CHAMBER OF MINES OF SOUTH AFRICA

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN STRATA CONTROL – METALLIFEROUS	**EXAMINER:** Y Jooste
SUBJECT CODE: COMCSC	**MODERATOR:** DA Arnold
EXAMINATION DATE:	**TOTAL MARKS:** [100]
TIME: 14:30 – 17:30	**PASS MARK:** (60%)

NUMBER OF PAGES:

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer all the questions. Answer questions 1,2,3,4,5 and 8 and select one of question 6 and 7. Write **legibly** in English.
2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in. Your name **must not** appear on any answer book or loose sheets.
3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for calculations. Reference notes may not be programmed into calculators.
5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. **Final answers** must be given to an accuracy which is typical of practical conditions. However be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers.

   NB Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
11. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

Use the table supplied at the end of the exam paper and hand it in with your answer sheet.

1.1 GCD stands for:

a. Grout control district
b. Ground cycle district
c. Ground control district
d. Ground control database

1.2 A right angled triangle has one side of length 3m and a hypotenuse of length 10m. What is the length of the remaining side?

a. 9.52m
b. 9.54m^2
c. 9.54m
d. 9.58m^2

1.3 What is the stress called before any mining takes place?

a. Original stress
b. Virgin strength
c. Virgin stress
d. Pre-mining stress

1.4 Stemming is used in a blast hole as a plug to prevent the blowout of a blasthole.

a. True
b. False

1.5 What will the average pillar stress be if the virgin stress is 81 Mpa and the extraction ratio is 85%?

a. 540 Kpa
b. 531 Mpa
c. 540 Mpa
d. 580 Mpa

1.6 An elongate (180mm in diameter) yields at 20 tons. If units are installed on a 2,0m x 1,5m skin-to-skin spacing, what is the support resistance offered by the system? To get the correct answer, assume that g =10 m/s^2.

a. 54.6 kN/m^2

b. 212.2 kN/m^2

c. 66.67 kN/m^2

d. 52.5 kN/m^2

1.7 A loco with a full span of hoppers travels at a velocity of 15km/h. The operator applies the break and the loco decelerate at a rate of $0.2 m/s^2$. The loco will stop within ….?..m.

a. 24.23m

b. 28.21m

c. 43.47m

d. 44.21m

1.8 It is generally accepted within the industry that the standard support system should prevent at least 80% of all observed fallouts.

a. True
b. False

1.9. Name the testing machine in the figure below:

a. Closure meter
b. Tri-axial testing machine
c. UCS testing machine
d. Point load testing machine

1.10 A cylindrical rock sample is placed in a press and loaded with a 100 000 N force. The rock sample has a diameter of 0.065m. Calculate the stress on the sample.

a. 30.14 GPa

b. 30 Mpa

c. 32.14 Mpa

d. 30 GPa

[10]

QUESTION 2 – DEFINITIONS

Define the following terms:

2.1 Energy release rate

Is the energy change not accounted for during mining, or the available energy for release during mining,

ERR = $\Delta u/\Delta a$ (MJ/m^2) where Δu = strain energy available prior to mining and /Δa= area to be mined with stope width of 100cm

2.2 Geophone

A **geophone** is a device which converts ground movement (displacement) into voltage which may be recorded at a recording station. The deviation of this measured voltage from the base line is called the seismic response.

2.3 Gully

An excavation cut in the immediate footwall or hangingwall of the reef for the purpose of enabling the removal of rock from the face or of providing access to the face for men or material.

2.4 Subsidence

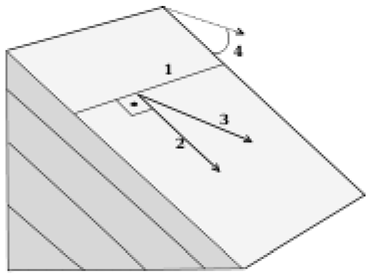
Downward movement of the overburden (soil and/or rock) lying above an underground excavation or adjoining a surface excavation.

2.5 Tensile stress **[10]**

Normal stress tending to lengthen a body along the direction in which it acts.

QUESTION 3 – GEOLOGY

3.1 Sketch and describe a normal fault, a reverse fault, strike, true dip and apparent dip.



1-Strike, 2-True Dip, 3-Apparent dip

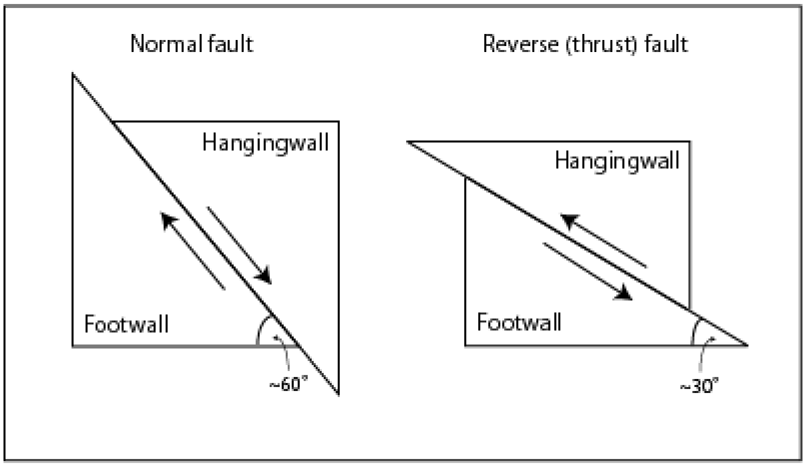
Strike – Strike is the direction of a level line on that tilted surface. It is more difficult to visualize, but easy to remember because it is always perpendicular to the direction of dip.

True dip - Dip is the angle of tilt, measured from the horizontal. Think of the direction of dip as the direction that a ball would roll if placed on the surface. The angle of dip is measured in degrees.

Apparent dip is the name of any dip measured in a vertical plane that is not perpendicular to the strike line.

Normal fault - an inclined fault in which the hanging wall appears to have slipped downward relative to the footwall. Results in the loss of reef

Thrust/reverse fault: a geological fault in which the hanging wall appears to have been pushed upward relative to the footwall. Results in the gain of reef



(10)

3.2 Explain sedimentary, metamorphic and igneous rocks and give an example of each one.

Igneous Rocks
These rocks are formed from a body of magma (molten rock below the surface of the earth) that cools down and solidifies. When heavy minerals and crystals settle out of suspension during the cooling down process, the result may be layers of igneous rock. Examples granite, rhyolite, gabbro, basalt, dolerite

Sedimentary Rock
Are layers of rock that were deposited on top of each other by forces of nature such as water, wind or ice. Each layer represents an uninterrupted uniform deposit, and is followed by a variable time interval until the next similar layer is deposited. The thickness of these layers varies from a few millimeters to several meters. Examples Shale, coal , sandstone

Metamorphic Rock
When the characteristics of some pre-existing rocks have undergone change, these changes in solid rock are described as metamorphism. Factors that bring about changes in rock are temperature, pressure and active fluids. The altered rock is referred to as metamorphic rocks. Examples marble, slate, gneiss

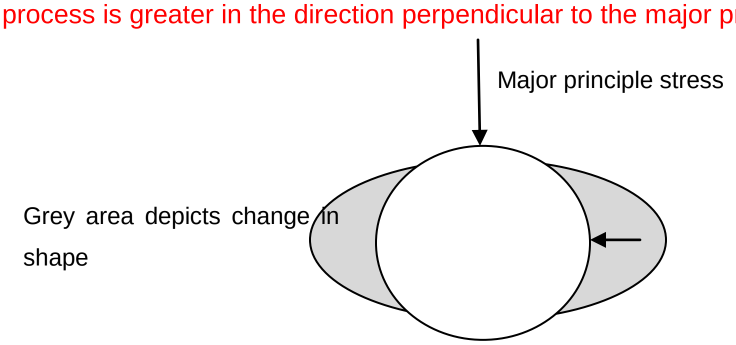
(10)
[20]

QUESTION 4 – FORCES AND STRESSES

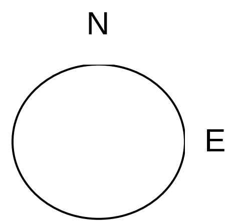
4.1 The attached plan represents a flat, tabular stope at a depth of 2 000m below surface. Sketch and annotate the hangingwall fracture orientations. (4)

4.2 Describe with an annotated sketch how "dog-earing" forms in underground development ends. (2)

Dog earring is the change in shape of an excavation due to scaling and fracturing. The fracturing process is greater in the direction perpendicular to the major principle stress.



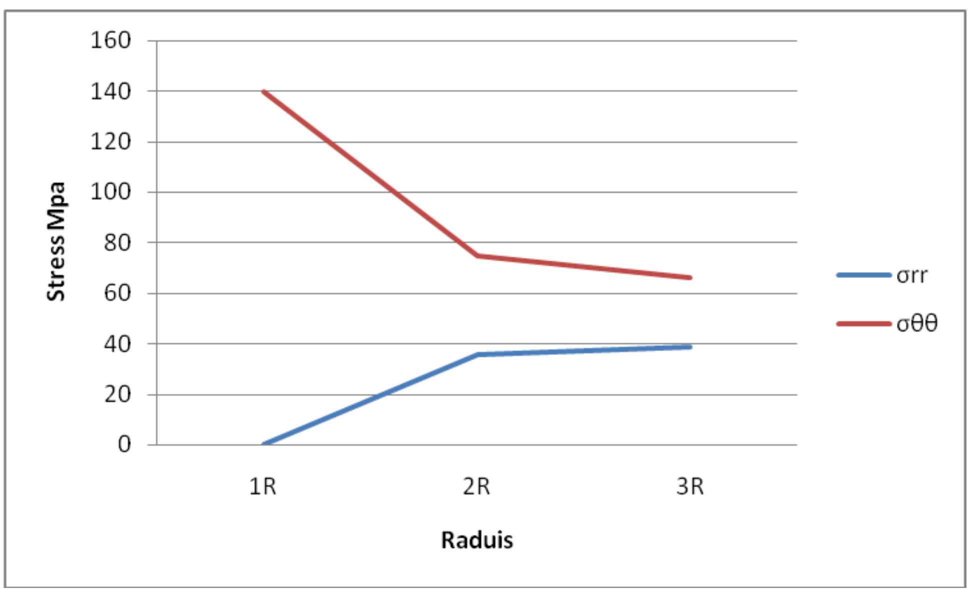
4.3 A vertical raise bore hole (3m in diameter) is planned to be used as an orepass. The field stress is estimated to be 40MPa in the east-west direction and 60Mpa in the north-south direction. Make use of analytical equations to calculate the radial and tangential stress in the side wall of the raise bore hole in the east west direction at the following distances: r=R, r=2R and r=3R. Assume the theta angle is 0 degrees to the east. Draw a graph showing schematically the radial and tangential stresses.



K ratio = 0.67

q_v = 60Mpa

	σ_{rr}	$\sigma_{\theta\theta}$
1R	0	139.98
2R	35.63	74.37
3R	38.53	65.93



(14)

[20]

QUESTION 5 – PILLARS AND MINING

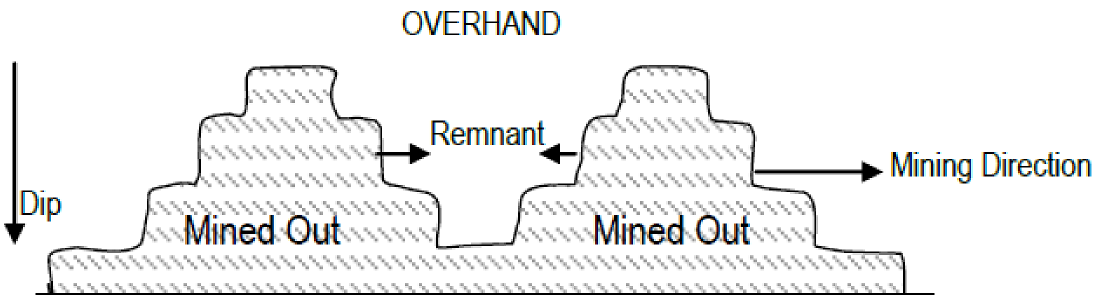
5.1 Name and describe the function of any two types of regional support pillars typically used in underground mines. (4)

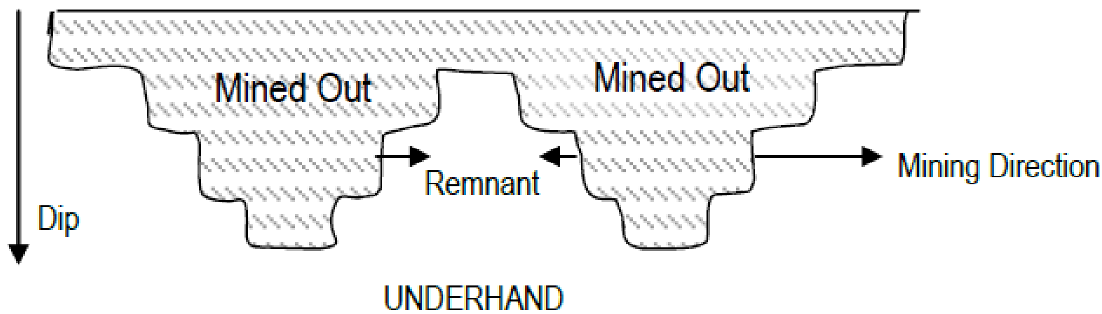
- Barrier - These pillars are often used for "compartmentalization" in shallow mines. They are the final line of defense against regional collapse. They are used to resist surface subsidence and strata movements in all non-deep mines, especially those using crush or yield pillars. Rule of thumb for the maximum span between barrier pillars is: Span < (¼ - ½). Depth
- Stability - Stabilizing pillars work on the principle that if a calculated percentage of the reef is left on dip or strike in a systematic layout of pillars, the overall level of stress and E.R.R. at the face can be substantially reduced, support up to surface.
- Boundary - The statutory 18m minimum for boundary pillars is probably too low for water pillars. At depth, severe fracturing occurs. However, no known cases have been reported of heavy water inrushes even with 18m barrier pillar. This is mostly attributed to the clamping effect caused by the overburden on such pillars.
- Bracket - Bracket pillars are strips of un-mined ground left against hazardous geological structures to act as partial barriers against seismic activity. Whether or not bracket pillars are used, the basic principles of negotiating hazardous geological structures (mining obliquely at > 35˚ to, or preferably away from, the feature need to be adhered to if at all possible.Especially in highly geologically-disturbed regions, the identification of which structures to protect seems best left to local experience supplemented with well-analysed quantitative seismic information.
- Water-barrier - The statutory 18m minimum for boundary pillars is probably too low for water pillars. At depth, severe fracturing occurs. However, no known cases have been reported of heavy water inrushes even with 18m barrier pillar. This is mostly attributed to the clamping effect caused by the overburden on such pillars.

5.2 Explain the meaning of the factor of safety in pillar design and comment on acceptable factors of safety for stable pillar systems. (3)

In any given non-yield pillar layout, the ratio of pillar strength to applied pillar stress is called „ safety factor‟: SF = $\boldsymbol{\sigma}_s$ / APS. Safety factors of 1.6 are applied in coal engineering, and values at least this high are appropriate for hard rock non-yield pillar design

5.3 Use a sketch and show clearly with annotation the difference between an overhand and underhand mining configuration. (3)





[10]

QUESTION 6 – SUPPORT

6.1 Backfill is a support system that is used to address various rock engineering problems. List the advantages of backfill when used for a) local and b) regional mining conditions.

Local advantages:

- Maintain integrity of fractured rockmass
- Improve face and gully conditions
- Reduce rockburst damage
- Better stoping width control
- Provide areal support coverage

Regional advantages:

- Reduce volumetric closure in back areas thus ERR on faces
- Percentage extraction increase
- Reduce stresses acting on stabilizing pillars

(4)

6.2 Describe what happens with the fracturing of a rockmass when a panel is stopped for an extended period of time. (2)

Increase fracturing.

6.3 What special rock engineering precautions would you implement and recommend for a stopped panel? (2)

Decrease last row of support to face distance

Blast shorter length holes and decrease burden spacings when blasting starts again.

Decrease dip and strike spacings of support units

Use support with areal coverage

6.4 Define areal coverage. Under what conditions would you recommend this characteristic of support as being important? (2)

Areal coverage – a higher percentage of the hanging wall is supported for example packs will have a higher areal coverage than elongates

Severe fractured hanging wall

Highly jointed or friable HW conditions

6.5 With the aid of annotated sketches, describe the extraction stages and the support sequence you would recommend for long (>10m), wide (>4m) chamber that is to be 4m high. (10)

Explained any sequence used on your mine with a bit of detail on:.

- Blasting rounds lengths.
- Temporary support
- Primary support
- Secondary support

[20]

QUESTION 7 – MASSIVE MINING

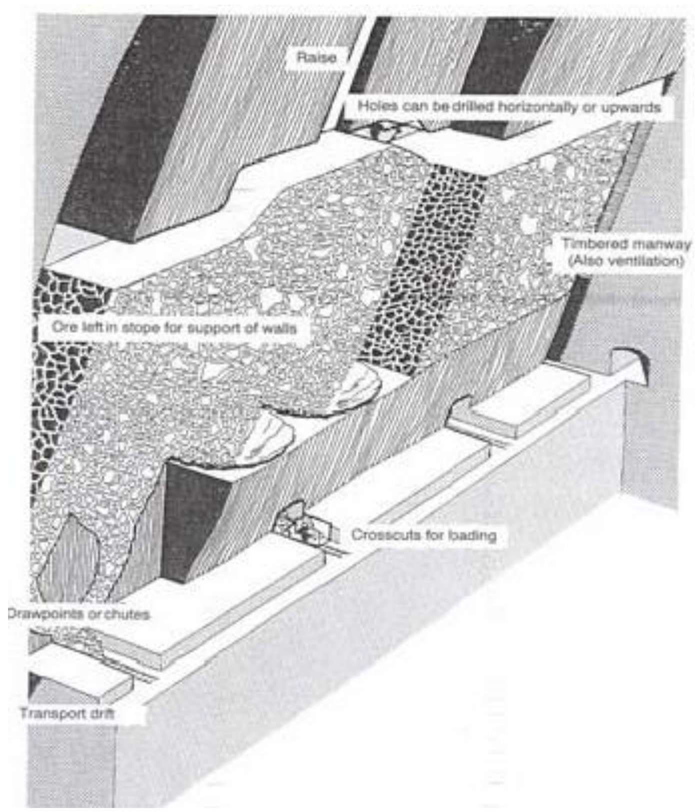
7.1 List 5 factors that need to be considered for the selection of a mining method. (5)

Geometry of the deposit and the physical characteristics of the deposit and wall rock.

- Method adaptable to irregular ore limits, yielding good recovery and minimal dilution.
- Deposit strike length and dip.
- Consistency of the ore body width.
- The dimensions and regularity of deposit.
- The geomechanical properties of the wall rocks and ore.
- Nature of the grade distribution.
- Hydrogeology.

7.2 Sketch and describe any 3 of the following massive mining methods:

- Shrinkage mining



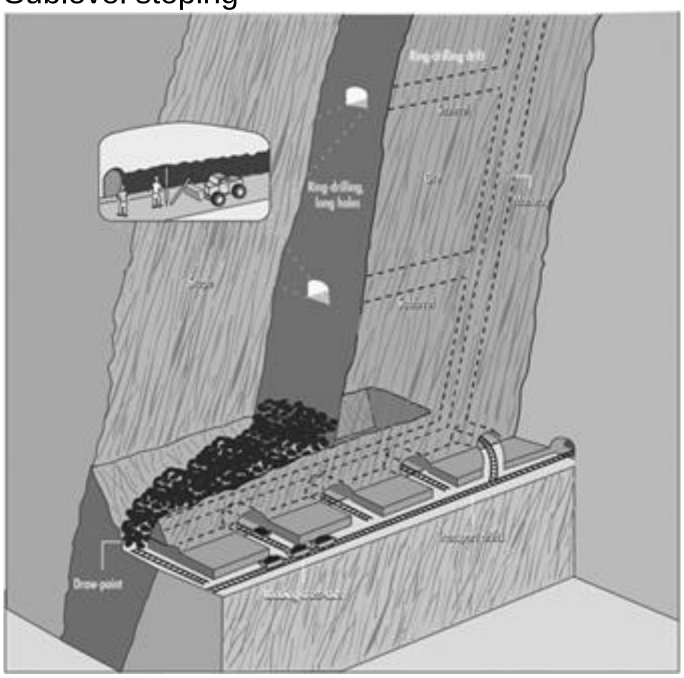
In shrinkage stoping, traditionally a common mining method, ore is excavated in horizontal slices, starting from the stope bottom and advancing upwards. Part of the blasted ore is left in the stope, to serve as a working platform, and to give support to the stope walls.

Blasting swells the ore by about 50%, which means that a substantial amount has to be left in the stope until mining has reached the top section, following which final extraction can take place.

Shrinkage stoping can be used for orebodies with: steep dips; comparatively stable ore and sidewall characteristics; regular ore boundaries; and ore unaffected by storage (some sulphide ores oxidize, generating excessive heat). The development consists of: haulage drift and crosscuts for mucking at stope bottom; establishment of drawpoints and undercut; and a raise from the haulage level passing through the undercut to the main level, providing access and ventilation to the working area.

Drilling and blasting are carried out as overhead stoping. The rough pile of blasted ore prevents the usage of mechanized equipment, making the method labour-intensive. As such, working conditions are hazardous, and a large part of the ore has to be stored until final extraction. Despite these drawbacks, shrinkage stoping is still used, especially for small-scale operations

- Sublevel stoping

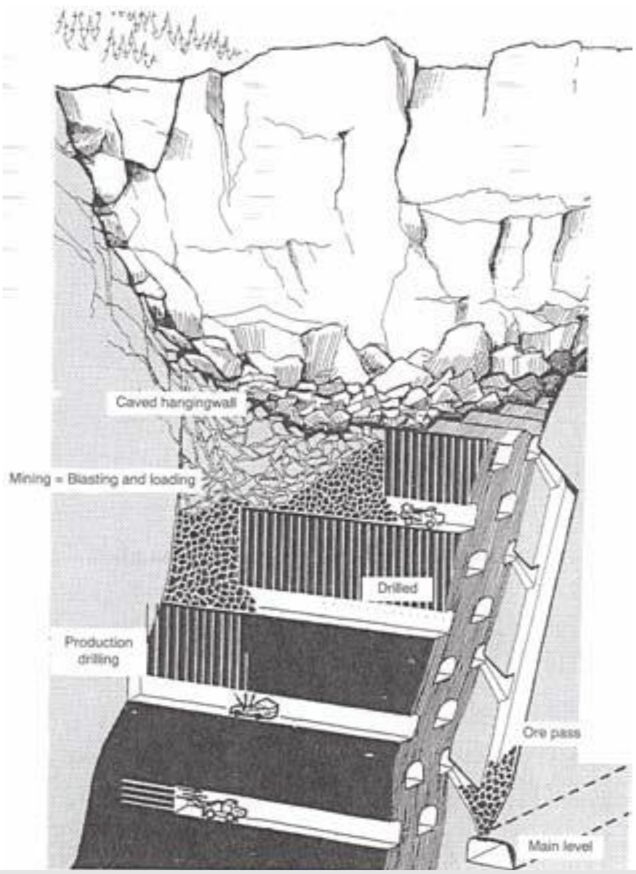


Sublevel stoping is a method of underground mining method that involves vertical mining in a large, open stope that has been created inside an ore vein. Usually the stope operates as the center for production. In sublevel stoping, this is not the case. The stope is not meant to be occupied.

Drilling, blasting, and mining are carried out at different elevations in the ore block.
In sublevel stoping, an ore pass is first drilled into a series of sublevel drifts that begin at a lower elevation within the stope, ending at a higher one. The drilled sublevels are situated directly above a main haulage level. Jumbo drills are used to selectively drill out holes in the roof of the drifts; the holes are then filled with explosives. The explosives, once detonated, blast apart the roof of the sublevel drift and loose rock and muck fall through the drilled ore

pass. Load haul dump trucks (LHDs) and scoop trams are used to transport the muck to another ore pass where it is placed into a crusher before being elevated up to the surface on a conveyor. Blasting of the drift roof continues until it is out of reach of the drilling jumbo. Another jumbo drill working on another higher drift is used to intersect the stope with drilling and blasting. The loose and broken ore falls down to the lower sublevel drift. A load haul dump truck or scoop tram, able to maneuver inside the lower drift, loads up the ore and muck and dumps it into the ore pass. The excavation process is repeated until the stope is left completely empty and then backfilled from the bottom up to support the stope walls and roof.

- Sublevel caving



Sublevel caving is applicable to mineral deposits with steep to moderate dip and large extension at depth. The ore must fracture into manageable block with blasting. The hanging wall will cave following the ore extraction and the ground on the surface above the orebody will subside. (It must be barricaded to prevent any individuals from entering the area.)

Sublevel caving is based on gravity flow inside a broken-up rock mass containing both ore and rock. The rock mass is first fractured by drilling and blasting and then mucked out through drift headings underneath the rock mass cave. It qualifies as a safe mining method because the miners always work inside drift-size openings.

Sublevel caving depends on sublevels with regular patterns of drifts prepared inside the orebody at rather close vertical spacing (from 10.0 m to 20 0 m). The drift layout is the same on each sublevel (i.e., parallel drives across the orebody from the footwall transport drive to the hanging wall) but the patterns on each sublevel are slightly off-set so that the drifts on a lower level are located between the drifts on the sublevel above it. A cross section will show a diamond pattern with drifts in regular vertical and horizontal spacing. Thus, development for sublevel caving is extensive. Drift excavation, however, is a straightforward task which can readily be mechanized. Working on multiple drift headings on several sublevels favours high utilization of the equipment.

When the development of the sublevel is completed, the long-hole drill rig moves in to drill a blast holes in a fan-spread pattern in the rock above. When all of the blast holes are ready, the long-hole drill rig is moved to the sublevel below.

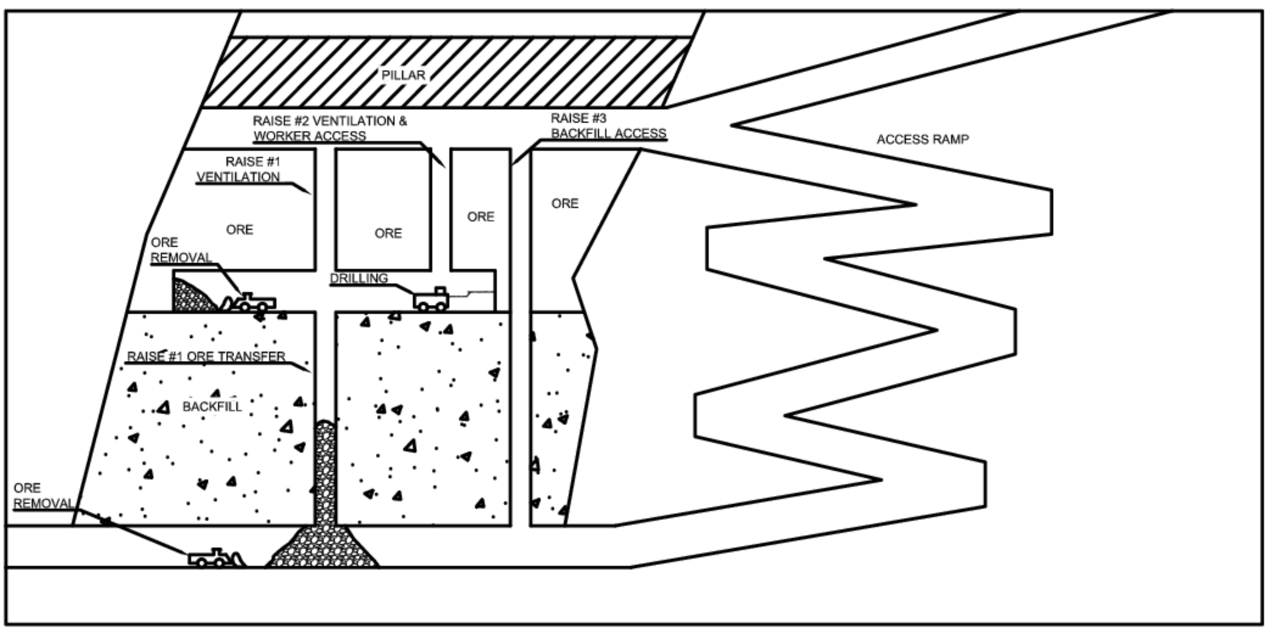
The long-hole blast fractures the rock mass above the sublevel drift, initiating a cave that starts at the hanging wall contact and retreats toward the footwall following a straight front across the orebody on the sublevel. A vertical section would show a staircase where each upper sublevel is one step ahead of the sublevel below.

The blast fills the sublevel front with a mix of ore and waste. When the LHD vehicle arrives, the cave contains 100% ore. As loading continues, the proportion of waste rock will gradually increase until the operator decides that the waste dilution is too high and stops loading. As the loader moves to the next drift to continue mucking, the blaster enters to prepare the next ring of holes for blasting.

Mucking out on sublevels is an ideal application for the LHD vehicle. Available in different sizes to meet particular situations, it fills the bucket, travels some 200 m, empties the bucket into the ore pass and returns for another load.

Sublevel caving features a schematic layout with repetitive work procedures (development drifting, long-hole drilling, charging and blasting, loading and transport) that are carried out independently. This allows the procedures to move continuously from one sublevel to another, allowing for the most efficient use of work crews and equipment. In effect the mine is analogous to a departmentalized factory. Sublevel mining, however, being less selective than other methods, does not yield particularly efficient extraction rates. The cave includes some 20 to 40% of waste with a loss of ore that ranges from 15 to 25%.

- Drift and fill



Applications
Cut-and-fill mining is applied for mining of steeply dipping orebodies, in strata with good to moderate stability, and a comparatively high grade mineralisation. Cut-and-fill mining provides better selectivity than alternatives SLOS and VCR mining. Cut-and-fill is therefore preferred for orebodies where with irregular shape and scattered mineralisation. Cut-and-fill allows selective mining, to

recover high grade sections separately, and leave low grade rock behind in stopes.

Description

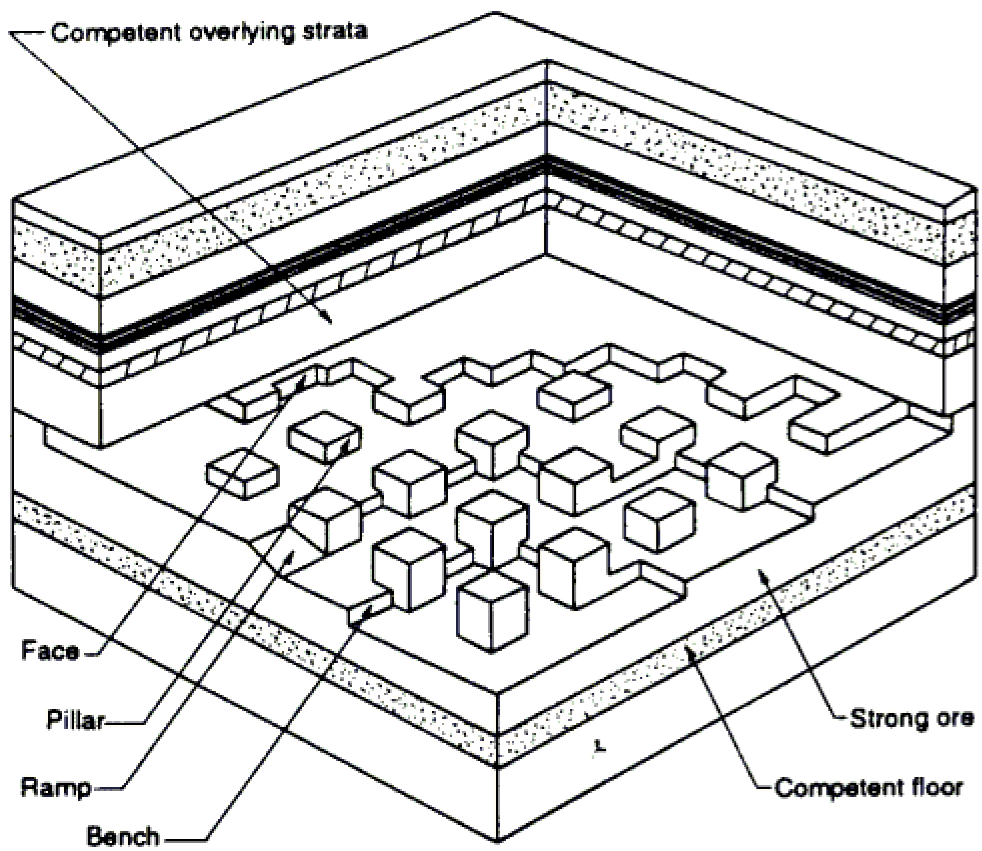
Cut-and-fill mining excavates the ore in horizontal slices, starting from a bottom undercut, advancing upward. The ore is drilled, blasted, the muck loaded and removed from the stope. When the full stope area has been mined out, voids are backfilled with sand tailings or waste rock. The fill serves both to support stope walls and working platform for equipment, when mining the next slice. The fill often consisting of de-slimed sand tailings from the mine's dressing plant, at times complemented by waste rock produced by development excavations, dumped in empty stopes by LHD-loaders. Hydraulic sand fill is used with cut-and-fill mining. The fill, coarse-grained waste particles from the mine's dressing plant, are mixed with water to 60 to 70 % solids, and distributed to stopes via a network of plastic tubing. Before filling, stopes are prepared by barricading entries, and drainage tubes laid out on the bottom. The sand fills the stope to almost full height. As a harder fill is required on the surface, cement is mixed in the last pour. When the water has drained, the fill surface is smooth and compact, and a good base for mobile machines while mining the next slice of ore.

Development

Development for cut-and-fill mining includes:

1. Footwall haulage drive along the orebody at the main level.
2. Undercut of the stope area with drains for water
3. Spiral ramp in the footwall, with access drive to undercut.
4. Raise connection to level above, for ventilation and filling material

- Room and pillar



Room-and-pillar mining is applicable to tabular mineralization with horizontal to moderate dip at an angle not exceeding 20° (see figure 5). The deposits are often of sedimentary origin and the rock is often in both hanging wall and mineralization in competent (a relative concept here as miners have the option to install rock bolts to reinforce the roof where its stability is in doubt). Room-and-pillar is one of the principal underground coal-mining methods.

Room-and-pillar extracts an orebody by horizontal drilling advancing along a multi-faced front, forming empty rooms behind the producing front. Pillars, sections of rock, are left between the rooms to keep the roof from caving. The usual result is a regular pattern of rooms and pillars, their relative size representing a compromise between maintaining the stability of the rock mass and extracting as much of the ore as possible. This involves careful analysis of the strength of the pillars, the roof strata span capacity and other factors. Rock bolts are commonly used to increase the strength of the rock in the pillars. The mined-out stopes serve as roadways for trucks transporting the ore to the mine's storage bin.

The room-and-pillar stope face is drilled and blasted as in drifting. The stope width and height correspond to the size of the drift, which can be quite large. Large productive drill jumbos are used in normal height mines; compact rigs are used where the ore is less than 3.0 m thick. The thick orebody is mined in steps starting from the top so that the roof can be secured at a height convenient for the miners. The section below is recovered in horizontal slices, by drilling flat holes and blasting against the space above. The ore is loaded onto trucks at the face. Normally, regular front-end loaders and dump trucks are used. For the low-height mine, special mine trucks and LHD vehicles are available.

Room-and-pillar is an efficient mining method. Safety depends on the height of the open rooms and ground control standards. The main risks are accidents caused by falling rock and moving equipment.

(15)

[20]

QUESTION 8 - Monitoring

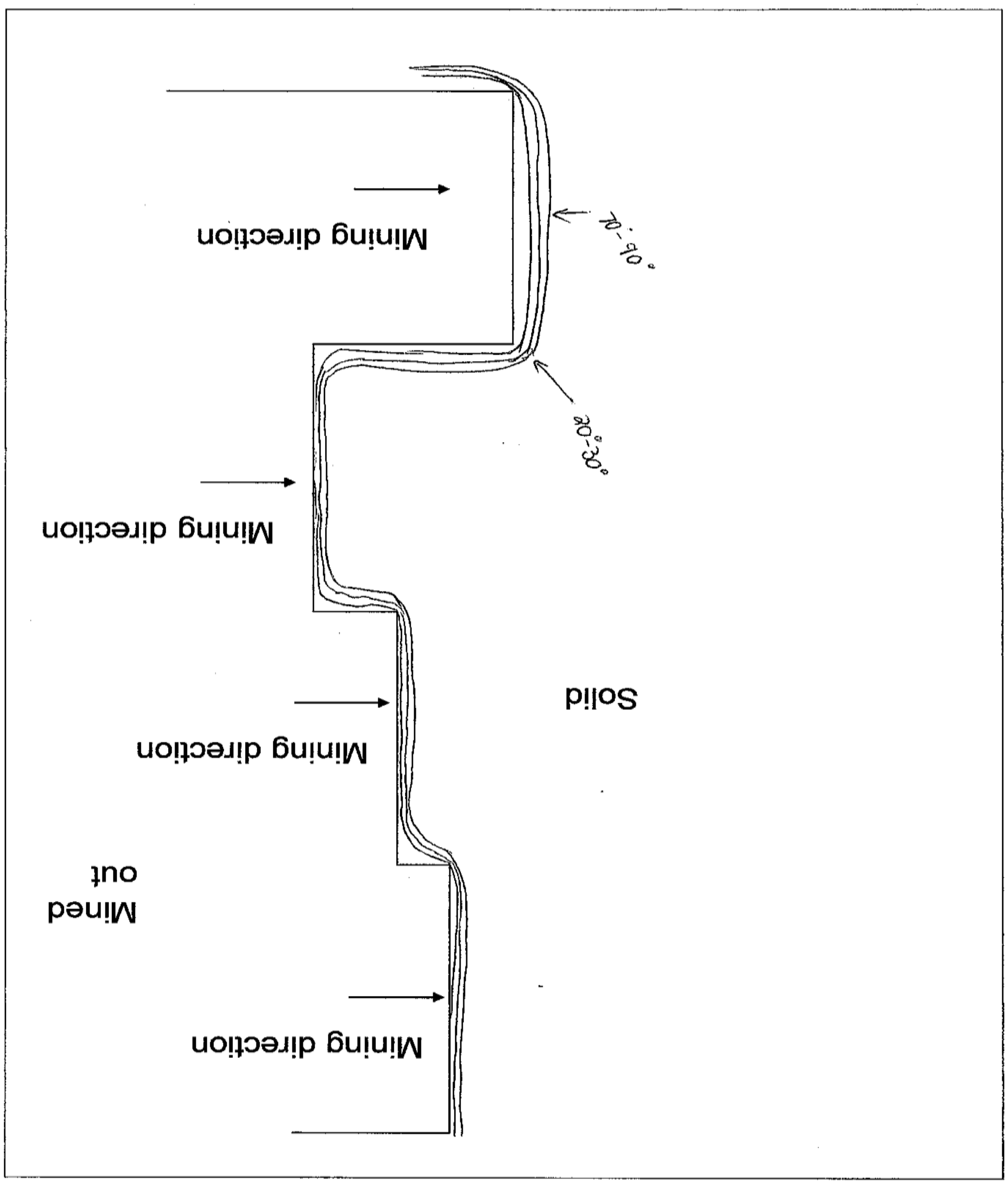
You are a rock engineer appointed on a new medium depth mine. What types of rock engineering monitoring would you recommend to management and explain shortly why?

- Seismic monitoring
- Closure monitoring
- Stress monitoring
- FOG thickness monitoring
- Rock Mass Rating methods
- Pull tests
- Backfill performance
- Ground water – influence on support
- Pillar performance monitoring
- Support performance
- Back break monitoring

[10]

TOTAL MARKS: [100]

Question 4.1



Question 4.1