ than 31,5m	1	Face length < or = than 31,5m Maintain good face length			
Strike Length	<90m	1	Continue mining.			
Ledging	No ledging from centre line	1	Adhere to mine standard.			
Surface Panel Rating		MEDIUM (B)				
Comments						
	In stope support		Recommendations			
Support Type	Standard					
Standard Applicable	Normal					
Special Support Rec.						
Comments						
	Secondary support		Recommendations			
Special Support Rec.						
Comments						

WORKING PLACE	PANEL	RATING	DEVIATIONS								
2W10	1E	HIGH (S)	Stoping width	Face shape	Pillar Robbing	0	0	0	0	0	0
2W10	2E	HIGH (S)	Stoping width	Face shape	Pillar Robbing	0	0	0	Face length	0	0
2W10	5E	HIGH (S)	Stoping width	Face shape	Pillar Robbing	0	0	0	0	0	0
2W8	4W	MEDIUM (B)	Stoping width	0	0	0	0	0	0	0	0
2W8	4E	MEDIUM (B)	0	Face shape	0	0	0	0	0	0	0
2W8	5E	HIGH (S)	Stoping width	Face shape	Pillar Robbing	0	0	0	Face length	0	0
2W6	3W	MEDIUM (B)	0	0	0	0	Mining Towards, Through or stripping along a Dip Geological Structure	0	0	0	0
2W6	5E	HIGH (S)	Stoping width	Face shape	0	0	Mining Towards, Through or stripping along a Dip Geological Structure	0	0	0	0
2W6	5W	MEDIUM (B)	Stoping width	0	0	0	0	0	0	0	0
2W6	6W	MEDIUM (B)	Stoping width	Face shape	0	0	0	0	0	0	0
2W4	1W EAST	HIGH (S)	0	0	Pillar Robbing	0	0	0	Face length	0	0
2W4	2W	HIGH (S)	0	Face shape	Pillar Robbing	0	0	0	Face length	0	0

(10)

Total: 20

Question 3 (Mine support and design)

3.1 Mechanical full column grouted long anchors are extensively used in mines. Describe and discuss these long anchors under the following headings.

a) Describe installation procedure and sequence of events. Under each phase of the installation procedure mention the salient points to look out for to ensure a proper installation.

EXAMINE & MAKING SAFE:

Water down area, barring, make sure all permanent support are in place (1)

PREPARE PANEL FOR SUPPORT:

Mark holes to be drilled in accordance with Rock mechanic recommendations (1)

Ensure temporary support are in place before drilling commences (Jacks & Safety nets) (0.5)

INSTALLATION OF CABLE ANCHOR:

Inspect hole to

- Determine correct depth and diameter (0.5)
- Look for any obstructions (0.5)

Make sure breather/filler tubes are not twisted or crimped during installation (1)

Plug hole with fast setting grout (optional area specific) (0.5)

Apply grout gasket, plate barrel and wedge in correct order (0.5)

TENSIONING OF CABLE ANCHOR:

Connect stress jack correctly to Air/Hand pump (0.5)

Test stress jack prior to applying it to the cable anchor (0.5)

Apply stress jack correctly and safely to cable anchor and secure with a safety sling (0.5)

Tension anchor until the snap ring break (1)

(8)

b) Give technical specifications of typical long anchors used on your mine (2)

4,5m x 15mm diameter mechanical shell x 25 ton cable anchor **or**

6,5m x 18mm diameter mechanical shell x 40 ton cable anchor

Other exceptable lengths also acceptable as well as 12mm also available.

3.2 Describe and give the procedure for the Brazilian indirect tensile strength test. Also comment on the thickness/diameter ratio, loading rate, specimen diameter and the formula used to calculate the tensile strength. (7)

In the Brazilian test, a disc shape specimen of the rock is loaded by two opposing normal strip loads at the disc periphery. The specimen diameter shall preferably be not less than NX core size (54 mm), or at least 10 times the average grain size. The thickness/diameter ratio should be 0.5 to 0.6. The load is continuously increased at a constant rate until failure of the sample occurs within few minutes. The loading rate depending on the material and may vary from 10 to 50 kN/min. At the failure, the tensile strength of the rock is calculated as follows.

$$\sigma_T = \frac{2.F}{\pi.L.D}$$

Where:

σ_T = Brazilian Tensile Strength
D = Diameter of the core sample
F = Maximum Failure Load
L = Length of the core sample

3.3 Name 3 types of Borehole Extensometers

Wire , Rod and Sonic extensometers

Total: 20

Question 4

You are the Shaft Rock Engineer on a Bushveld Platinum mine. Recently the FOG's in the stopes increased significantly over the past few months to unacceptable high levels. The Mine Manager requested you to investigate, report and recommend systems to reverse this trend because the current systems are not effective.

The mine is mining a scattered mining layout at a depth ranging from 60m to 400m B.S at a stoping width of 1m. The elastic pillar system is pillars on the ASG (4mx4m) with no sidings and numerous potholes used as regional natural pillars.

Comment on the following:

a) Safety Management System that can be used and the requirements of such a system if implemented

A Safety Management system is a simple system that is used on site by the safety department as well as other departments like Rock Engineering to manage and control all Safety and health issues for the mine. The system must have the following requirements:

- The safety management system must contain the Health and Safety Policy, procedures, references and all records.
- There must be a procedure where documents like standards, COP's etc are approved and current versions available for all employees on a intranet or website.
- Safety system that can capture data like accidents, LTI, Fatals Injuries ext. In addition also capture Sect 54's results of audits etc.
- Must contain all checklists, PTO's, Material data sheets etc.

From this safety management system graphs, trends and statistics must be drawn to highlight areas of concern that can be addressed and managed to improve safety of the mine. (7)

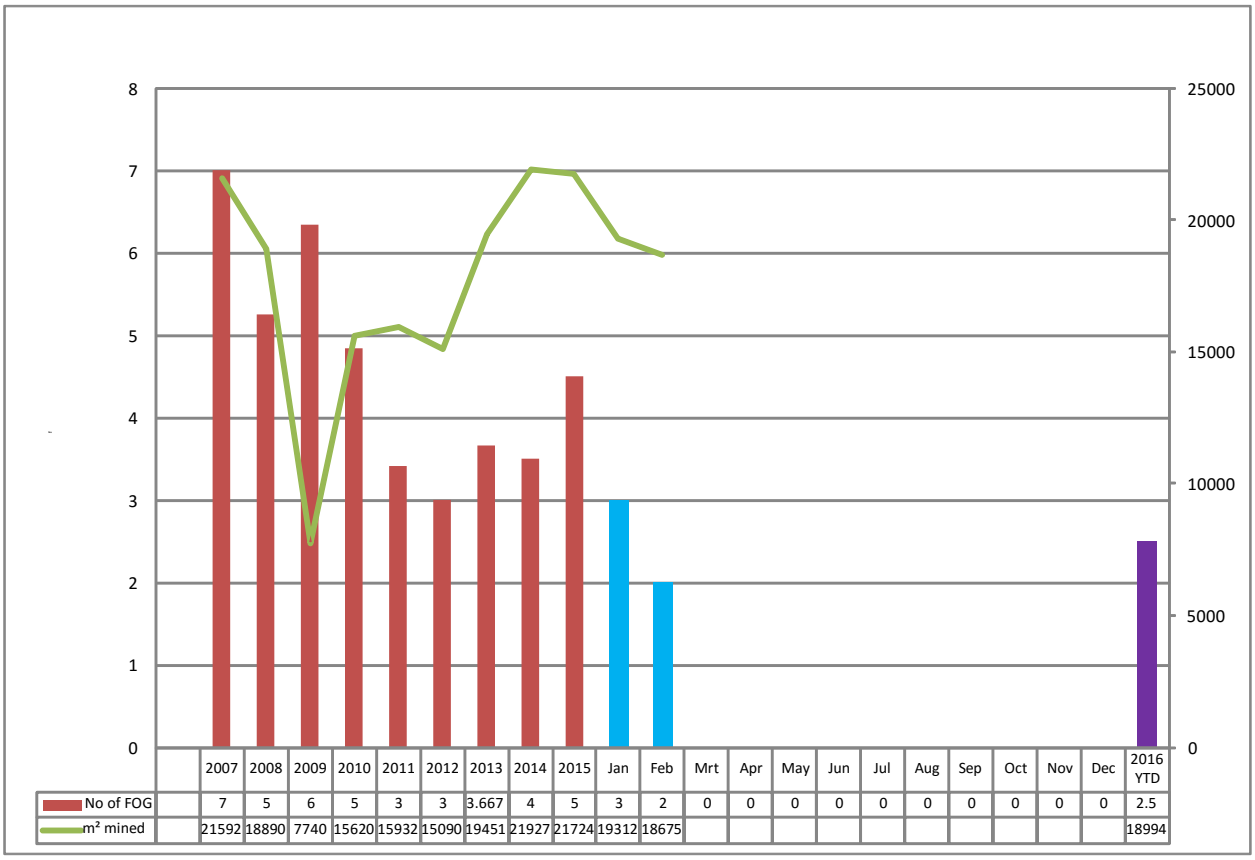
b) Fall of Ground data collection or database requirements from Rock Engineering perspective

A FOG database must be created to capture all data from FOG's investigated.

From this database graphs can be created to determine sections, areas or agencies that require attention due to high FOG numbers.

A typical extract from such a database is given below and if the student describes such a database marks are obtained.

DATE	REEF TYPE	SECTION	WORKPLACE	REPORT NUMBER	FOG AREA	FOG DESCRIPTION	GEOLOGY PRESENCE	MINING AND SUPPORT DISIPLINE	ROOT CAUSE	ACTIVITY
4/1/2016	UG2	M113	1 East 30 P1W	..\Reports 2016\BPM_002_20160104_1 East 30_P1W_F.O.G Investigation_JM.docx	Face (0 to 4,2m from face)	The ground conditions are poor at the bottom of the due to the intersection of closely spaced calcite joints that dips and strikes opposite each other resulted in un-stable brows and excessive stoping width of approximately 1.6m high. Due to concussion in the panel after	bounded by closely calcite filled joints that dips opposite each other and flat dip joints that is parallel to the face resulted in the formation of un-stable brows.	Cluster mine poles were installed on the western side of the re-raise and c-packs were installed at the bottom of the panel were the ground conditions identified to be poor. The support was within the where the F.O.G occured	Back break	Nightshift cleaning
29/01/2016	UG2	M113	1 east 36 P4W	..\Reports 2016\BPM_055_20160129_1 East 36_P4W_F.O.G Investigation_JM.docx	Face (0 to 4,2m from face)	While busy conducting the early examination the poor ground codntions was identifed along the brow at the middle of the		The support was within the 3.5m from the the face, with safety nets and camlock props installed to	Poor barring	Early morning examination



	2007	2008	2009	2010	2011	2012	2013	2014	2015	Jan	Feb	Mrt	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2016 YTD
No of FOG	7	5	6	5	3	3	3.667	4	5	3	2	0	0	0	0	0	0	0	0	0	0	2.5
m² mined	21592	18890	7740	15620	15932	15090	19451	21927	21724	19312	18675											18994

(4)

c) Recommendations, implementation plan and action to be taken to reverse or improve the number of FOG's.

- Collect sufficient data.
- Analyze data to determine main factors responsible for FOG.
- This will include activity, area in stope (gully, face or backarea), support, identiofication of geological features etc. etc.

- Once this determined investigate the reasons for these deviations by investigating and using the Rock Engineering FOG reports.
- Select a few high risk factors that can be changed/improved by a safety campaign.
- Safety campaign may include posters, a specific campaign like ABS or "no rock will fall uncontrolled" cawareness, competitions, safety theatre illustrating safety issues etc. etc.
- Improve support standards or support types may also improve safety.
- Revised training may also be required to improve compliance.
- Monitor all of above to see if actions are working and safety is improving.

(9)

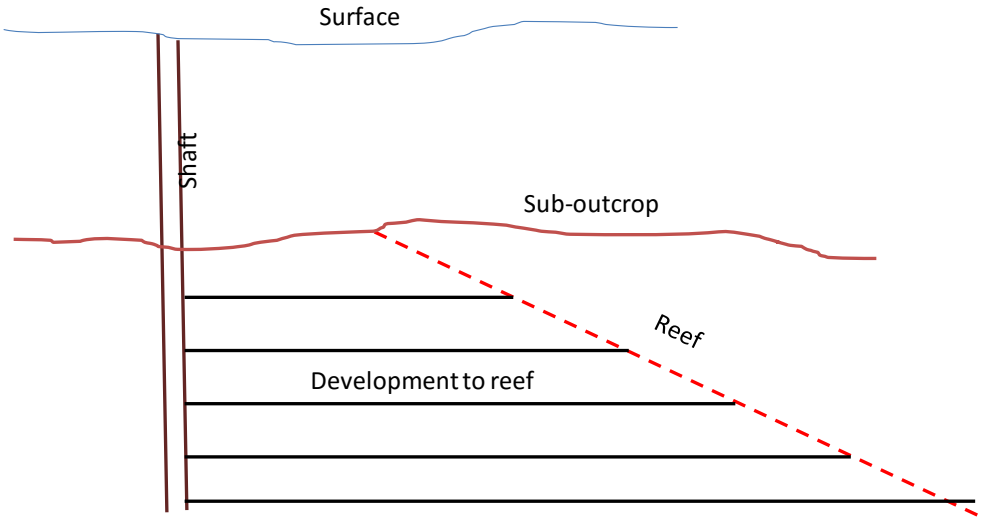
Total: 20

Question 5

5.1 It is sometimes possible to avoid leaving a shaft pillar in vertical shafts. The Rock Engineer must always be on the look-out for such an opportunity, which can save the company considerable expenses and/or inconvenience at some time in the future.

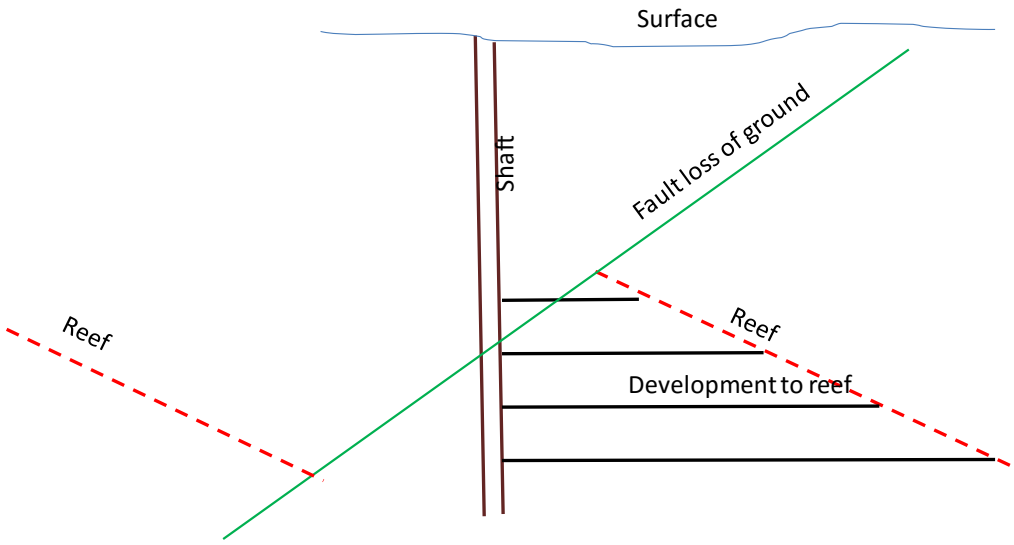
List and briefly describe 4 possible arrangements to avoid a shaft pillar. Make use of a sketch where possible.]

- Sinking shaft beyond sub-outcrop.



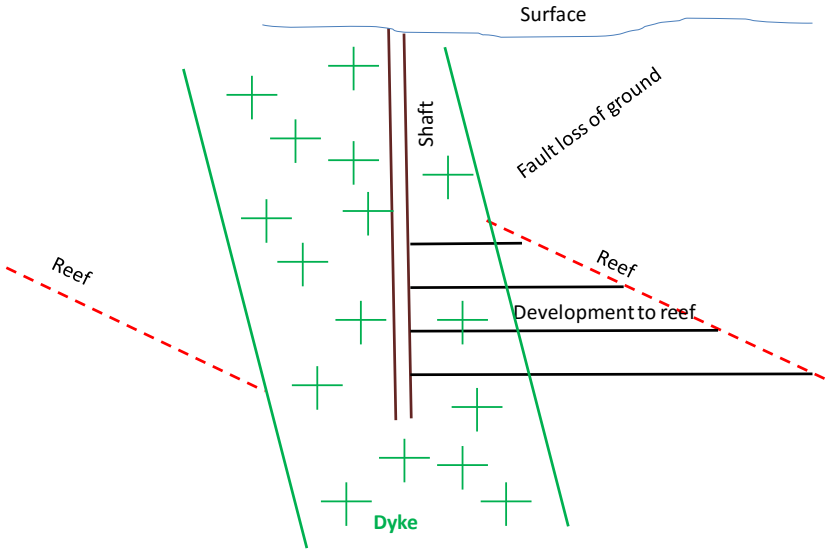
- Positioning the shaft in a large loss of ground

This is possible with surface and sub shafts. It is usually necessary to leave additional blocks of reef to ensure the desired stress and strain levels. Be carefull in faulted strata because subsequent movement on a fault plane can damage the shaft.

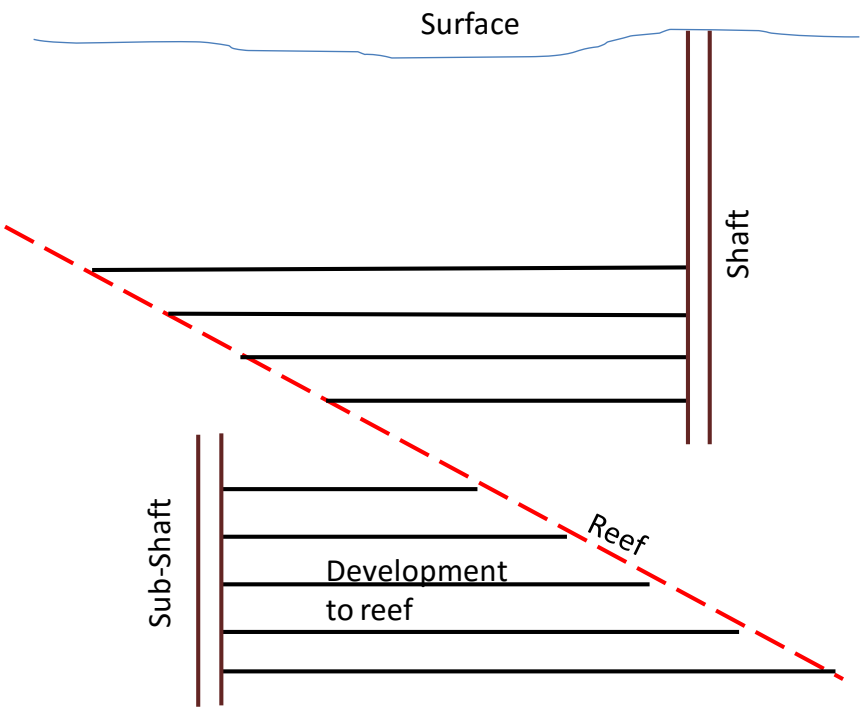


- Positioning the shaft in a large vertical Dyke

This can be done for surface shafts but can be dangerous for sub-vertical shafts due to possible seismicity at depth. Care must be taken to ensure stress levels are kept to acceptable level.



- Stepped arrangements with reef between priomary and secondary shafts.



(8)

5.2 Give 3 possible **practical** reasons why holes are on excessive burden. (3)

- Marking of positions and direction is absent or incorrect.
- Face cleaning took too long so some have been omitted at end of shift.
- Ground is harder near a dyke.

5.3 Give 3 reasons why holes are firing out of sequence. (3)

- The fuse spacing along the igniter cord was too short
- Faster igniter cord was used with longer fuses than standard
- Fuses from different bundles were mixed along the face
- The shock tube precision was low.

5.4 See attached table 1 and complete the blank spaces with regard to common gasses found in mines .

Exam number or ID number: _____

Table 1 (Question 5.4)

Gas	Chemical formula	Sources of gas	Dangers	Senses
Carbon Dioxide	CO_2	Blasting, Fuels, Fires	Oxygen deficiency- Asphyxia	Colourless and odorless
Carbon Monoxide	CO	Incomplete combustion, fires, Blasting and diesel equipment	Poisoness	Colourless and odourless
Oxides of nitrogen (Nitrous Fumes)	NOx	Explosives and Diesel Equipment	Lungs become waterlogged (oedema)	Can smell
Hydrogen	H2	Charging of electrical accumulators. Occur in conjunction with methane	Highly Explosive	Nil
Ammonia	NH_3	Blasting, excessive liming of settlers, refrigerants	Arrested breathing results in oedema(flooding of lungs)	Colourless. Can smell and irritatation of eyes nose and throat.
Methane	CH_4	Decay of vegatable and organic material	Burns, explodes and oxygen deficiency	Nil

(12)

Total: 20

Answer sheet multiple choice (Question 1) May 2016 Paper 3.2

ID Number

	a	b	c	d	e
1.1	X				
1.2				X	
1.3			X		
1.4		X			
1.5	X				