MINING METHODS (UNDERGROUND METAL)

1.0 Development in underground Metal Mine

1.1 Explain formation of blocks of mineral deposit.

In early stage an underground mine required carefully planned network of shaft drifts and rises etc. The formation of network of shaft drifts and rises is known as development of the mine.

At the time of development following points should be kept in mind.

1. The deposit has to be divided in separate blocks by driving drifts, levels, horizon from the shaft.
2. The haulage drive at any horizon from footwall should be straight and wide with much as possible.
3. The mineral are transported downwards in different section to the lower levels as far as possible. All ore carried which is located usually at lower levels.
4. Normal mining or stopping is carried out from boundary to the shaft in a retreating manner.
5. With steep deposit the miners enter the working from above.
6. Timber and other materials tools and machinery are transported to the mine from upper levels to the working place.
7. Filling or packing materials are transported to working place through upper levels and then down to the site by tubs. Now a days filling material are hydraulically transported.
8. The support used in working place should be lasting to avoid the expense stopping.
9. Air current must goes to the lower levels and then rises to upper levels to ventilate the working district.

1.2 Explain level interval.

The vertical distance between two levels is known as level interval. Level driving is narrow work involving more cost per m^3 than stopping. Each level requires timbering haulage track, pipe line, loading machine and haulage machine. The cost of the plats crusher and ore chutes cabe minimized by connecting haulage on alternate or every 3^{rd} level.

During lateral development in metal mines the level interval varies between 15-100m.

The drive cross cuts drifts, benching of levels gives the correct idea of deposit their quality and quantity.

Level interval are short if,

- The deposit has not proved adequately during explosion stage.
- The deposit is irregular in dip quality and quantity.
- Some of the ore body has been missed during initial prospecting stage.

High grade of ore requires proper levels to be close together to avoid missing ore.

Thicker the ore body lesser level interval. If ore body is thin level interval is more.

The selection of level interval is governed by least cost per tone of ore, mined by method of mining. The economical level intervals in any mine decided by management taking into consider the factors.

1.3 Describe raising methods in metal mines.

i) Open raising method, ii) Two compartment method, iii) Jora raise lift, iv) Long hole drilling method, v) Alimak raise climber, vi) Raise borer

i) Open raising method : For moderate length upto 8m and inclination of 40°-60° with the horizontal. In order to accmodate the stopper and starting drill steel of 800mm length, a clear hand of 2m is required.

Description:

- This is simple and most common method adopted in majority of metal mines.
- The workers stand on a platform made of timber supported on iron bars into the footwall.
- The drill hole is done by jackhammer and generally done by wedge pattern.
- Holes are 32mm dia and 1.5m deep.
- Before each round of blasting the platform is dismentaled.
- Immediately after blasting compressed air is forced to the working face to remove the fumes of blasting and for ventilation.
- The platform is shifted after 2 to 3 round blasting i.e. after getting a sufficient progress.

Disadvantages :

- Lack of ventilation.
- Damage to pipes and ladders etc, from the blasting.
- Loss of efficiency when the raise go higher as the workers have to frequently ro up and down the ladders.
- Platfrom holes requires careful alignment.

ii) Two compartment method : Adopted for vertical or very steep raises. Relatively large cross section. The working stage rests on 2 or 3 stalls temporarily set into holes, made in walls of the raise. If consists of wooden plunks laid over stalls.

Description:

- Depending upon requirement two or three compartment are made.
- In two compartment method one compartment will be serve as ore pass and the other compartment will serve as man ways, pipes, cables etc.
- Initially the excavations 2m done from the lower level.
- Then the raise is divided into compartment and the raise is driven continuously.
- After getting sufficient progress, the platform is extended. Generally after two or three blasting compartment is required to be extended.

Advantages :

- Strong platform can be erected.
- Pipes, cables are well exacted.
- Since one compartment is act as ore pass, so loading is easier at lower ends.
- Person can be protect in the compartment when climbing from flying rock or adjacent roof on side fall.

Disadvantages :

- Ventilation is sluggish.
- Maximum space occupied by compartment.

iii) Jora raise lift :For vertical raise. The strata should be strong.

Description:

- In this method a bore hole is drilled upper level to meet lower level.

- The bore is drilled such that if represents the center of raise drive.
- A small hoist pully is set in the upper levels from roof. The pulley is set such that it is above the bore hole.
- The pulley carries a steel wire rope on end of the rope is wound on hoisting drum set in the upper level. The other end of rope passed through this hole. This end of the rope will be in the lower level.
- Wedge cut holes are drilled in the roof of lower level around the rope. These holes are charged with blasting cable.
- The face is well dressed and blasting material shoveled and dropped in lower level for further transport.
- The raise is ventilated for 10-15 minutes after blasting.
- The complete area of the raise is highered. Now the platform is withdrawn, the jora compartment is made free. The jora raises is further raised. When the canopy is just touching the roof of raise it is stopped.

Advantages :

- It is suitable for vertical and inclined drivage of raise
- Preparation is very quick and less time is lost in setting the platform.
- The ladder way is not required as the workers are traveling in jora compartment.
- The time wasted on softening is less.
- The workers works on a strong protecting cover of canopy, hence there is no danger to workers during drilling.
- Time is not wasted in loading as the blasted material on the platform is shoveled to lower level.
- The working progress is high.

iv) Long hole drilling method :

In this method, the size of the raise is marked on the floor of upper level. The center of the raise in the upper level roof and on floor.

Raising is through long hole, all the drilling loading and blasting operation are performed from horizontal working. There is no need of miner presence at the face.

In order to put the raise between horizontal working 1 and 2 long parallel blast holes 3 are drilled from the upper level.

The holes are then fired portion wise, either simultaneously or in succession.

The length of the sections depends on the properties of rock ranging from 1.5-6m or even 9m.

The bottom of the blast hole is filled with plugs 4 from below and explosive charges 5 are lowered down into the holes on string. The holes are then stemmed material 6.

the explosives are fired by detonating fuse. For better accuracy care should be taken that straight without any deviation.

The practical limit in adopting this method is holes of 15-50m at a maximum inclination of 35°.

The method is used only in firm ground mainly for excavating cut out raises in stopping.

v) Alimak raise climber : The method of driving long raise with the help of machine called. Alimak raise climber was introduced in 1957.

The Alimak raise climber consists of :-

1. A reel with air hose of provide compressed air to the twin air motors causing travel of cage. The reel automatically winds upto the hose when the raise climber descends and feed its during ascent.
2. Guide the rails with the rock and pinion. The length of guide rails 1 or 2m. Some pieces are suitably curved for smooth profile. The guide rails are bolted into rock bolts fitted in side of the raise.
3. The guide rails have recess to carry 2 compressed air tubes. 1 water tube and a telephone cable which is used for blasting.
4. The rock bolts are of expansion shell type recoverable spears are provided to cover up the length between the rock bolt and guide rail.
5. There is a cage that travel along the guide rail and carries the driller and other screw to the face of the raise.
6. The working platform on the top of cage materials are transported on the platform.
7. compressed air drive unit with air, motor for travel of the cage.
8. Protection canopy.

The Alimak climber can be used only where the raise is driven at an angle 40° or more with the horizontal since the rock blasted at the face of the raise has to come down by gravity.

Advantages:

1. The materials falls due to gravity in lower level.
2. Loading of material in lower level is quick.
3. Much of the time is saved by climber as workers are riding in it.
4. No ladder ways, pipes lines etc. are required.
5. Dressing is safe under canopy.
6. Platform is not damaged.
7. Cycle time is short.
8. It is quick method.
9. Suitable for vertical and inclined raise.

vi) Raise borer : Raise bore are first introduced in mines of western countries in 1962 and at present 300 raise bores are in use throughout the worlds.

1. The method of raise drilling of pilot hole, 230 mm to 300 mm dia between two levels at the site, and in the direction of proposed raise and then reaming the pilot hole by reaming bit to the size of the raise.
2. If the pilot hole is reamed from upper level to the lower level, it is known as down reaming method. If the pilot hole is reamed from lower level to upper level, called up reaming method.
3. The cutting rock fall down from the face by gravity and the pilot hole does not need large dia holes. Down reaming method demands pilot hole of large diameter to permit cutting rock between drill rod and the hole sides.
4. Normally the diameter of the drilled raise varies from 1 m to 3.7 m as the raise drill bit are available in these sizes.

Driving rises has often creates difficulty in many mines using conventional method. Ventilation, transport, safety of person, cost are the problem in conventional raise. Now hard rocks can be cut by various type of rotary bit developed in recent years. This is possible by raise bore method ranging from 1 m to 3.7 m dia.

Advantages :

1. They are usually drilled faster.
2. They are less cost in many cases.
3. Personnel are not exposed to the hazards of raise driving in drilling, blasting method.
4. The finished section is often smooth which offers less resistance to flow ventilation of air and drilled raise may not require support.
5. A large cross section are not needed and a small dia raise is easier to drill, if can be drive congenitally.
6. The raising cost per length becomes less as the raise length increases.

2.0 Give a comparative study between coal and metal Mining.

SN	COAL MINE	METAL MINE
1	Bedded deposit.	Non-bedded deposie.
2	Geological disturbances i.e fold, fault, occurs.	Geological disturbance not effect.
3	Research & planning is very easy .	Research & planning less easy.
4	It is softer than metal.	It is harder than coal.
5	Electricity is the main power.	Compressed air is the main power.
6	Extraction is easy.	Extraction is difficult.
7	Roof is soft.	Roof is hard.
8	It is uniform in quality thickness & dip.	It is non-uniform in quality thickness & dip.
9	Regular in extent shape thickness.	Irregular exist shape thickness.
10	They exits in patche or shoots.	They doesn't exit in.
11	It is less varied.	It is more varied.
12	It can be used directly after extraction from the mines as a fuel.	It can be used directly processed for getting the mineral & metal.
13	Extraction is not heavy.	Extraction is heavy.
14	Underground mining is much simpler.	Underground mining is less simpler.
15	Underground mining produce an infalmable & explosive gas fire damp must be explosive is done.	Such danger is not exist in underground metal mines.
16	Sampling are not important day to day operation.	Sampling are important day to day operation
17	Geologist is not important in initial exploration.	Geologist is an essential staff.
18	It is not required a high standard of surveying.	It is required a high standard of surveying.
19	Gestation/Incubation period for underground is smaller (2-3 years)	Incubation period for underground is longer (4-5 years)
20	It is amenable to large scale mechanism.	It is not amenable to large scale mechanism
21	It is involves detailed exploration & carefully planning before opening up a mine.	It is involves more detailed exploration and careful planning before opening up a mine.

3.0 Stopping Method :

Stope : It is a solid are block or ore pillar which is under extraction is called stope.

Stopping : It is the method of extraction of ore from a block or pillar formed during development. As a rule stopping is started on each side of a raise winze connection.

Stopping Method : Stopping is the final extraction of an ore body that has already been developed. The main work consists of drilling & blasting or ore. Removal of the broken ore from working place & supporting the ground, so that the operation can be carried out safely varies methods of stopping are adopted have been adjective to exploit the ore in the sagest & economical way observing the rule of conservation of minerals.

3.1 Classify stopping methods with application and factors affecting methods of stopping.

Classification :

(A) Stopes naturally supported.
- (1) Open stopping.
  - (a) Open stopes in small ore bodies.
  - (b) Sublevel stopping.
  - (c) Long hole stopping.
- (2) Open stopes with pillar supports.
  - (a) Casual pillars.
  - (b) Room (or stope) and pillar (regular arrangement)

(B) Stopes artificially supported.
- (3) Shrinkage stopping.
  - (a) With pillars.
  - (b) Without pillars.
  - (c) With subsequent waste filling.
- (4) Cut and fill stopping.
- (5) Stulled stopes in narrow veins.
- (6) Square-set stopping.

(C) Caved stopes.
- (7) Caving (ore broken by induced collapse)
  - (a) Block caving : including caving to main levels and caving to chutes or brached raises.
  - (b) Sublevel caving.
- (8) top slicing (working under a mat, which together with caved overburden follows the mining downward in successive stages)

(D) Combination of supported and caved stopes, (as shrinkage stopping with pillar caving, cut and fill stopping and top slicing of pillars, etc.)

Application of underground metal mining methods.

Type of ore body	Dip	Strength of ore	Strength of walls	Possible Method of Mining
Thin bodies.	Flat	Strong	Strong	Room and pillar, casual pillar, Open stopes.
		Weak or strong	Weak	Top slicing, Longwall
Thick bodies.	Flat	Strong	Strong	Sub-level stopping, Room and pillar, Cut and fill
		Weak or strong	Weak	Sub-level caving, Top slicing
		Weak	Strong	Square set, Cut and fill, Sub-level stopping.
Narrow veins.	Steep	Weak or strong	Weak or strong	Resuing in (a) Open stopes or, (b) Stulled stopes
Thick veins.	Steep	Strong	Strong	Open stopes, Sub-level stopping, Shrinkage stope, Cut and fill method.
	Steep	Strong	Weak	Cut and fill stopes, Square set stope, Top slicing, Sub-level caving
	Steep	Weak	Strong	Open casual pillar, Square-set stope, Top slicing, Block caving, Sub level caving
	Steep	Weak	Weak	Square-set stopes, Top-slicing, sub-level caving
Massive		Strong	Strong	Shrinkage stope, Sub-level stopping, Cut and fill stope
		Weak	Weak or strong	Square-set stope, Top-slicing, Sub-level caving, Block caving

Factor affecting methods of stopping :

1. Thickness of ore body : There are ore bodies which are thin, thick and extra ore bodies. Thin ore bodies are suitable to work with breast-stopping method.
2. Dip of the ore body : The ore bodies with low inclination and not extending 35° inclination are suitable for breast stopping method.
3. Character of ore bodies : Some of the ore bodies are strong and some of the ore bodies are weak.
4. Character of walls : Some cases the hanging wall or footwall of ore bodies are strong and in some cases either the hanging wall or footwall or both may be weak.
5. Cost of ore bodies : Some of the ore bodies contain, costly minerals and some of the ore bodies costly due to rich mineralization.
6. Nature of Mineralization of ore body : The ore body contain low percentage of mineral can be worked by breast stopping method.
7. Continuity of ore body : Some of the ore bodies are continuous and regular ore bodies are worked by timer stopped method and shrinkage stopping method.
8. Cost of supports and availability : In case of timber stope method and top slicing method regular supply is supplied.
9. Depth of the ore body from surface : When ore bodies are at shallow depth the harrying bore method can be used.
10. The shape, size and regularity of the deposit.
11. Mineralogical character and value of ore and the distribution of values.
12. The dip, width and strength of the ore.

13. Nature of overburden.
14. Surface features : their support vis-à-vis caving.
15. Possibility of dilution of ore with waste.

3.2 Describe the methods with layout including drilling, blasting, transportation and supports.

(A) Open stopping : It is a stope in which no filling or timber is used to support walls and only simple forms of scattered timber is used as temporary supports. The walls are sometimes supported by temporary or permanent pillars of ore, Open stopping permits of mechanization in drilling, loading and hauling. Dilution of ore is minimum. A typical stop block may have maximum dimensions 30m X 120m with the height varying from 10m to 50m. Steeply dipping ore bodies are also extracted by open stopping but up to a depth of about by intermittent pillars.

Open stopes further classified as follows :

(a) Overhand stopping
(b) Underhand stopping.
(c) Breast stopping.

(a) Overhand stopping : The two levels enclosing an ore block are connected by raises at interval, 25-40m and stopping starts from one direction only. The stopping operation proceeds from lower main level towards the upper main level and ore is extracted in an ascending manner. Horizontal slices are taken parallel with the haulage level. If the ore body has a mild gradient which prevents gravitation of blasted ore, scrapers are used to collect and load it into mine cars. In the method of overhand stoping with stull timbering the preparatory arrangement consists in driving roof haulage drift and raise from lower level to upper level. If the ore body is not steep and nearly 3m in thickness. Overhand stopping is replaced by room and pillar method of stopping. In thick ore body (nearly 3m and above) stopping dipping the overhand method of stopping is usually changed to shrinkage method or sub-level method of stoping.

Condition :

1. The thickness is selected is upto 4.5m.
2. The ore body required strong.
3. Both hangwall and footwall should be strong.
4. The inclination of ore body is 40°-90°.

Preparation :

1. Preparation are made for ventilation supply of power, supply of material, addition man power and additional handling of production.
2. The lower level is prepared for ore transport.

Development :

1. The ore body is approached from the shaft, inclines or adits.
2. The ore body is further approached by cross-cuts, set regular interval from shaft and inclines.
3. When cross-cut touch the ore body, the ore body is developed by driving the levels or caompanion levels at their horizons.
4. These levels are inter connected at regular intervals, by raise or winzes.
5. The raise and winzes are connecting the upper and lower level.

6. When the development of two adjecnet levels is complete the stopping operation is under taken.

Advantages :

1. The full advantages of gravitational force is taken from face.
2. Blasting efficiency is high.
3. The broken ore fall away from face.
4. The danger is less.
5. Ventilation is good.
6. The dust and smokes can be easily cleared.

Disadvatages :

1. Setting of platform cann't done easily.
2. Sometimes drilling creates problems.
3. No. of benches blasted are 3-4 only.
4. Muck falls on body of workers.
5. Not suitable for weak ore body.
6. Selective mining is not possible.

(b) Under hand stopping : It is used in working thin steeply dipping veins enclosed in strong wall rocks. In an underhand stope the face is below the driller who is supported partly by footwall. The stope is worked in a downward direction from upper main level to the lower main level commencing from a winze. A horizontal slice 2 to 2.5m high is started on top of an ore block. The ore is broken in horizontal slices. Miners stand on the steps formed and drill the shot holes downwards. It is a common practice to open new chutes as the stope is extended along the strike. Underground stopping is practiced relatively rarely. The transport of ore is somewhat difficult and vlasting efficiency is poor as the blast has to lift the ore that is blasted. Ventilation is also not simple. Efficiency of miners in breaking the ore is however high.

Advantages :

1. It allows high blocks.
2. It makes a systematic sorting of the ore possible.
3. Broken ore falls clear of the face.
4. High wall & face can be conviently examined.

Disdvantages :

1. The performance of the drillers is less.
2. With a dip exceeding 45° platform have to be erected in the stopes for the mines.
3. Much supporting material is used.
4. The losses of fine ore are considerable.

(c) Breast Stopping : Breast stopping is suitable for
(i) The deposite must be horizontal or mild up.
(ii) Laying at a moderate depth.
(iii) Country rock must be rock.
(iv) Medium thickness of ore body upto 5 m.

Description :

- The horizontal movement of a vertical face is called breast or when the holes are drilled in front of face such holes are called breast holes. When a stope is extracted by breast holes the method of stoping is called breast stoping.
- In this method 2 levels are driven in the horizontal direction & serve for haulage way.
- In this method ore is broken by flat or slightly inclined holes drilled in a vertical or nearly vertical face (breast) of considerable lateral area, which is being advanced in a nearly horizontal direction and the work resembles that of advancing the face of a very wide drift.
- The face is in dip rise direction & mining process along the strike. Breast is used exclusively in the case of open stopes as opposed to the overhand & underhand stope which is adopted with other support systems as well.
- Breast stopping is a low cost, simple method much preferred for low grade ore deposite where supporting ore pillars may be left. The ore and the wall rocks should therefore be strong.
- The method is best suited deposits of horizontal or mild dip of thickness of upto 5m, lying a moderate depth.

Advantages :

1. Selective mining is possible.
2. High intensity is possible.
3. Simplicity and low prime cost of ore.
4. Possibility of mechanization of drilling & load at the face.
5. More safe than other methods.
6. No lateral development proceeds mining.
7. It is simplest method.
8. It gives high intensity of stoping & competable stopping area.
9. Higher productivity of mines compaires to other method.

Disadvantages :

1. Chances of high ore losses due to in sit pillars.
2. High stability are required.
3. Higher output is not possible.
4. Initial cost is high.
5. The need for keeping a constant watch of the condition of the back.

(B) Open stoping with pillar support :

It is two types (a) open stopping with casual pillars and (b) room and pillar method of mining.

Open stopping with casual pillar : It is more convenient to drill and blast everything in the stope to keep mining costs to a reasonably minimum level.

Room and pillar method of mining : It is a standard method of development in coal mines in India, where the development is followed by depillaring for maximum extraction of coal from the standing pillars, supporting the roof over the coal seam.

Condition :

1. when ore body is strong.
2. Hanging wall and footwall are strong.
3. the ore body thickness is not more than 4-5 mt.
4. Inclination of ore body is 0° - 30°.

5. It is poor mineralization of ore body and less costly mineral.

Description :

1. In this method the ore is extracted in wide rooms separated by pillars provided in regular manner for support of hanging wall.
2. The dimension of room and pillars depends on such factors like stability of hanging wall and ore thickness of deposits and rock pressure.
3. Pillars are generally arranged in regular pattern.
4. The ore left in the pillars may to some extent be recovered but generally to be required as lost.

Application :

1. Ores with horizontal or flat dip.
2. Comparatively stable hanging wall and ore.
3. Ore body upto 12 m thickness.

Preparation :

1. The ore block near the boundary is to be stopped first and the stoping operation will be carried up to the shaft.
2. The last ore block is divided in two valves by driving the raise or winze.
3. The lower level is provided with main haulage and center raise of the block provided with trackline of the block.

Development :

1. Ore body is approached through shaft and cross-cut.
2. The cross-cuts are located at regular interval of 100mt – 200mt.
3. When cross-cut touch the ore body the ore body is developed by levels.
4. Here the size of the cross cut is 3-5m wide and 2-3mt height.
5. As levels are developed at their horizons, they are interconnected by raises or winzes at regular intervals of again 100-200m.

Advantages :

1. the pressure on hanging wall is distributed on barrier.
2. It is used for comparatively more depth.
3. The supervision of work is more effective.
4. work distribution is more.
5. More workers can be employed.
6. working can be well ventilated.

Disadvantages :

1. the loss of ore in barrier pillar more.
2. The percentage of extraction is less.

(C) Shrinkage stopping :

It is a temporary accumulation of the broken ore in the stope, working in which the broken ore is stored are called shrinkage stopes. In shrinkage stopping the ore is excavated in horizontal slices, starting from the lower part of a slope and advancing upwards i.e towards the rise.

Condition :

1. This method is used for thick or thin ore bodies.
2. It is suitable for strong ore body that can stand the pressure in its own weight.
3. The grade of the ore body required is high as there is the possibility of diluation of ore body.
4. The inclination required is more than 40° upto 85°.
5. The dip must exceed the angle of repose of the broken ore,
6. The ore should be free flowing.
7. Undercut the stope by taking a complete bottom, bottom slices 5-10 above haulage drift.

Description : In shrinkage stopping the ore is excavated in horizontal slices, starting from the lower part of a stope and advancing towards rise. A characteristics feature of shrinkage stopping is that a part of the blasted ore is left in the stope where it serves both as a working platform for drilling and as support for the stope wall. The ore so left in the stope is removed when the block is fully stopped out.

Shrinkage stopping is based on the fact that when a solid rock is broken by blasting the broken rock fragments occupy a larger volume. The increase in volume may vary from 30% to 70 %.

Application : Shrinkage stopping can be used in over bodies with :--

1. Steep dip : The dip must exceed the angle of repose of the broken ore.
2. Firm ore : The ore should be free flowing. Too much line or clayey materials will hamper free flowing. If should not develop spontaneous heating and should not deteriorate during storage in the stope. This problem is experienced with sulphide ores which have a tendency to oxide and decompose when exposed to air. In most cases these problems can be minimized by limiting the size of stopes, by minimizing the duration of mining activity in each stope.
3. Thickness of ore body from 3m to 12m.
4. Comparatively stable hanging and footwall. It can not be used in weak rock because the sides of the stope would squeeze together. It can be adopted if the wall rocks are slightly weaker.

Preparation : Preparation for shrinkage stopping consist of :

1. Haulage drift along the bottom of the stope.
2. Cross cuts into the ore under the stope.
3. Finger raises and cones from cross cuts to the under cut.
4. Under cut of the stope by taking a complete bottom slice 5-10m above the haulage drift.
5. A raise from the under cut to upper level for ventilation and manway.

Development :

1. The shrinkage is an conventional overhand stopping method.
2. The broken ore is used as support to walls.
3. In this method, there is complete extraction of narrow vein.
4. the ore body is approached through shaft or incline.
5. At regular interval of 50-100 mt the cross0cut are developed to reach the ore bocy.
6. When two adjacent levels are developed upto the boundary, the complete mine developed the stopping operation is under taken.

Advantages :

1. It is not a cyclic operation as compared to the cut and fill method of stopping.
2. It is more efficient and cheaper.
3. The broken ore in the stope forms a reverse to cope with sudden demand for more ore.
4. No scraping of ore is required.
5. It involves smaller capital outlay and less development work.
6. No ore has to be handed in the stope and use of wheel barrows and tubs is dispensed with.
7. The broken ore with in the compartment form a platform for the workers to work face.
8. Broken ore is used as temporary support hanging wall and foot wall.
9. There are less preparation of stope.
10. No shoveling of broken ore.
11. Less timber support.
12. Face ventilation is good.
13. No loss of firm ore.
14. Broken ore is clear at face.
15. Face can be well dressed.
16. Blasting efficiency is high.
17. It is a cheap method of working.
18. Working is safe.
19. Production can be boosted in short notice.
20. Faces can be additionally supported.

Disadvantages :

1. If walls are flexible there is possibility of dilution of ore due to mixing of rock.
2. Chutes are to be closely placed.
3. Sorting of ore in the stope is not possible.
4. Selective mining is not possible.
5. Large amount of broken ore is locked in stope.
6. There is possibility of accident or fire.
7. The chutes may jammed.
8. Traveling in broken ore is difficult.
9. There is danger of failure of crawn pillars.
10. The upper level may be badly affected when broken ore is loaded.
11. The cavity of walls can't be controlled when the broken ore is loaded.
12. Shorting is not risible.
13. Mechanization is not possible.
14. Man power requirement is high.

(D) Cut & fill stoping :

In cut & fill mining the ore is excavated by drilling and blasting in horizontal slices, starting from the bottom of a stope and advancing upwards.

Description :

A slice has a thickness more than 3m. The broken ore is loaded and completely removed from the stope, when one slice of ore has been excavated, the corresponding volume is filled with waste material. The filling serves both as support for the walls and as a floor when the next slice above is mined.

The filling material may be waste rock excavated during development crushed and distributed mechanically over the stope area. In modern cut and fill mining the hydraulic filling method is normal practice. The filling material may be sand, crushed rock, boiler plant ash or slag at smelter plants. The filling material mixed with water, is transported into mine and distributed through pipe lines.

Application :

1. It can be used with steeply dipping as well as mildly dipping ore bodies with reasonably firm ore.
2. Smelt as well as large deposits with regular outline can be worked easily.
3. Important advantage of this method is the flexibility and high degree of extraction.
4. High grade of ore can be extracted leaving the low grade ore behind in the fill.
5. Dilution of ore is very little. Therefore if is often used for ores with irregular boundaries.
6. This method is suitable where ground surface is to be prevented from substances.
7. Compared cut and fill method offers advantages of selectivity.

Preparation :

1. Haulage drift along ore body at the lower main level.
2. Undercut of the stope, usually 5-10m above the haulage drift,
3. Short raises for manwaus and ore passes from haulage drift to undercut.
4. Raises from undercut to the above for transport of filling material and for ventilation.
5. Provision of sufficient water and filling material and arrangement for their storage and transport.
6. Adequate pumping capacity for underground to pump out water overflowing from the filled stope.

Development :

The ore slices can be drilled in two different ways, with horizontal shot holes or with upward, vertical holes, for drilling light rocks simple wagons are often used. An advantage of up hole drilling method is that large section of the roof can be drilled without interruption and large round can be blasted.

A the stope proceeds upwards timbering and filling proceeds on a cyclic basis. Cut & fill mining permit of mechanization of drilling and loading operation. Cut & fill mining has a very broad range of application due to the flexibility good recovery and the possibility of mining rather weak rock condition.

Advantages :

1. Ore is removed immediately after blasting.
2. There are no fire hazards and no oxidation problem.
3. Preparatory arrangements or stopping are not heavy.
4. A large area is not exposed and the workers work in newly exposed area.
5. Stopes can be brought into production comparatively quickly.
6. Ventilation is comfortable because of small area of stope for air current.
7. Dilution of ore is reduced to the minimum as there is no falling of wall rock.
8. Secondary blasting can be done in stope.
9. The methods provides permanent supports for structires.
10. mill tailings, if they are used for filling, reduce their disposal problem on the surface.

Disadvantages :

1. It is a cyclic method.
2. Production of ore is intermittent unless a few stopes are worked simultaneously.
3. Suitable filling material may not be available.
4. Arrangements for procuring filling material and transport to the stope involves a sizable cut.

(E) Square set stopping :

It is the method of mining in which the walls and back of the stope are supported by regular frame work of timber called square sets.

Condition :

1. This method is suitable for thick and extra thick ore bodies.
2. The suitable indination in between 40° - 85°.
3. The ore body is strong and can stand it's own weight.
4. The hanging wall and footwall are weak and they require support.
5. The ore body should be costly mineral.
6. Rich ore body with high percentage of mineralization is preferred.
7. The deposit required is regular.
8. There should be continuous supply of timber.

Application :

1. where the walls of the ore body and back of the stope are weak and don't stand without support even for a weak.
2. For recovery of fractured remnants and pillars.
3. Can be used in almost any size of deposit regardless of its shape or depth the method of mining as aquare set stopping is costly and labour intensive method.

Preparation :

1. the lower levels is used as main haulage level.
2. The arrangements of ventilation, power supply increased transport of ore and additional manpower is made.

Description :

The square set stope is timbered stope. In square set stopping is support to the walls and back.

The four vertical timbers of a square set are called posts. To start timbering a stope with square sets, sills are laid in trenches cut in the floor of the stope. A clear height of 2m is about the minimum height desirable and at a number of mines posts are 2-3m high in the clear, particularly on main levels or sill floor.

If waste rock filling is used to fill up the square set, such filling provides additional support and the method is then called filled square set stopping.

The square set stopping is labour intensive, costly and requires skilled labour for setting the timber in a systematic manner. The scarcity of timber and gradual deplection of skilled labour makes the system unpopular. It is used in Beloghat mines of MOIL in MP.

Advantages :

1. Irregular ore bodies of any shape can be worked by this method.
2. It can be adopted where ground condition is bad.
3. Wasted rock can be stored out and allowed to remain in the stope.

4. The grade of the ore can be controlled at as each new face, can be sampled.
5. If the sets are filled with waste rocks as soon as possible after they are ereced, only a small space is open at a time.

Disadvantages :

1. A large quantity of timber is required. It constitutes a fire hazard.
2. Production of the ore is slow and the OMS is poor.
3. It is a labour intensive method with high cost of mining.
4. Square set stopping has a high accident rate compared to other method of stopping.

(F) Block Caving :

In block caving method, the ore will cave over a small unsupported area. In block caving the ore is divided in large blocks with a horizontal cross section usually larger than $1000m^2$. At the bottom a horizontal slot is blasted, which removes support of the over lying ore.
The under cutting create a series of fractures in the ore body which gradually affects the whole block. The ore at the lower part of the block is crushed by the cracked upper portion and gives. The drilling blasting required only in the lower portion of ore body. The upper portion caves down.

Application :

1. Block caving is used in large ore bodies.
2. The ore body should have steep dip.
3. Ore should be weak enough to cave under its own weight wall rocks also should be weak enough to cave under the weight of the over burden.
4. Ore should be comparatively low value or grade.
5. A fairly uniform distribution of values in the ore is necessary.
6. The surface should be allowed to subside.

Preparation : Preparation for block caving consists namely of :

1. Loading or haulage drifts in regular pattern below the bottom of those block.
2. Ore pass or finger raises upto a grizzly level from such loading or haulage drifts.
3. A grizzly level for the control of the ore and secondary blasting.
4. Finger raises and come up to the under cut.
5. Under cut due to complicated preparation and narrow sections mechanized methods are often difficult to apply.

Advantages :

1. Mining cost is low and may be nearly as economical as in opencast method of mining.
2. The accident rate is fairly low.
3. After the caving starts a high rate of production is possible.
4. Control of ventilation is less compare compared to other methods of mining.

Disadvantages :

1. Capital expense is large.
2. Preparation for the stope is complicated and time consuming.
3. The ore is diluted with waste and there is some loss of ore.
4. Caving of a block is difficult to control.
5. There is no chance of selective mining of high and low grade ore.
6. There is excessive dilution if caving is uncontrolled.

7. There must be careful supervision of ore drawing.
8. Mechanization is possible only to a limited extent.
9. Secondary blasting is required on a large scale.
10. As in all methods of caving, a large flow of surface water or ground water finds.

At present block caving is not adopted at any of the mines in India.

(G) Sublevel caving :

Sublevel caving is a development of top slicing method. Sublevel caving is a caving methods where the over burden and part of the ore is induced to cave in. The over burden and the ore must be weak enough to cave readily. Sublevel caving is carried out with timber mat as in top slicing but in recent years the timber wire is replaced by wire netting.

In sublevel caving the ore is divided by sublevels with 8-10m vertical spacing. The sub-levels are developed with a regular network of drifts, covering the whole area of the ore. Each sub-level consists of 2 or 3 slices and the ore at each sublevel is brought down by drilling blasting and loading operations.

When developing the sublevel with a regular network of drifts, in wide footwall drift. But in narrow deposit the drifts are made along the strike.

From the drifts the ore is drilled with a fan shaped pattern in an upward direction. Blasting of fans starts at the hanging walls or at the ends of the ore and proceeds towards the footwall of the ore pass, several drifts and levels are worked simultaneously to keep a roughly even in retreating front.

When a fan blasted the ore caves into the drift, where it is loaded and transported to ore passes. The hanging wall caves continuously and follows the extraction of ore.

Application :

1. Sublevel caving is used in steeply dipping ore and in other deposits with comparatively large vertical thickness.
2. The method can be vertical thickness.
3. The hanging can be used in weak ore.
4. The surface conditions must sllow subsidence.
5. Due to the dilution and loss of ore sub level caving is mostly used for ores which are not too valuable or which can be connected by a relatively cheap ore dressing process.

Preparation :

1. The main part of preparation consists of very comprehensive drifting on the sub levels.
2. In addition to drifts ore passes and raises are required to connect the sub levels with main levels.
3. Initially 20% inclined service ramp is driven in the footwall rock.
4. The ramp normally turns at 180° about every 150m to keep it reasonably close to the rock.
5. Sublevel are established by driving horizontal access drifts on the ramp approximately every 9m vertical.
6. In general, drifts in rock are 4.3 m wide by 3.9 m high, while in ore they are 1.9m wide by 3.9m high a wider drifts improves recovery.

Advantages :

1. It can be applied to both hard and moderately weak ground.
2. It is flexible so that it can be applied to irregular ore bodies.

3. All operation takes place in drift size heading, that can be well supported.
4. It provide good condition for accident prevention.
5. It is suitable for high degree of mechanization.

Disadvantages :

1. More dilution of the ore.
2. There is practically no sorting of ore in the stopes.
3. The stopes are difficult to ventilate.
4. Low grade of ore in the aver burden or near the boundary of the deposits is lost.
5. High development cost.

(H) Top Slicing :

In this method the ore is mined out in a series of horizontal slices by drilling and blasting beginning at the top of the ore body. The ore from first slice is being taken out. Top slice continues a timbered mat is spread out on the floor of the first slice. The timber mat consists of their wooden lags (about 125 mm dia) and thick wooden planks. The next slice of the ore body is then extracted by drilling and blasting. The slices, each about 2-3 m thick are then extracted in a descending manner.

Application : The method is applicable to

1. Thick deposit of horizontal extent. The minimum thickness of ore body should be 2-3m.
2. soft ore which is weak enough to stand without support only for a short period.
3. Weak walls and over burden which can easily cave in.
4. Ground surface which is not to be supported.
5. Areas with cheap and plentiful supply of timber as well as skilled timber man.
6. The timber should be tough and strong.
7. The stopes or slices may be blasted down so that the ore body remains in good conditions.
   Top slicing can be employed under sand and other loose surface material and does not require as clean a mat as does sublevel caving.

Preparation :

The development for top slicing consists of driving a series of drifts and cross cuts at some distance below the top level and then raising to the top of the ore for mining.
The ore is removed in slices 2-3 m thick. A block is divided into horizontal slices. A drift is driven under the over burden near and parallel to footwall. The drift extends to each end of the block from the body of the drift cross cuts are driven to the hanging wall. The drift is timbered upon removing the ore from the slice.

Advantages :

1. it is safe method to use where overhand stopping cannot be employed.
2. It is suitable for intermittent operations.
3. The method permits of high recovery and dilution is little.
4. It can be employed under sand or other loose material and does not require as clean a mat.
5. After the initial development is completed the method can be reasonably cheap.

Disadvantages :

1. The method causes surface substance
2. Ventilation is somewhat difficult.
3. A considerable number of working places are needed for a large output and the rate is not flexible.
4. Period of development prior to production is fairly long.
5. Handling of timber and laying of mats is expensive in labour and time consuming as in the case of square set mining.
6. Waste or low grade ore can not be easily left in place.
7. The method is not adopted to sorting of waste in the stopes.
8. Rate of output can not be suddenly increased to meet market demands.
9. If the roof does not collapse over a long period, its sudden collapse results in air blast and can be dangerous in the slice below.
   Top slicing is not adopted at any of the mines in India.

4.0 Pysico-mechanical properties of rocks :

4.1 Define physico-mechanical properties such as Hardness, Compressive Strength, I.S.I., P.S.I., & Drill Ability. Time dependent properties of rocks.

Hardness : Hardness of rock defined as its resistance to abrasion. This property helps in estimating rock decay when put to all condition. If gives an idea of strength of criteria of rocks. Hardness of rock depends upon the strength of chemical bonds.

Moh's scale of hardness

Talc	----	$Mg_3Si_4O_{10}(OH)_2$
Gypsum	----	$CaSO_42H_2O$
Calcite	----	$CaCO_3$
Fliorite	----	CaF_2
Apatite	----	$Ca_5F(PO_4)_3$
Feldspar	----	$KAlSi_3O_8$
Quartz	----	SiO_2
Topaz	----	$Al_2SiO_4(F_1OH_2)$
Corrundum	----	Al_2O_3
Diamond	----	C

Compressive Strength : It is normally defined as the stresses required to cursh a cylindrical rock sample unconfined at its sides.

$$\text{Compressive Strength} = \frac{\text{Total lead}}{\text{Cross Section Area}}$$

It is off two types,

(a) Unaxial or unconfined compressive strength (b) Traxial compressive strength.

Unaxial compressive strength : It is compressive stress per unit area in which a specimen fails. If "Pc" is the compressive strength applied on the specimen of failure in "kg" and "A" is the area of side of the specimen on which the compressive stress applies in cm^2

$$\text{Then compressive strength} = \frac{Pc}{A} kg/cm^2$$

It is used for rock mass classification and as a basis parameter for the rock mass strength criteria.

Triaxial compressive strength : When a rock mass is subjected to an all round pressure and it is further subjected to an additional vertical pressure, known as triaxial compressive strength.

Impact Strength Index (I.S.I.) : It is shown by the crushing of coal fragments by a succession of hammer blows provides a method for estimating the compressive strength of coal because of this a number of experiments were carried out to determine whether the I.S.I is suitable as a measure for the compressive strength of rock types other then coal.

Protodyakanov strength index (P.S.I.) : Hardness of rock is expressed by a protodyakanov strength number indicates the relatives with which a rock can be broken. For example, strong lignite and weak day shale's have P.S.I. 1.5 to 2.
Strong quartzite's and Gabor-diorites have the number 20-25.

Drill ability : The rate of drilling in a rock is known as drill ability. It depends upon following factors:

- The crushing strength of rock.
- Types of rock.
- P.S.I. higher is to P.S.I. less is the drill ability.

Time dependent properties of rock : While discussing the time dependent properties we have to get the information of creep of a rock by plotting a curve between strain and time. Thus time dependent behavior as represents the points of failure of a rock under strain after what time factor.
It has been found that the creep curve for number of materials can be expressed by the relation.
$E = A + Bt + CE(t)$
Where
A = two dastir strain at t = 0
Bt = Steadily creep.
CE(t) = is the fuasient of primary creep.
E = is the crushing strength.

5.0 Rock Burst .

Explain causes and prevention of rock brust.

Rock burst : It is a sudden violent failure of rock in and around mine opening. In the rock bursts the strain energy is released from the stressed rock mass violently with a magnitude of seismic events ranging from 1 to more than in a Richter scale.

Causes of rock burst :

1. Presence of fault, dykes and geological disturbances, their presence increases the occurrences of rock burst.
2. Rate of face advance : Lower the rate of face advances more be the chances of rock burst.
3. Extraction height and depth of working : More the height of extraction and depth of working more would be the occurrences of rock burst.
4. Decrease in abutment size will increase the occurrences of rock burst.
5. Increasing the spam of face will increase the incidents of rock burst.

Occurs of rock burst :

1. It occurs in strong brittle rocks which contain few ore and existing fracture.
2. Rocks are weak in tension and strong in compressive and hence large quantity of potential energy is stored in the rock under high compressive strength.
3. Rock bursts occurs frequently if the rate at which the energy is released is greater than the rate of which the energy can be dissipated in a non violent fracture process as the excavation enlarge.
4. Rock burst occurs frequently if the amount of energy released increases rapidly with the increase of stopping span, while energy can be dissipated non violently remains almost constant.
5. Some of the gravitational energy is increased as strain energy in stress concentration in rock and the remainder is released either non violently through crushing of rock and supports and violently through, which is generally known as rock burst.

Prevention of rock burst :

1. By reducing the energy release slowly by developing yielding pillars which yield gradually instead of accumulating high stress over the pillars.
2. Leaving no remnant pillars in the goaf since these pillars will be under the envelope of very high stress as the time passes on.
3. Avoid dykes, fault and other geologically disturbed zone which are highly stressed, working should be starting from the near by spot of the disturbed area and shall be moved away from them.
4. By fracturing the rock ahead of the face blasting which will reduce the level of stress in the rock.
5. By back filling the extracted out area and providing very high support density in the face.
6. By partial extraction of the developed pillars or by leaving pillars spaced regularly along the whole length of the long wall panel.
7. By reducing the kinetic or seismic energy which is produced due to tectonic forces, gravitational forces and also due to stresses induced by mining activity.
8. By having limited no. of working face and mining the faces towards, each other must be avoided.
9. By pre-distressing with blasting.
10. By providing adequate supporting in the underground mine working.
11. By introducing special short firing technique.

Factor affecting the rock burst :

* Both severity & fracture of rock burst increases with depth due to increases strain in rocks but rock burst have been reported in surface, mine as well as shallow mines due to lectoric stress.
* The frequency & intensity of rock burst vary with the kind of rock burst are most common in brittle rocks.
* Rock that stand well as long as excavation are small may develop rock burst after.

Mechanical Characteristics of rock burst : Rock usually connected with rock burst depending upon that it is strong of brittle.

1. Rock type : Plastically or vosco elastically deformabe rocks fall slowly & ore less likely to bursting.

2. Petrology : Igneous & metamorphic rocks are generally of no bursting zone that sedimentary rock.
3. Minerological composition : More siliceous rock quartz in those containing hard members are belongings to burst classes & carbonates & other sharp mineral are belonging to non burst classes.
4. Geological features : Measures geological features also played a role on the process of burst dyke may cause weakness in the mild structure and the rate increases in burst process in their rock series.

6.0 Face Mechanization :

6.1 Describe use of jumbo drill with air leg.

Jumbo drill with air leg : Where compressed air is the motive power for drills air legs may be advantageously used to mount the compressed air drills.

- An air leg is essentially a long cylinder in which a piston is actuated by compressed air controlled valve which is also used to release the air pressure to lower the piston.
- An air leg relives the operator of the fatigue involving in holding the drills and keeping if, pressed forward as the leg exerts on upward lift and a forward feeding pressure on the drill.
- The air leg does not increase the rate of penetration of feed and is used for drifts upto 2m height. In underground mine drilling rigs or jumbos have to be used for high speed drivage of large size drifts.
- The term jumbo are after used synonymously but jumbo is a portable carries for under ground use.
- A jumbo has a crew 3-4 operator who performs various operation of setting a drill, drilling, dismantling etc.

6.2 Describe various transportation machineries like L.H.D., rocker shovel, Spiral chutes and draw points, scraper etc.

Spiral chutes : A narrow opening in mine working through which broken ore is loaded into mine car. The term also applied to a box like structure equipped with controlling gate fitted to such opening.

Draw Points : A draw point is a place located at the bottom of stopping area and from where ore can be loaded manually or by machines into tubs or mine cars. It has no controlling gate.

L.H.D. : It is used to perform, loading, hauling and dumping of bulk material.
Applicability :

- Gradient 1 in 6.
- Floor condition required strong and good.
- Maximum speed for empty L.H.D. 8-30 mile per hour.

Advantages :

- Greater flexibility.
- High speed for transport (12 kmph)
- Maximum labour required.

- Higher productivity.

Disadvantages :

- Difficult in heavy load movement.
- High maintenance cost.
- Large consumption of engine.

SHORT NOTES

Hanging wall : This strata resting on the ore body.

Foot wall : The strata on which the ore body is resting.

Cross cut : It is a horizontal drivage which leads the shaft and passes through the country rock in order to cut across the load at an angle to strike.

Or

When the development of mine is carried in any direction other than the dip and strike direction.

Incubation period : It is the time interval between 1st local fall and 1st sign of spontaneous heating.

Level : It is an horizontal roadway which is driven in the ore body on the direction of strike is called level.

Drifts : When the drivage is made in rock across the veins is called as drift.

Limit : Firm ground mainly for excavating cut out raises in stopping.

Ore body : The part of a vein that caries ore generally all parts of a given are not ore.

Cut off grade : The minimum percentage of metal in the ore for economic extraction of the ore from a mine and its subsequent to extract the metal. It represents the average grade of run of mine ore below which mining in no longer variable. It varies from time to time and depends upon market price of metal as well as on costs involved in excavating ore from time to time.

Finger raise : A finger raise is used for raise ore. The usual arrangement is as a system of several small cross-section short length that branch together to the same delivery point.

Dip of ore bodies : The line of true dip in a bed or surface is the steepest line in the inclined surface and is always at right angles to the strike. The strike of bed is a level line in the surface of the bed.

Stope block : An under ground area generally represented by a block or ore from which are has been extracted or is being extracted as a final mining operation before its abandonment.

Sub-incline : Sub incline is an incline roadway made from the upper level to be lower level in an under ground mine. It starts from underground and end in under ground.

Drive a drift : A horizontal tunnel or roadway nearly parallel to the strike of the lode or vein but it can be located on the country rock either on the footwall side of the bode or on the hang wall side. It is called a footwall drive in the former cases and a hang wall drive in the former cases and a hangwall drive in the later case.

Ore pass : An ore pass is a vertical or inclined under ground passage way for downward move ment of ore by gravity.
Ore bin : It is temporary storage of broken ore near the shaft at the lower level in under ground mine.

Mill tailings : The crushed and ground rejects material produced from one ore in a concentrating plant. It is often used in mine.

Raise : It is an upward drivage driven from the lower main level to meet the upper level.

Winze : It is downward drivage driven from the upper main level to meet the lower level.

The up-reaming method :

Up-reaming with standard raise drills :
Application : It access to upper and lower mine level is possible, the standard raise drill should be used. In this method the standard raise borer is set up on ore mine level or on the surface and a pilot hole is drilled from the level or on surface to the level below.
After completion the pilot hole is reamed back or up to the surface. The rock cutting fall down from the face by gravity and the pilot hole need not be of a longer dia. This is a commonly adopted method.

Down-reaming with reversible raise drills : If there is a good access to the lower level but only limited access to the upper level the ore of reversible raise drill should be considered.
In this method raise drilling machine is set up on a lower level of the mine and a pilot hole is drilled up ward to a higher level. The raise is them, reamed back from the upper level to the lower level. Down reaming method demands pilot hole of a longer diameter to permit rock cutting to fall through the hole in the space between drill rod & the hole sides.

Blind hole & box hole raise drill : If there is no access to an upper level a blind hole or a box hole raise drill is the only practical mechanized system. The blind hole or the box hole rise drilling machine is set up on a lower level of the mine and a full diameter raise is bored toa higher level without the ore of a pilot hole. Normally dia of most the raises drilled varies from 1 m – 3.7m.