DEVELOPMENT OF MINERAL DEPOSITS

GOAL OF DEVELOPMENT

- The ultimate goals of mining method selection are to maximize company profit, maximize recovery of the mineral resources and provide a safe environment for the miners by selecting the method with the least problems among the feasible alternatives.
- Selection of an appropriate mining method is a complex task that requires consideration of many technical, economic, political, social, and historical factors.

The purpose of Development of Mineral Development

The development will serve following purposes:-

1. It extends the purposes of exploration, a way of confirmation of exploration details,
2. It confirms the shape of the deposition or delineate the body or mass and its geometry that we propose to mine, thickness and dip of the deposit .
3. The confirmed information on the quality of the mineral.
4. Assess the quality of rock mechanics or the mineral, host rock and country rocks.
5. Combined with geometry the volume and tonnage at various grades of the mineral.
6. Provides access and transport facilities for men and material and the excavated ore and waste as necessary.
7. Permits arrangement for drainage of water, ventilation.
8. Permits planners to design the stope and fix on the method of stoping.

Definition of Mining General Terms

Assay - A chemical test performed on a sample of ores or minerals to determine the amount of valuable metals contained.
Assay map - Plan view of an area indicating assay values and locations of all samples taken on the property.
Back - The ceiling or roof of an underground opening.
Backfill - Waste material used to fill the void created by mining of orebody.
Breast - A working face in a mine, usually restricted to a stope.
Channel sample - A sample composed of pieces of vein or mineral deposit that have been cut out of a small trench or channel, usually about 10 cm wide and 2 cm deep.
Concentrate - A fine, powdery product of the milling process containing a high percentage of valuable metal.
Core - The long cylindrical piece of rock, about an inch in diameter, brought to surface by diamond drilling.
Core barrel - That part of a string of tools in a diamond drill hole in which the core specimen is collected.
Tailings - Material rejected from a mill after most of the recoverable valuable minerals have been extracted.
Trench - A long, narrow excavation dug through overburden, or blasted out of rock, to expose a vein or ore structure.
Wall rocks - Rock units on either side of an orebody. The hangingwall and footwall rocks of an orebody.
Waste - Un-mineralized, or sometimes mineralized, rock that is not minable at a profit.
Winze - An internal shaft

Terms connected with Development

Development - Underground work carried out for the purpose of opening up a mineral deposit. Includes shaft sinking, crosscutting, drifting and raising.
Development drilling - drilling to establish accurate estimates of mineral reserves.
Adit - An opening driven horizontally into the side of a mountain or hill for providing access to a mineral deposit.
Chute - An opening, usually constructed of timber and equipped with a gate, through which ore is drawn from a stope into mine cars.
Crosscut - A horizontal opening driven from a shaft and (or near) right angles to the strike of a vein or other orebody.
Decline - A sloping underground opening for machine access from level to level or from surface; also called a ramp.
Level - The horizontal openings on a working horizon in a mine; it is customary to work mines from a shaft, establishing levels at regular intervals, generally about 50 metres or more apart. ore from the stope is extracted.
Dilution (mining) - Rock that is , by necessity, removed along with the ore in the mining process, subsequently lowering the grade of the ore.

Terms connected with Development 2

Drawpoint - An underground opening at the bottom of a stope through which broken

Lens - Generally used to describe a body of ore that is thick in the middle and tapers towards the ends.

Lode - A mineral deposit in solid rock.

Muck - Ore or rock that has been broken by blasting.

Muck sample - A representative piece of ore that is taken from a muck pile and then assayed to determine the grade of the pile.

Ore pass - Vertical or inclined passage for the downward transfer of ore connecting a level with the hoisting shaft or a lower level.

Orebody - A natural concentration of valuable material that can be extracted and sold at a profit.

Ore Reserves - The calculated tonnage and grade of mineralization which can be extracted profitably; classified as possible, probable and proven according to the level of confidence that can be placed in the data.

Oreshoot - The portion, or length, of a vein or other structure that carries sufficient valuable minerals to be extracted profitably.

Stockpile - Broken ore heaped on surface, pending treatment or shipment.

Stope - An excavation in a mine from which ore is, or has been, extracted.

Strike - The direction, or bearing from true north, of a vein or rock formation measure on a horizontal surface.

Sublevel - A level or working horizon in a mine between main working levels.

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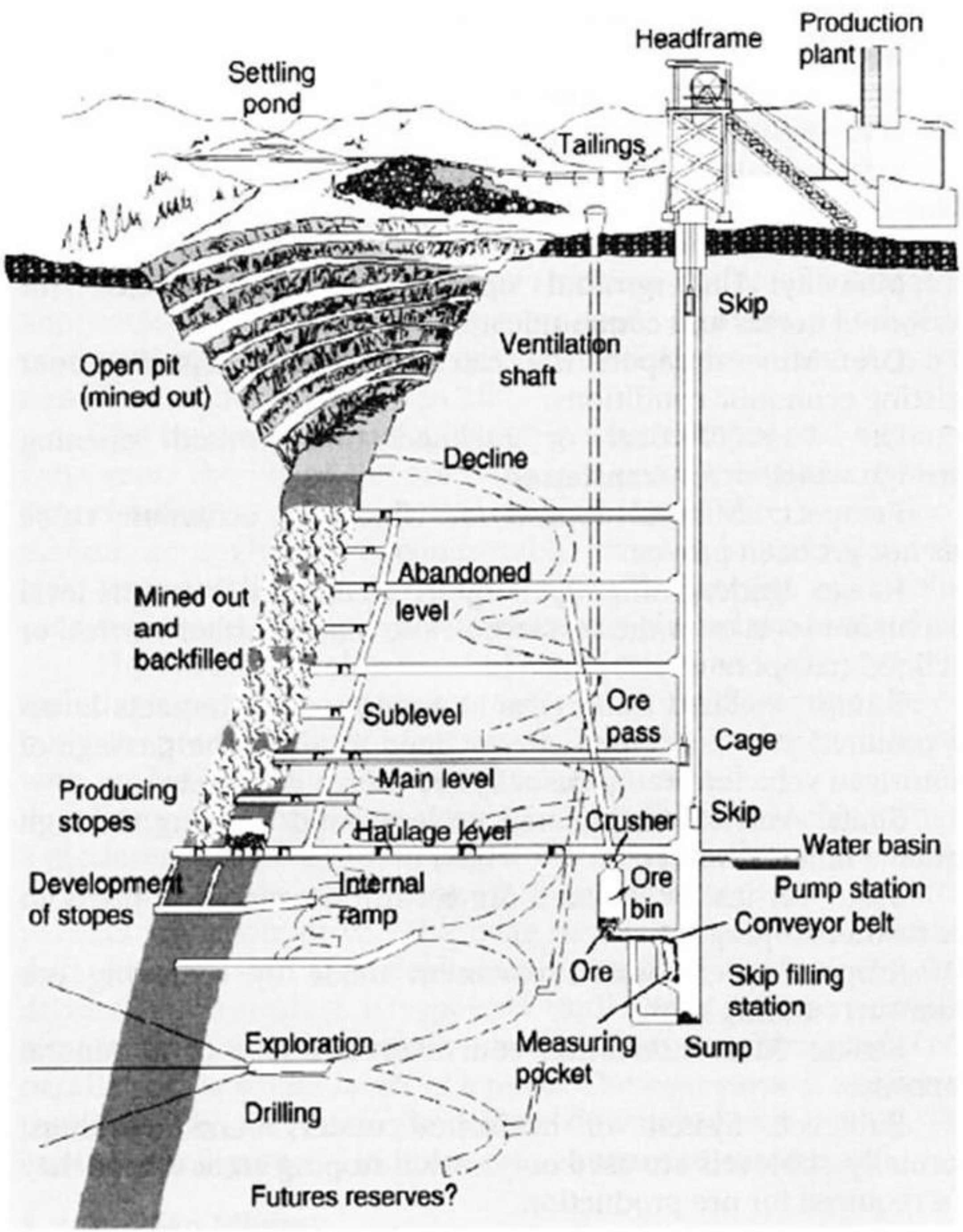


Mine openings

- Primary openings
- Secondary openings
- Tertiary openings

Principles during Development

1. The deposit has to be divided into blocks or sections by driving drifts, levels or horizons from the shaft .

2. Since the shallow portion of mineral can be developed first it is stoped first.

3. Generally shaft is in the footwall side.

4.Haulage drive at any horizon is in the footwall . It is generally designed to be straight so that transportation will not be problems. IF it can not be avoided the curves are designed to be smooth so that, track haulage is possible.

5. Cross cuts are driven from the haulage drive.

6. The mineral is transported towards in different section as far as possible to the lower level. All the ore is carried through the ore pass to the crusher which is located usually at the lowest level.

7. Normal mining or stoping is carried out from the boundary to the shaft, retreating manner.
8. Entry of persons and material is from upper level down into the stope.
9. Filling or packing material (waste) is transported to the working place through the upper level and then then down to the site in pipes, hydraulically.
10. Air current on the other hand is taken to the lower level. Air raises through the working places and reaches higher level and then reaches the upcast shaft.

Principles during Development 2

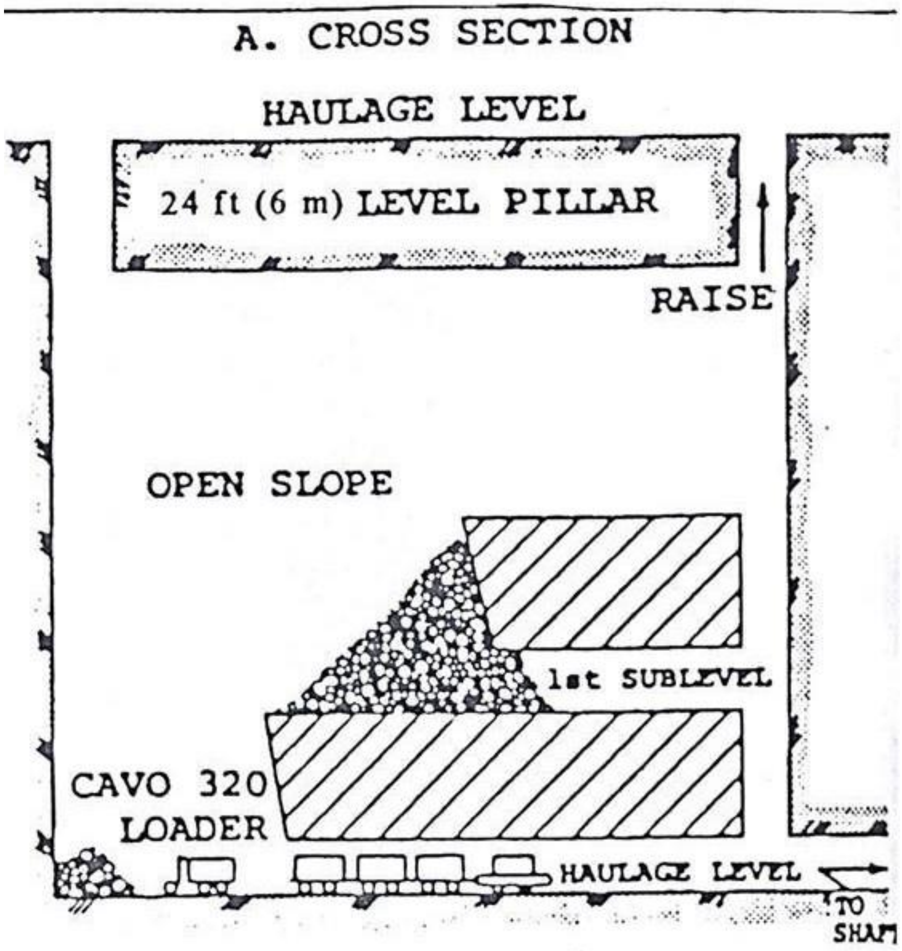
11. The supports erected in any development drivage is commensurate with the life it is supposed to serve. Thus strong and permanent supports are erected and the tertiary developments will have supports which serve the limited time like retractable bolts.
12. The conventional development drivage for levels, cross cuts are done with drilling holes with jack hammer and blasting with cartridge explosives is done.
13. Rises and Winzes are also developed conventionally top downwards and in some mechanised methods (Alimak rise climber) the rising / winzes is done bottom upwards.
14. Levels are driven slightly downwards towards shaft so that water accumulations are not causing difficulty @1 in 100 to 150. Where these levels are also used for transport of ore the inclination will be infavour of load so that hand tramming is easy.

Decisions on the Shaft:
It comes under primary development. It is designed in such a way that it is not disturbed in the entire life of mine, even though stopes are all extracted all around. Generally it will be developed on the footwall side of the lode or deposit. In the lateral dimension it will chosen to be in the middle, of the deposit so that it is easy to be accessed from both extremes of the deposit and cost of transport is minimum. Depending on the depth and rock mechanics some of the area around the shaft is (called shaft-pillar) left un-mined to protect it from damages.

Shaft sinking is highly skilled work and some times when shafts are to be passed through difficult strata special methods are adopted. It is very costly and time taking process. Before extraction is taken up in a stope it may take a period of 3-4 years, hence it should be started well in advance.

For deeper deposits the shaft will be deepened while levels are made at different horizons and stope work is started.

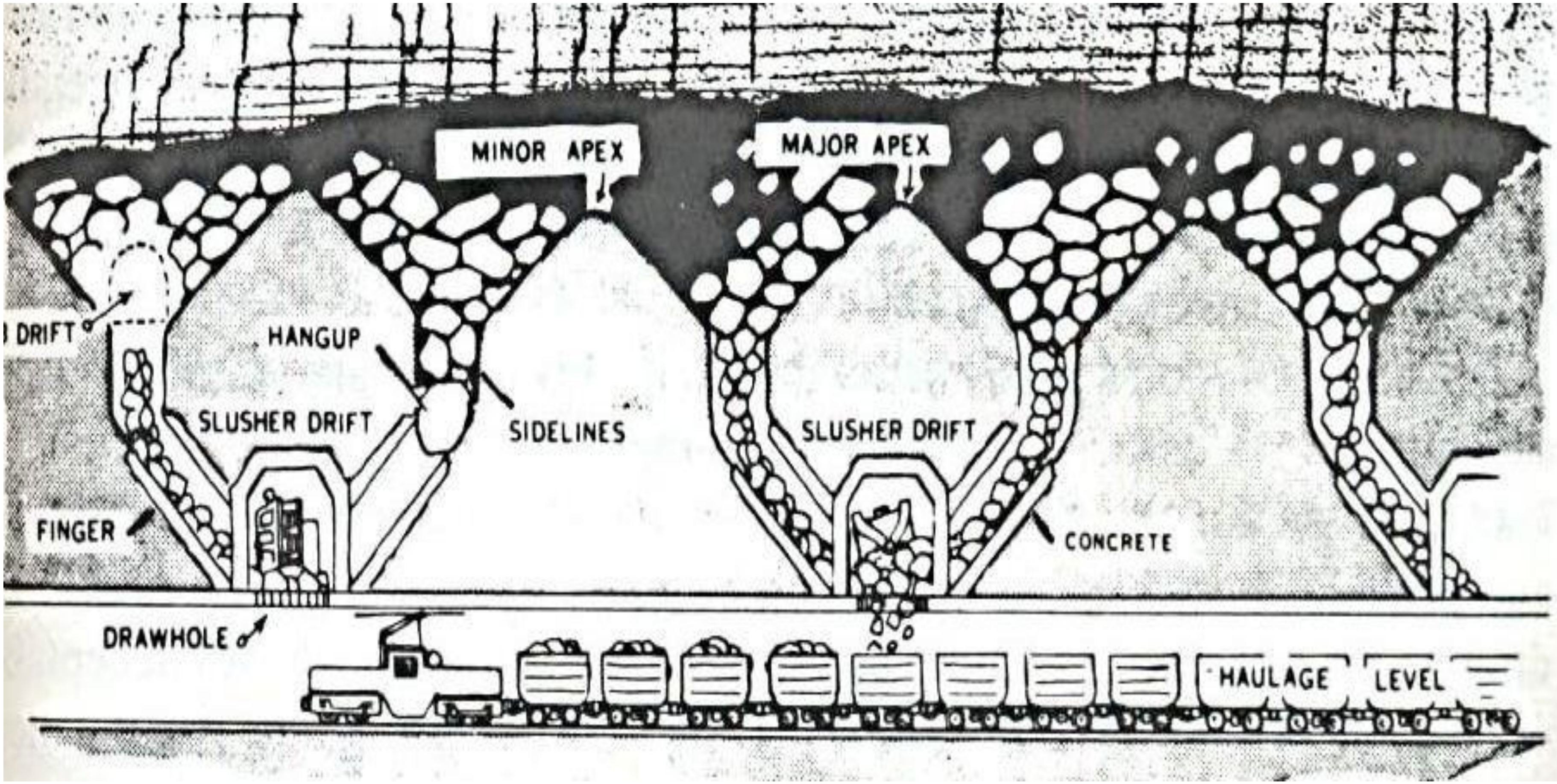
Thus it is not un-common to extend the depth of the shaft in the bottom of a working shaft, by taking proper precautions. In that case separate winders are installed for production work and development work.



The size of stopes means that their zone of influence, and is large relative to virtually all the other mine excavations.

Stope design exercises a dominant role in the **location, design and operational performance** of other excavations which sustain mining activity.

The principles of stope layout and design are integrated with the set of engineering concepts and physical operations which together compose the mining method for an ore body.



Stope developmental openings, ore draw points, slusher drifts

Mine Development

Decisions are to be taken for mode of primary development and the factors that are to be considered are:

type, location and number of openings, shape and size of openings, design of material handling systems.

Factors for decision making are depth, shape, and size of deposit, geologic conditions of ore and overlying strata, mining method and production volume and the mode of ore transportation

Selection of a suitable access to the deposit

The decision of selecting the suitable access to the deposit, between a vertical shaft and an incline is based on the following factors:

- depth of ore deposit,
- size and shape of ore body,
- surface topography,
- geological condition of the ore and overlying rock mass (it also includes the strength condition of ore body as well as the surrounding rock type.
- time for development,
- method of mining (stoping)
- cost and choice of material handling system 31.07.20.

Levels and Level Interval

- Level is an opening developed along the strike direction of an ore deposit and is driven with zero to near zero (1 in 200) gradient. It is considered as the secondary mine development operation of an underground metal mine.

- Every single underground mine developmental operation is a capital intensive and there is a significant degree of risk, because any increase in the length of development openings could augment high capital expenditures. The levels also offer the service of transportation, for men and material, from the shaft to the production site. Of the many factors influencing the selection of a suitable level interval, the important factor is to facilitate quick disposal of broken ore from the workings

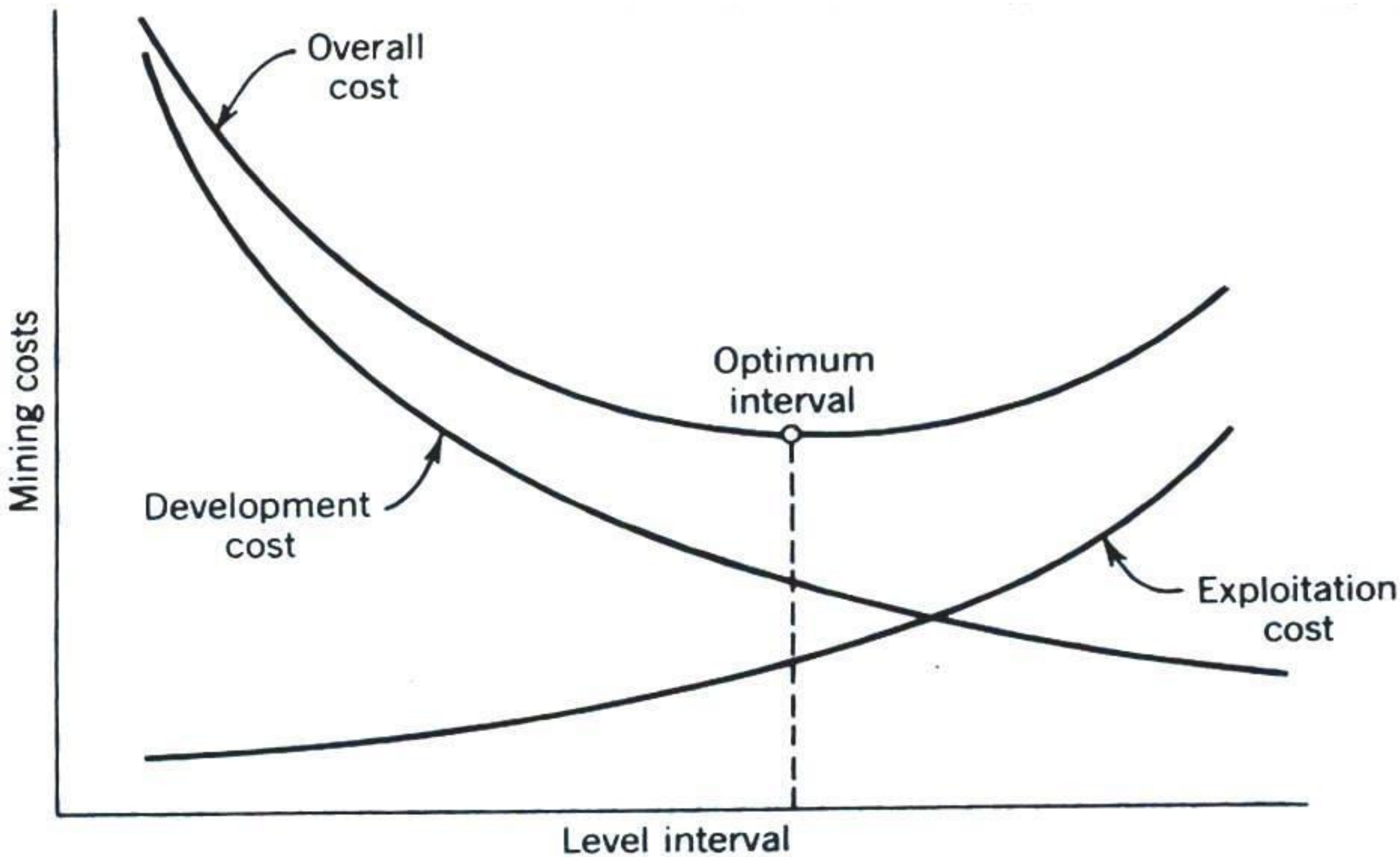
Level intervals

Underground mining of ore deposits is necessarily worked with multiple levels. A level interval is selected which lead to lowest overall mining cost for the mine development and exploitation plan chosen.

Number of factors affects these costs and some of them are following:

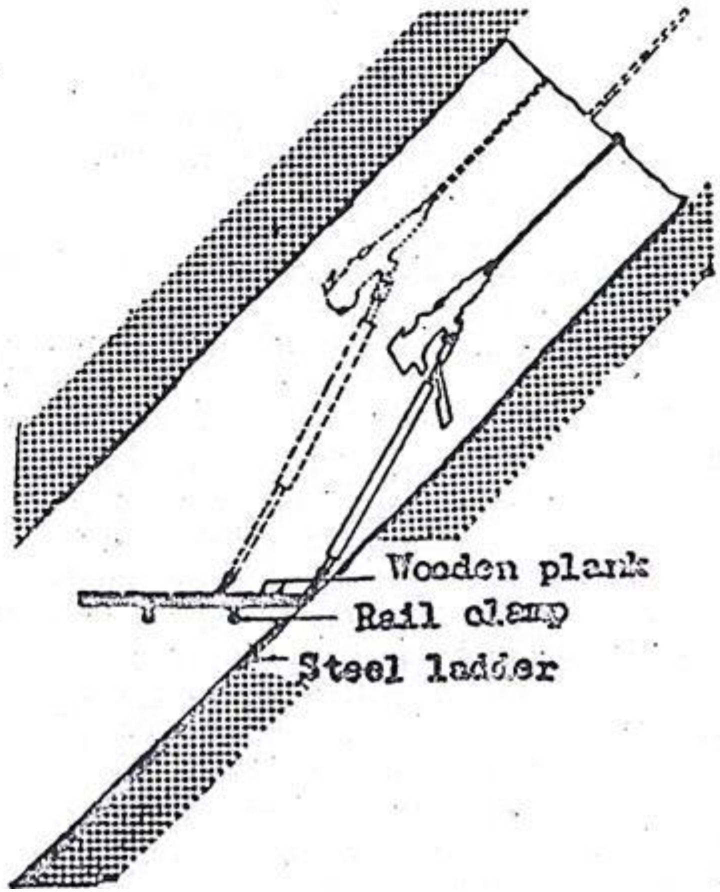
- geological and natural conditions of the deposit and country rock
- method of mining
- development layout
- method of drivages of openings
- life of openings, mine life
- other financial considerations

The current trend with mechanized high production method is to have fewer levels with large level intervals and supplemented by less cost sublevels as required by the stoping method adopted.

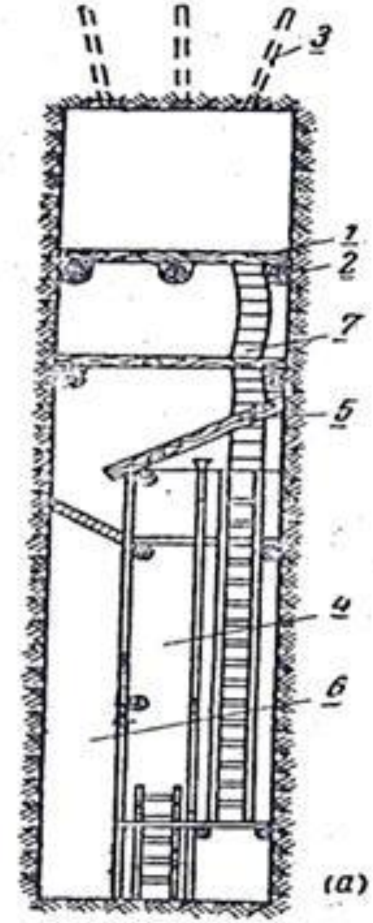


Raising Methods

- **Manual raising method**
- **Two compartment method**
- **Mechanized Raising**
  - Jora raising method
  - Alimak Raising
- **RAISE BORING METHODS**



Manual Method



Manual two-compartment Method

Alimak Raise Climber

- Drilling, loading and blasting are all performed from the platform of the Raise Climber, which is adapted to fit the precise dimensions and shape of the raise. Furthermore, the Alimak Raise Climber implements a rack and pinion rail, designed to carry air and water for increased ventilation.

Cycle of operation in Alimak raising method

- Drilling is undertaken from the drill deck on top of the raise climber, which is sized to suit the size, shape and angle of the raise.
- The Alimak climber is then lowered to the bottom of the raise and into a station for protection before the blast is triggered from a safe location
- The Alimak system provides for efficient post blast ventilation and a powerful air/water blast effectively dislodging loose rock from the freshly blasted face making ready for re-entry.

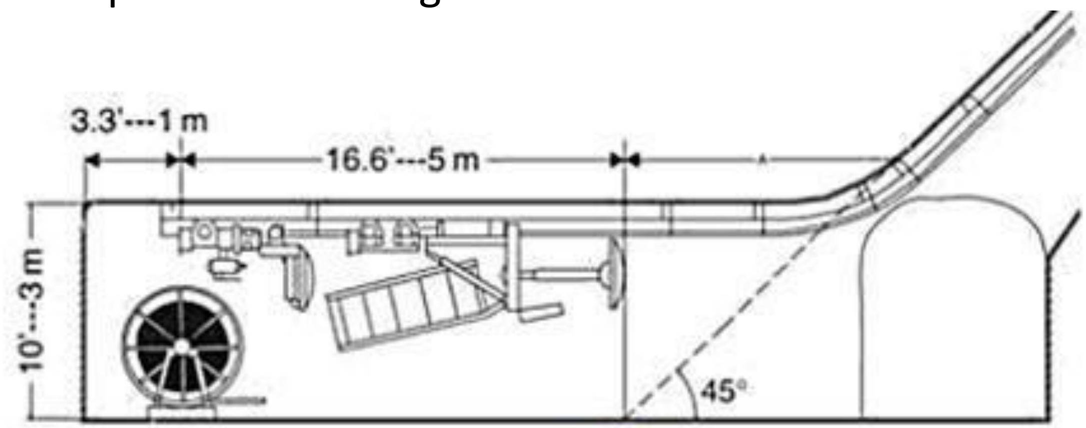
Alimak Raise Climbers.

- Drilling and charging of the explosives is carried out from a platform having a heavy-duty, all-steel safety roof. Once drilling and explosive charging is completed, the Raise Climber is driven down the guide rail to a parking area at the bottom of the raise where it is protected from the blast. After blasting the Raise Climber is driven back to the top of the raise and scaling operations are carried out.

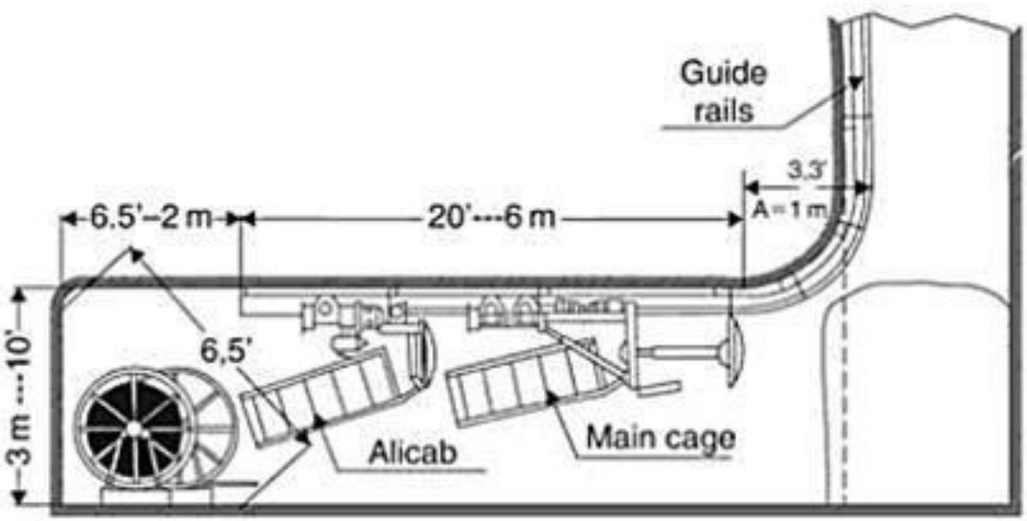
- The same raise climber can be used for a wide range of shaft sizes, shapes, inclinations and lengths with any combination of straight or curved rail sections.

- Vertical and incline raises varying in height from 18 to 1100 meters and in inclination from 39-90 degrees have been safely and successfully completed by using Alimak Raise Climbers. The Raise Climbers can also be used for production of mining, (Long – hole Drilling) of narrow ore veins or wide ore bodies. In India, their maximum use is in Hydro-electric projects.

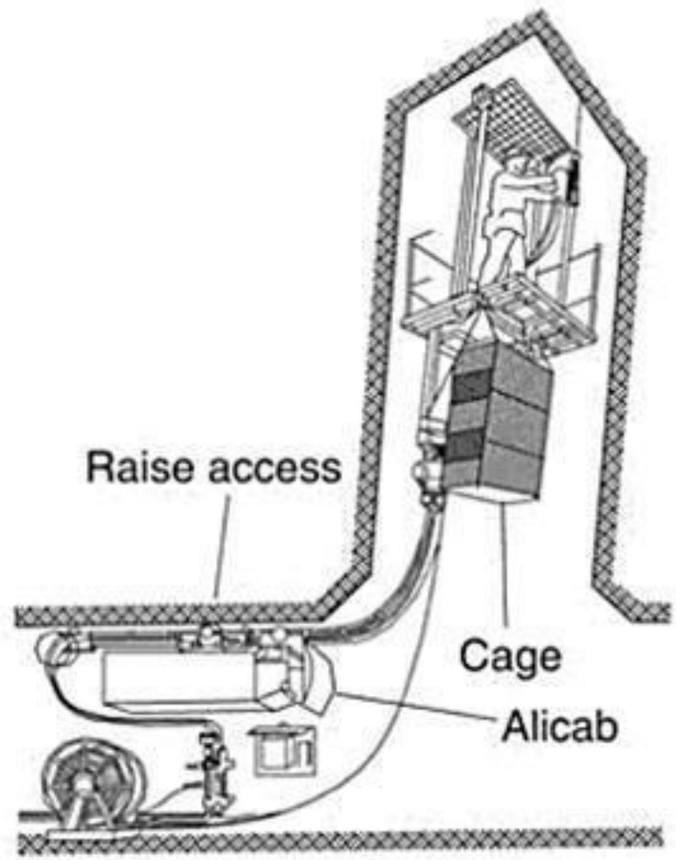
Using guiderails the raise climber can be driven to a safe position. The guiderail curves also offer the possibility to arrange quick communication between the bottom and the work platform by a special service hoist, known as Alirolley or Alicab, which is ready for operation on the guiderail all the time.



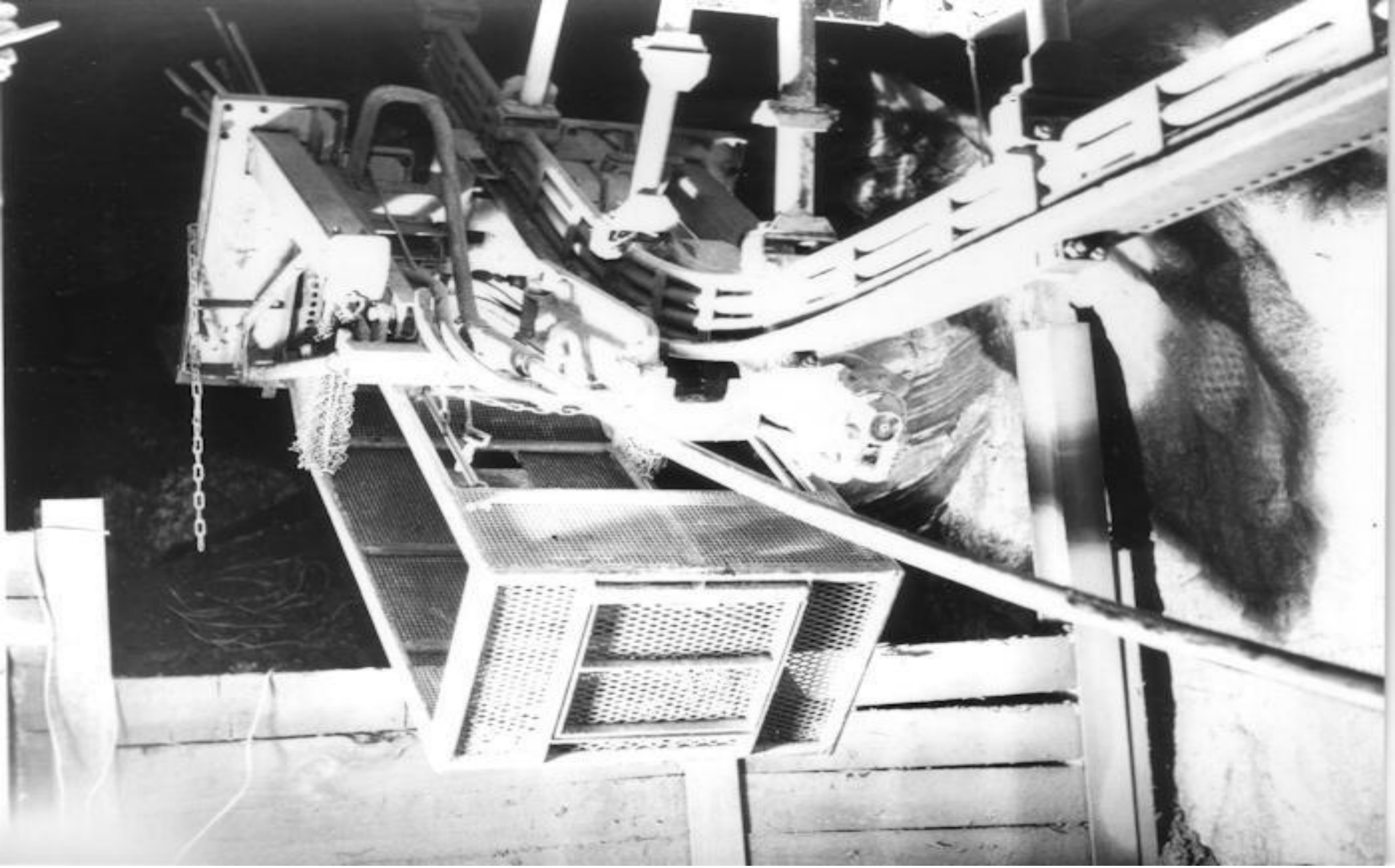
(a) Equipment for an inclined raise



(b) Equipment for vertical raise



(c) Alimak raise climber



Alimak Raise Climber

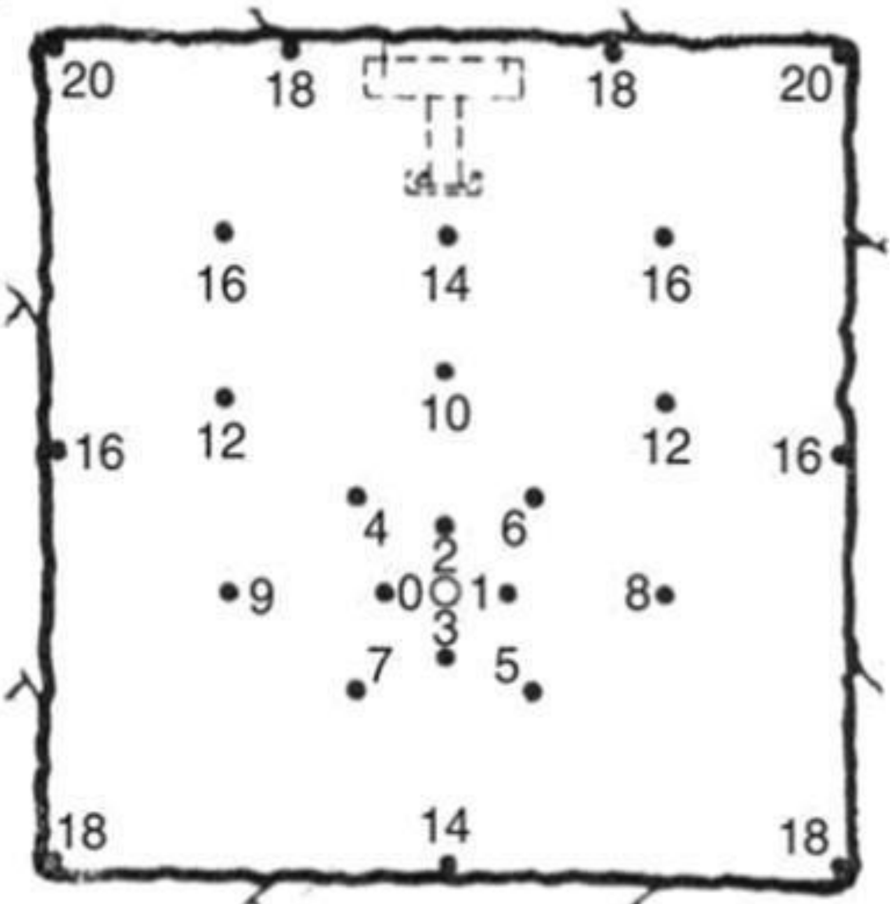
Preparatory work for Alimak

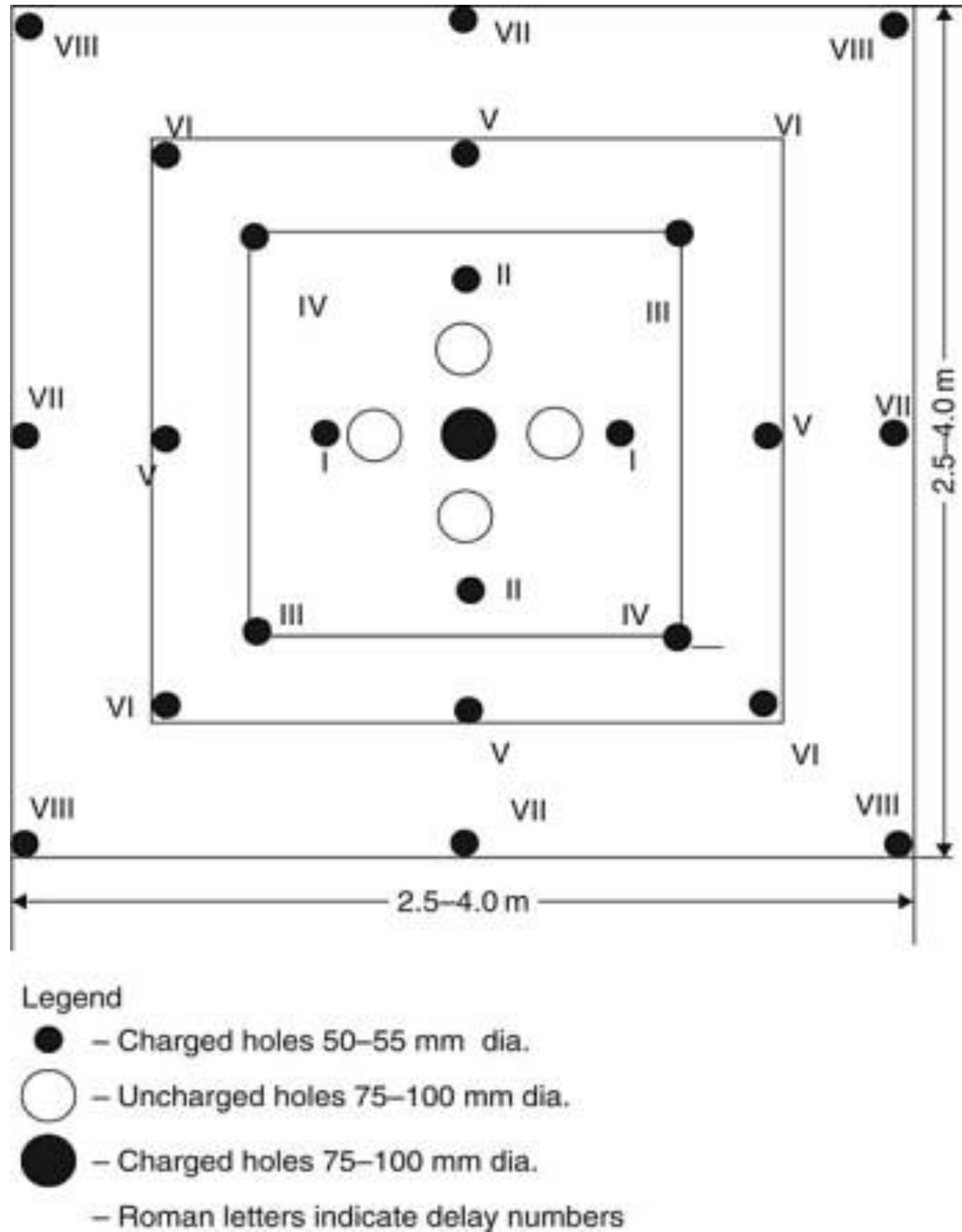
A horizontal cut (also known as raise access) of 9m length x 4 m width is required to accommodate a raise climber with Alicab, but without Alicab its length could be 7m.For vertical raises the curved guiderails used are 8^0, 25^0 , 25^0 , 25^0 , 8^0 that is the sum of the angles is 90^0.

First a vertical raise by conventional method is driven for a length of 5 m. To install the curve is fixed by lifting it with the help of pulley-block.
The platforms available are 1.6mx1.6m or 2.4mx2.4m.

Unit has safety devices for over-speed control, and to guard against air supply failure. It has got a steel umbrella and fencing attached with platform for the safety purpose.

Blasting patterns in raising





Advantages of Alimak Raising method

- The Alimak Raising method enables mining approaches, which cannot be carried out using raise borers and has the added advantage of in raise access to allow for the installation of ground support and grouting of water inflows as the raise is excavated, unlike raise boring where boring through highly stressed or bad ground conditions only ends up in ultimate failure or costly and time consuming remediation. Even multiple raises with directional changes in the raise of up to 90° can be carried out easily making this method the ideal choice for ore passes, crusher chambers, split level ventilation raises or any difficult excavation profile.

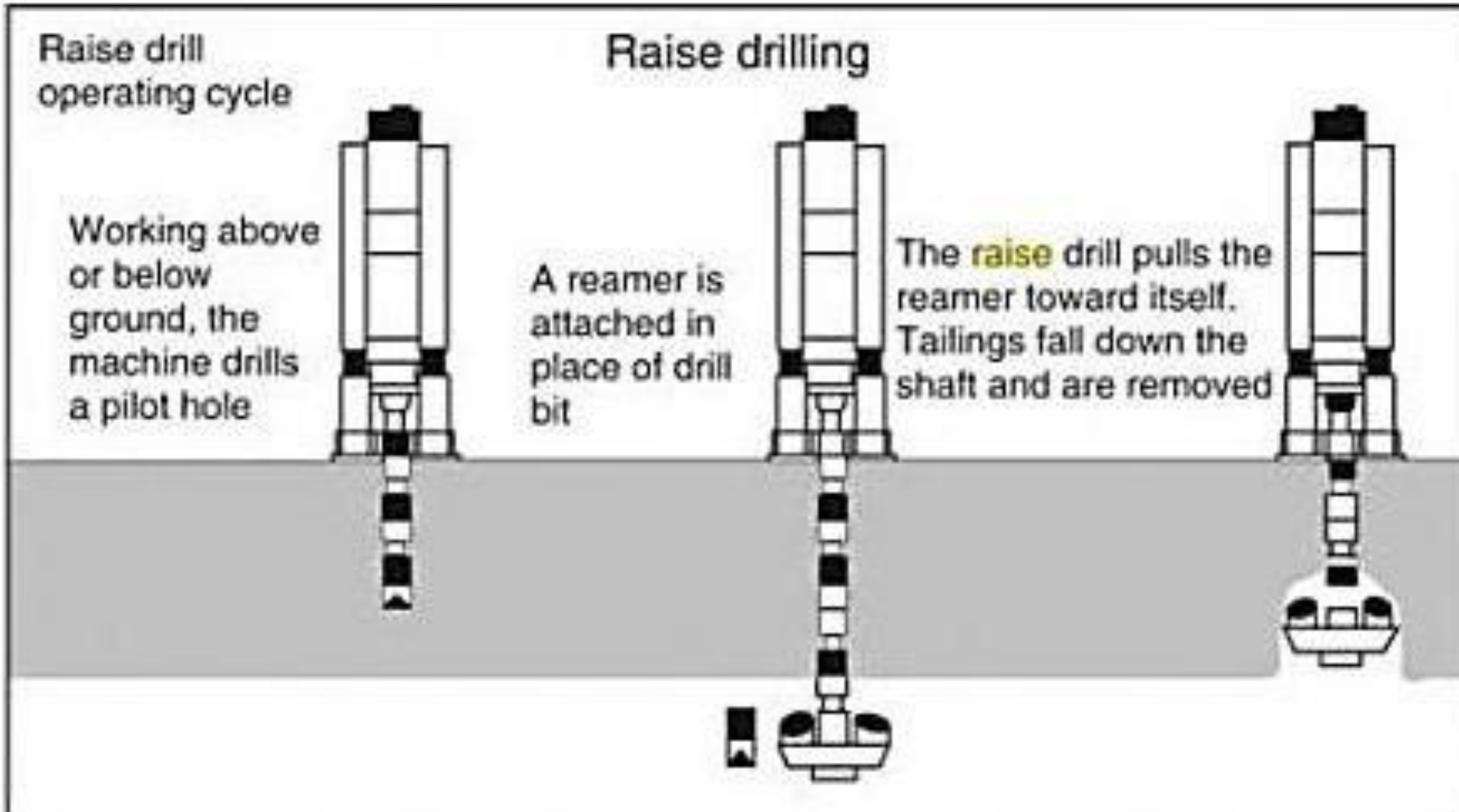
- Drilling Drilling is undertaken from the drill deck on top of the raise climber, which is sized to suit the size, shape and angle of the raise.

- Loading When drilling is completed the face is charged with explosives.
- Blasting The Alimak climber is then lowered to the bottom of the raise and into a station for protection before the blast is triggered from a safe location.

- Ventilation and Scaling The Alimak system provides for efficient post blast ventilation and a powerful air/water blast effectively dislodging loose rock from the freshly blasted face making ready for re-entry.

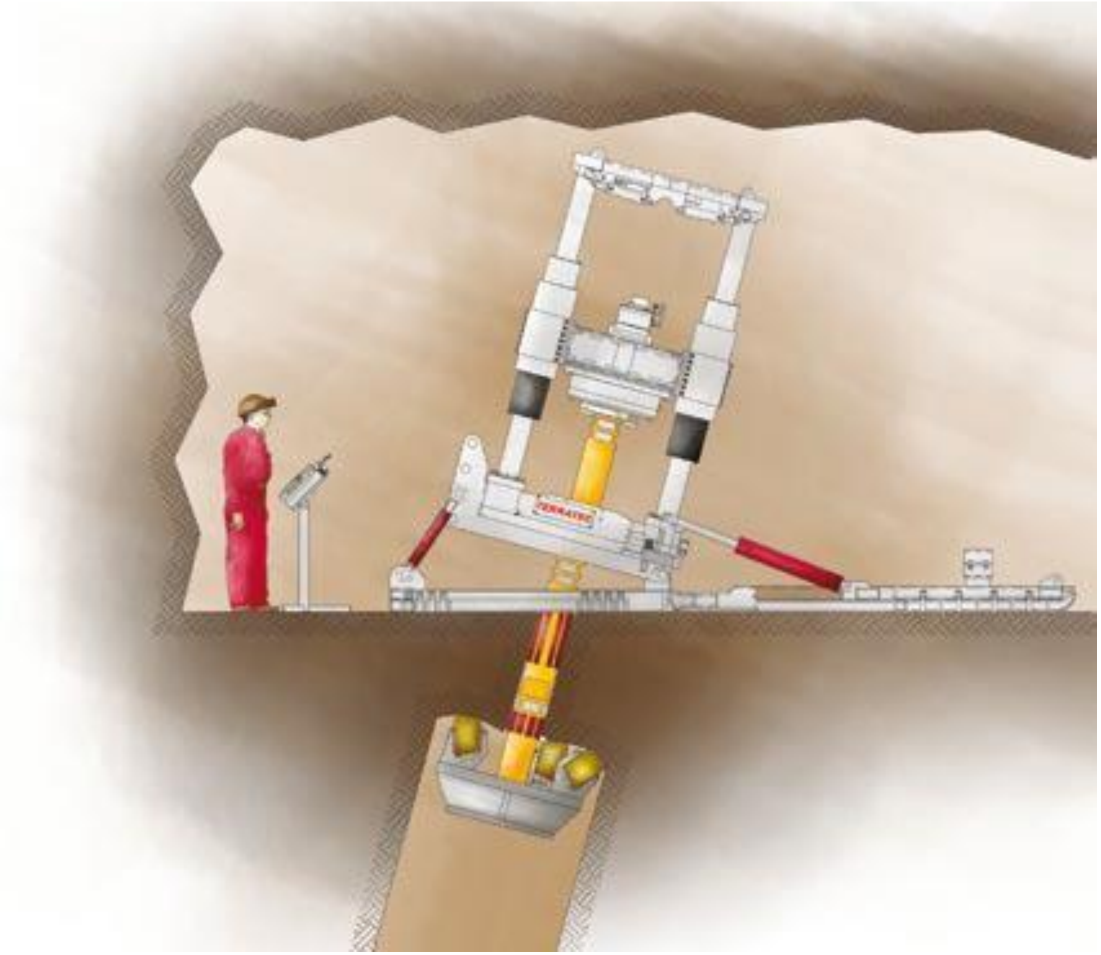
RAISE BORING METHODS

- In this system, the pilot hole is drilled down to a lower level in the mine drive. Once the pilot hole connects to the lower access level, the drill bit is removed and a reamer or raise head is attached and the reamer is rotated and pulled upwards. The broken rock falls to the lower level by gravity. This system operates with the drill string in tension and this provides the most stable platform.



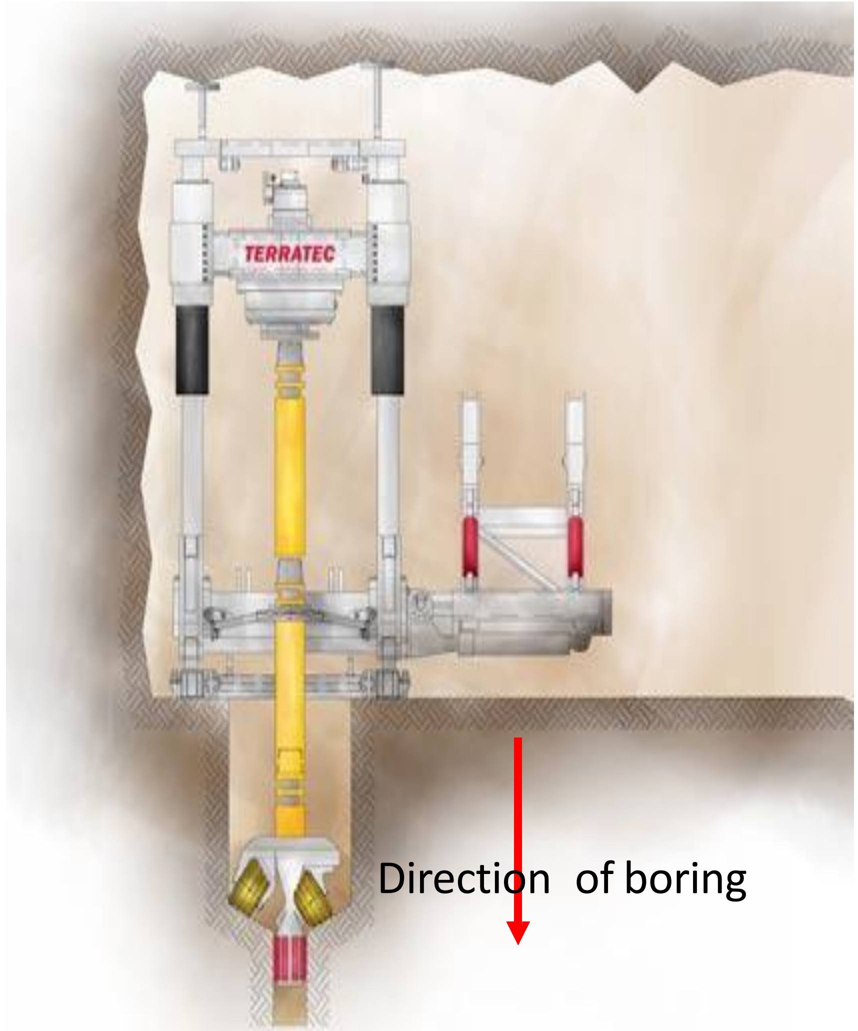
Driving vertical rises with raise borers

Raise boring



Down-Reaming

- In this system, the pilot hole is drilled downwards until it connects to a lower access level. The drill string (all drill rods, stabilizers and cutting bits) is retrieved and then a reamer is pushed downwards. The cuttings flow down the previously drilled pilot hole. This method uses drill string in compression and usually stabilizers must be installed to eliminate the potential of the drill string buckling.



ADVANTAGES OF BORED RAISES

- The most important are safety, speed, physical characteristics of the completed hole, labour reduction and cost reduction. The safety factor in raise drilling cannot be over emphasized. No men are exposed to the danger of rock fall from freshly blasted ground or to the continual use of explosives, with their fumes and inherent danger of misfires. Raises can be safely drilled in ground that would be extremely hazardous, if not impossible, to drive by conventional methods.

- A hole drilled by Raise Boring Machine can generally be completed in a fraction of the time required for conventional methods. The bored raise, with its firm undisturbed walls, is more adaptable to use as ventilation and rock passes. As conventional methods require a relatively large opening, it has become customary to drive raises

- Raise boring will not only reduce labour requirements by achieving a higher advance per day but, along with another technological advances, will have the tendency to attract a higher level of skilled labour to the mining industry.

- Last, and probably most important from the long-range viewpoint, is cost reduction. Although, it is true that the direct cost of conventional raises, especially short ones, may currently be less in many cases, labour and material costs are continually escalating and therefore their costs increasing. Skilled conventional miners, always in short supply, are not required to operate a Raise Boring machine. Improved raise drills, drilling techniques, pilot bit and cutters are lowering the cost of machine excavated (RBM) raises. Less total manpower, less rock to handle, less construction time and increased safety all add up to less costs and earlier projects.

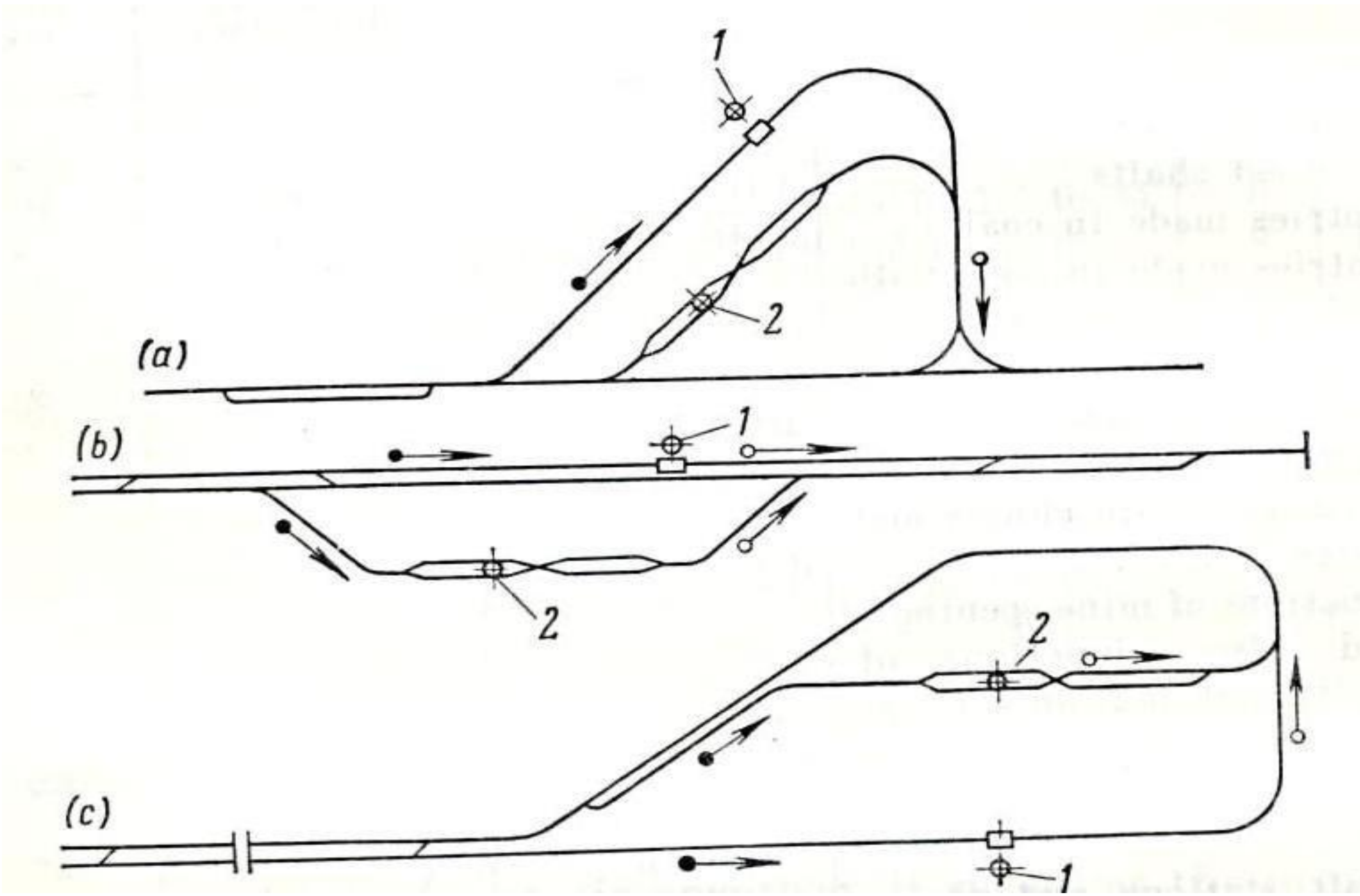
Shaft Station

- Underground mining operations involve deployment of different types of heavy duty rock excavation and transportation machines. Some are electric power driven, others are diesel operating machines. There are a few specialized openings such as bunkers, pumping station, electric sub-station etc., at the bottom of the main shaft, and it is the horizon where the vertical shaft intersects with horizontal openings. This is known as the shaft station.

- The shaft station serves as the principal terminus of all underground and surface operations. Those related to materials handling involve: skip loading pockets, retention bunker; ventilation arrangements; pumping stations; electrical sub-stations; underground mechanical shop / workshop; first aid centre & rest rooms etc.

- The design considerations depend on the number of shafts within the station, type of deposit, mode of materials handling in the mine and in the shaft, water inflow, ventilation requirements, mining equipment, etc.

Standard shaft station layouts



a-with circular mine traffic; b- with shuttle traffic; c- loop like layout of shaft staion;

1 Main shaft 2 SecondaryShaft

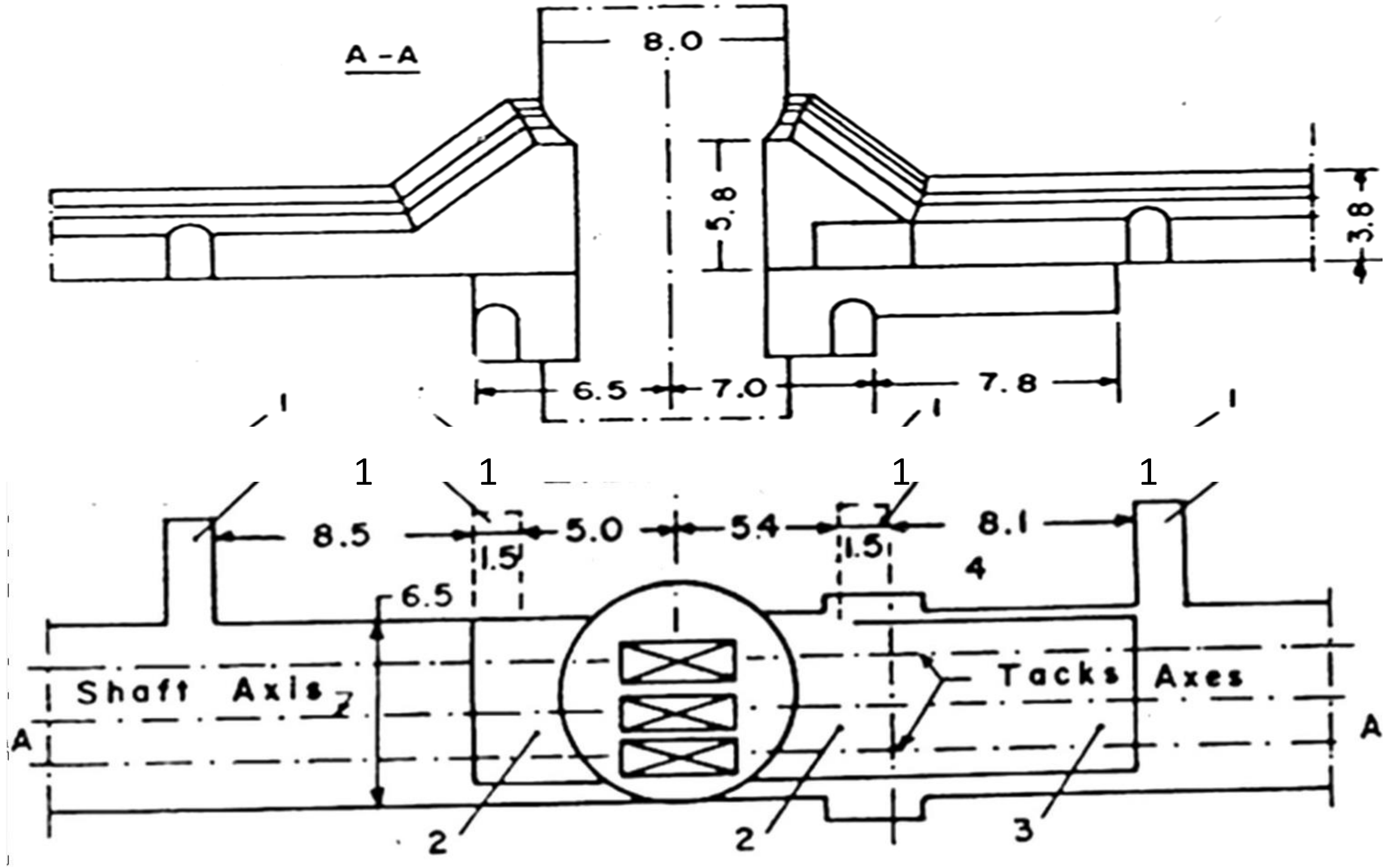
Generally the longer the life of a mine and larger the output the shaft station becomes more complex. Some of the factors that are considered for design of shaft station are:

- Type of deposit
- Mode of material handling in the mine
- Hoisting of ore in the shaft
- Water inflow and ventilation
- Mining equipment

The shaft stations in hard- rock mines for material handling arrangement will have the following:

- Skip loading pockets,
- Retention bunkers
- Pump chambers
- Main power station
- Explosive storage chamber
- Locomotive room
- Mechanical & electrical workshop
- Dump (ore/waste) chamber – with bunker & u/g crusher.
- Arrangements for the type of ore/waste transport system (eg: belt; train)

Shaft Station in Metal Mine



1- Access drift to waiting room; 2- basement for two-level traffic and swinging platforms;
3 – Basements for pushers and bangers (b backing cars) 4- a slot for control equipment.

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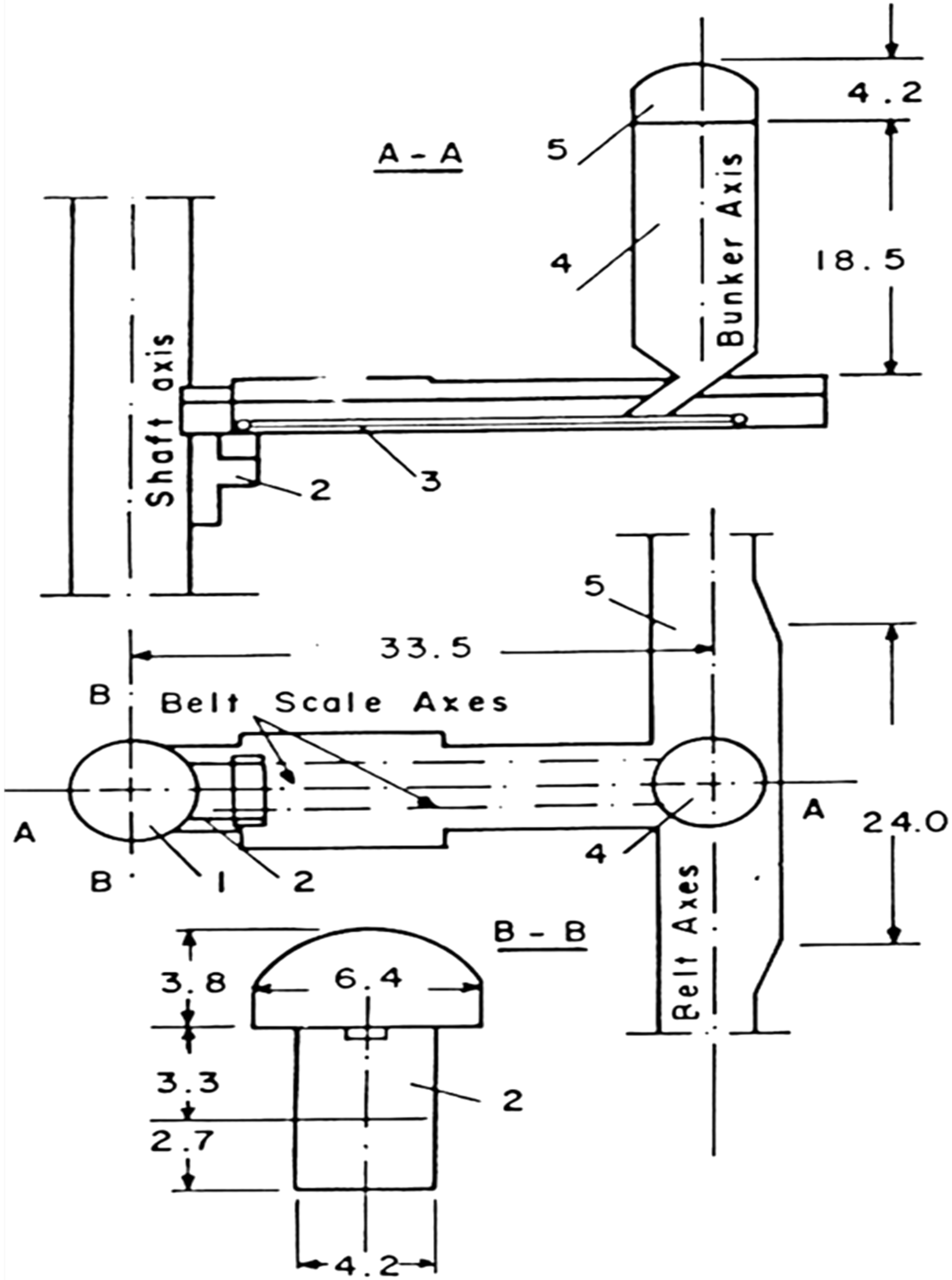


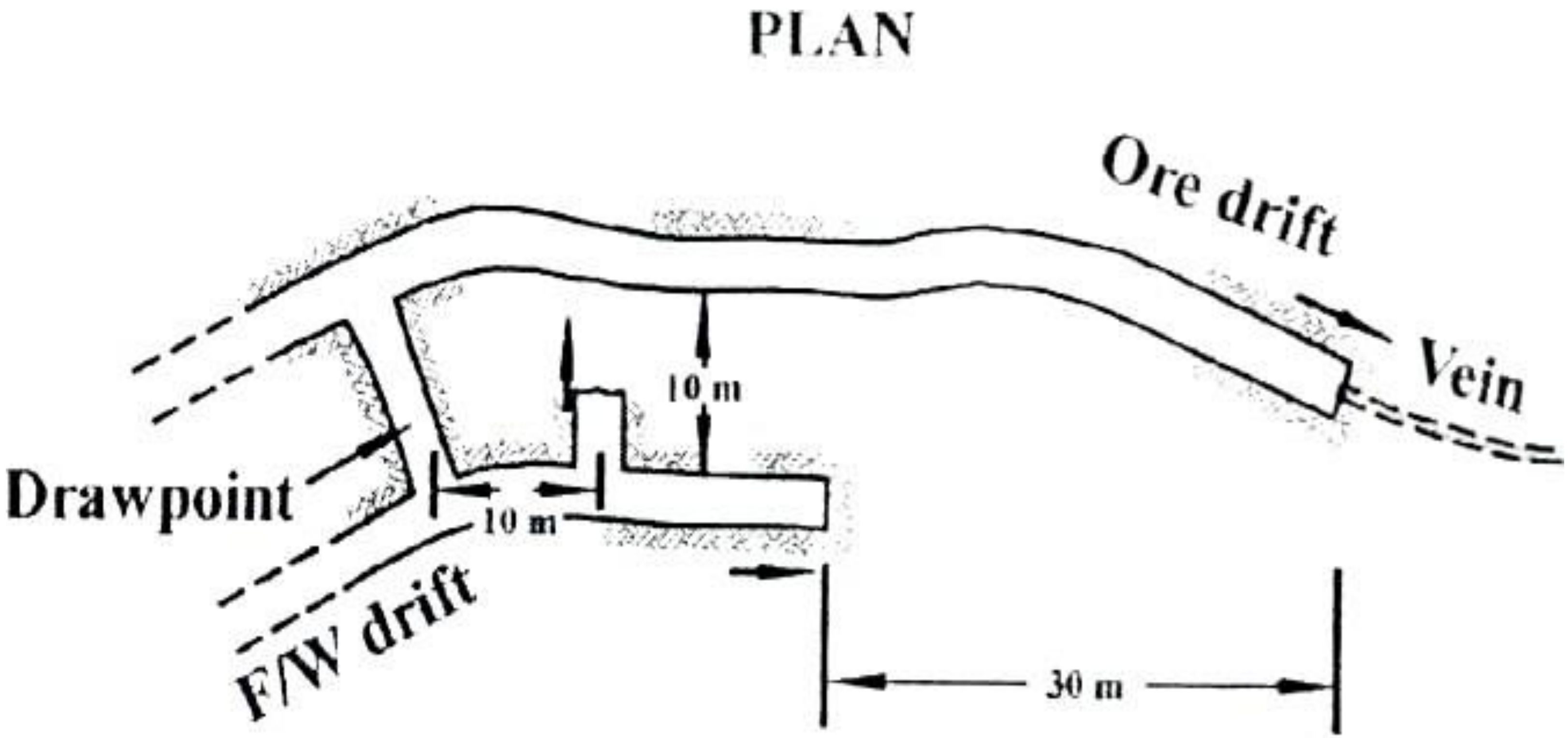
1. Skip shaft;
2- skip chamber;
3- belt scale ;
4 retaining bunker;
5 unloading chamber.

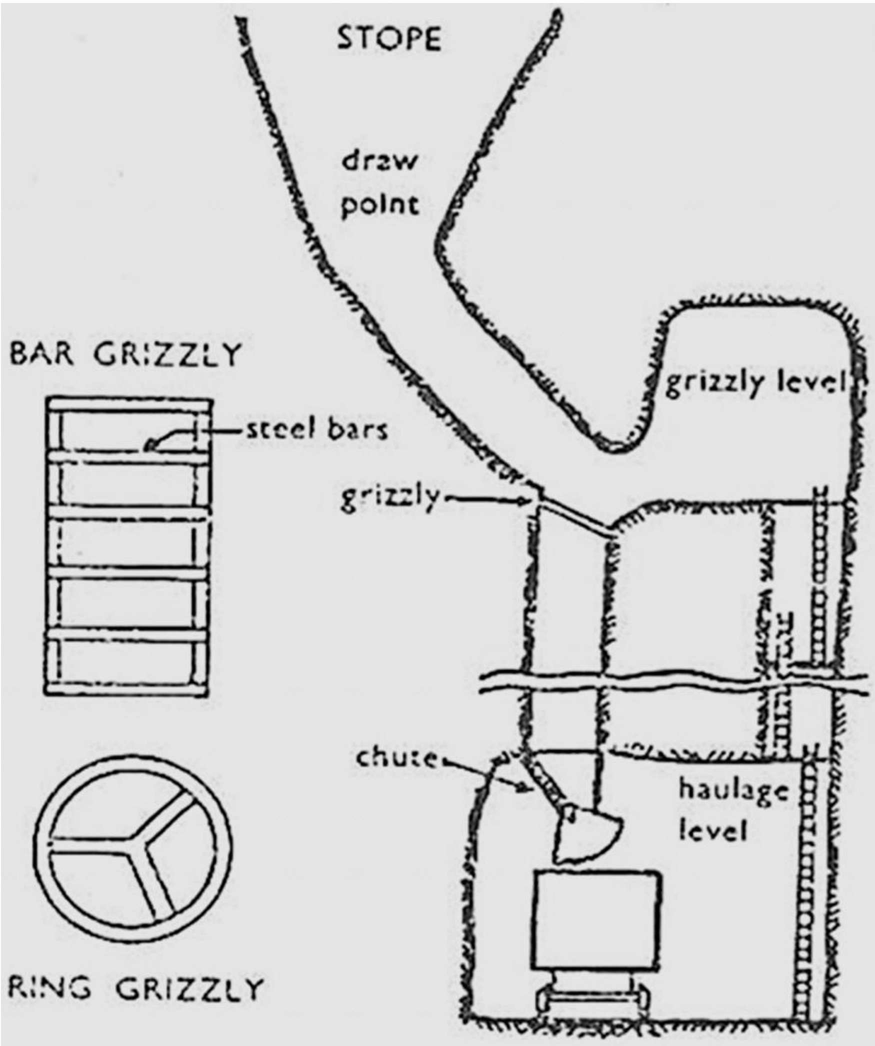
Stope Development

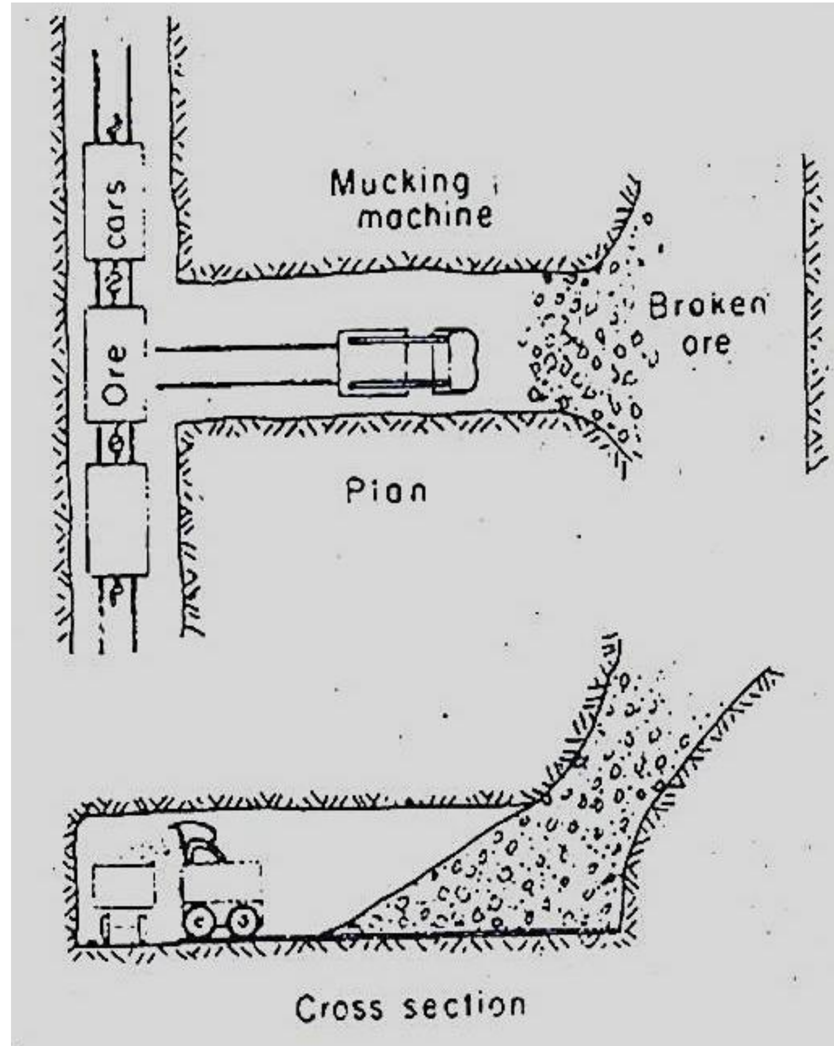
Once the economic extraction of ore body is ascertained, the step follows next is development and preparation stope for extraction or ore. The development of an ore drive(cross-cut) will confirm the thickness (extent of ore body) and continuity of the ore body and enable the planners to finalize stope design.

- Different development configurations and construction arrangements are possible for ore body geometry. The stope preparation involves development of haulage level and sill-level. This approach allows the development of draw points

Development of Ore and footwall drives.

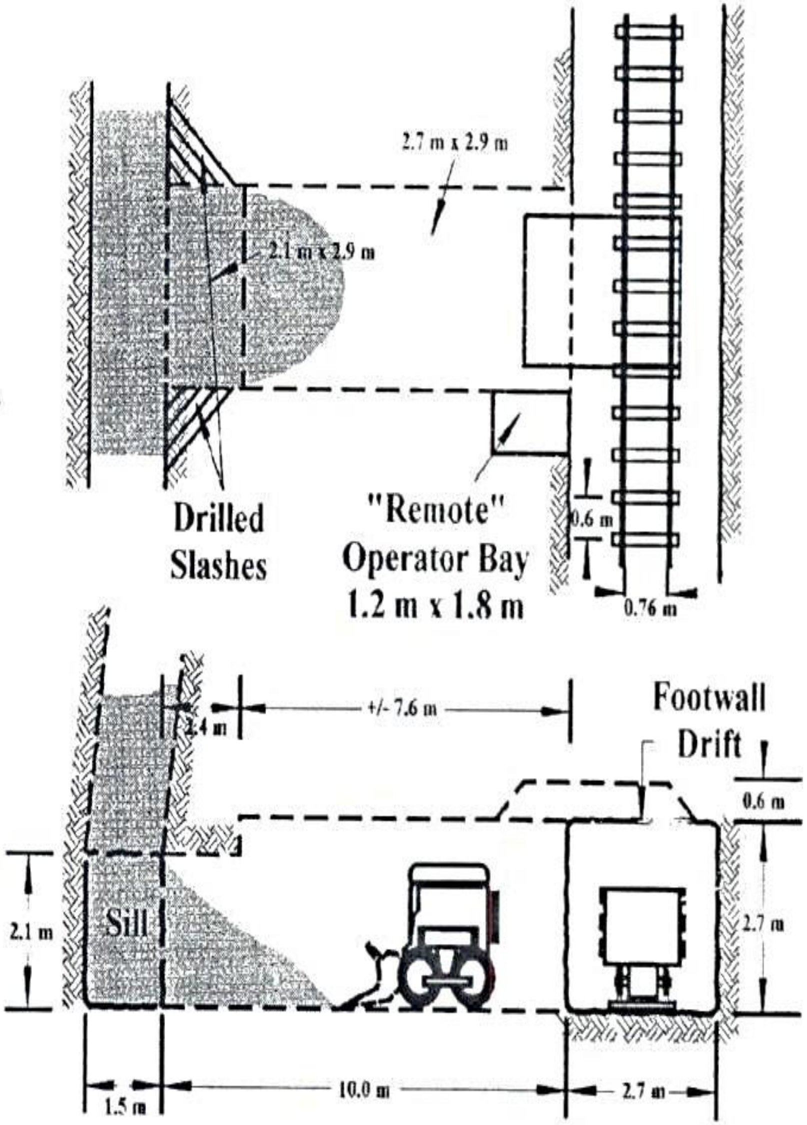


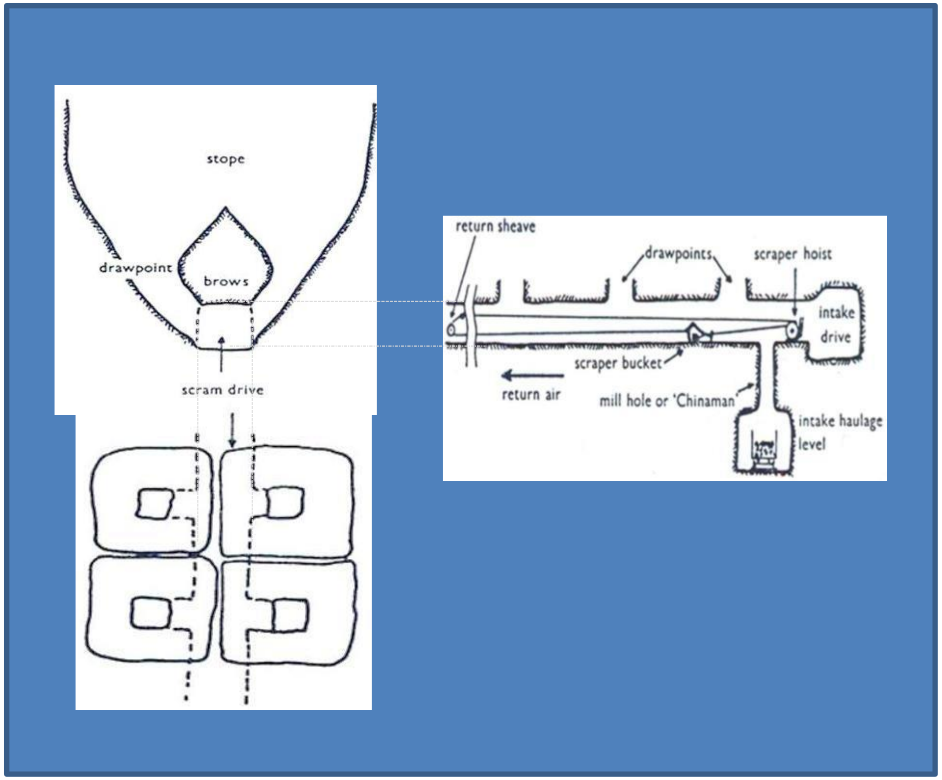


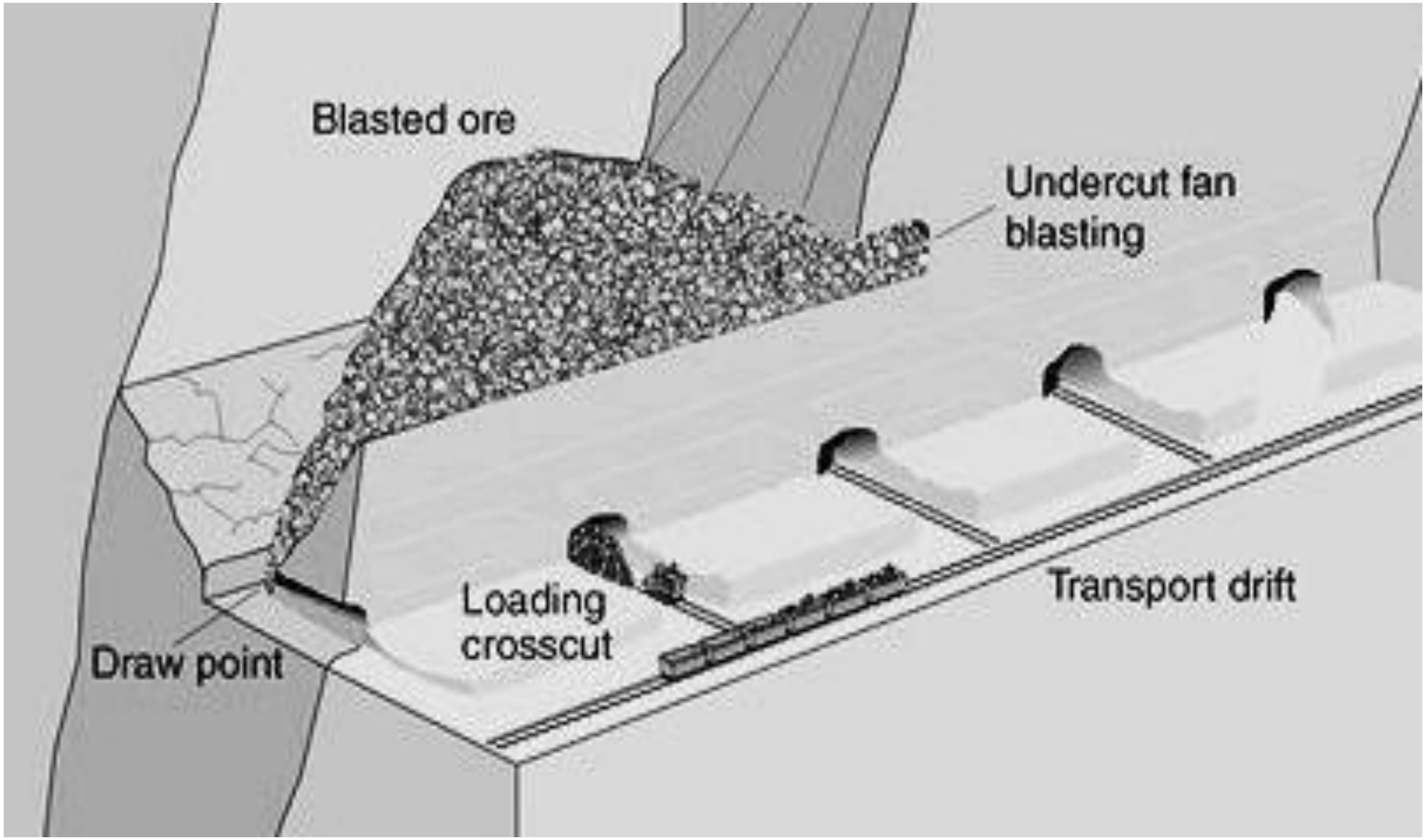


Ore loading chutes

LHD/ Rocker shovel draw points


2.7 m x 2.9 m
2.1 m x 2.9 m
Drilled Slashes
"Remote" Operator Bay 1.2 m x 1.8 m
0.6 m
0.76 m
2.4 m
+/- 7.6 m
Footwall Drift
0.6 m
2.1 m
Sill
2.7 m
1.5 m
10.0 m
2.7 m


stope
drawpoint
brows
scram drive
return sheave
drawpoints
scraper hoist
intake drive
scraper bucket
return air
mill hole or 'Chinaman'
intake haulage level


Blasted ore
Undercut fan blasting
Transport drift
Loading crosscut
Draw point

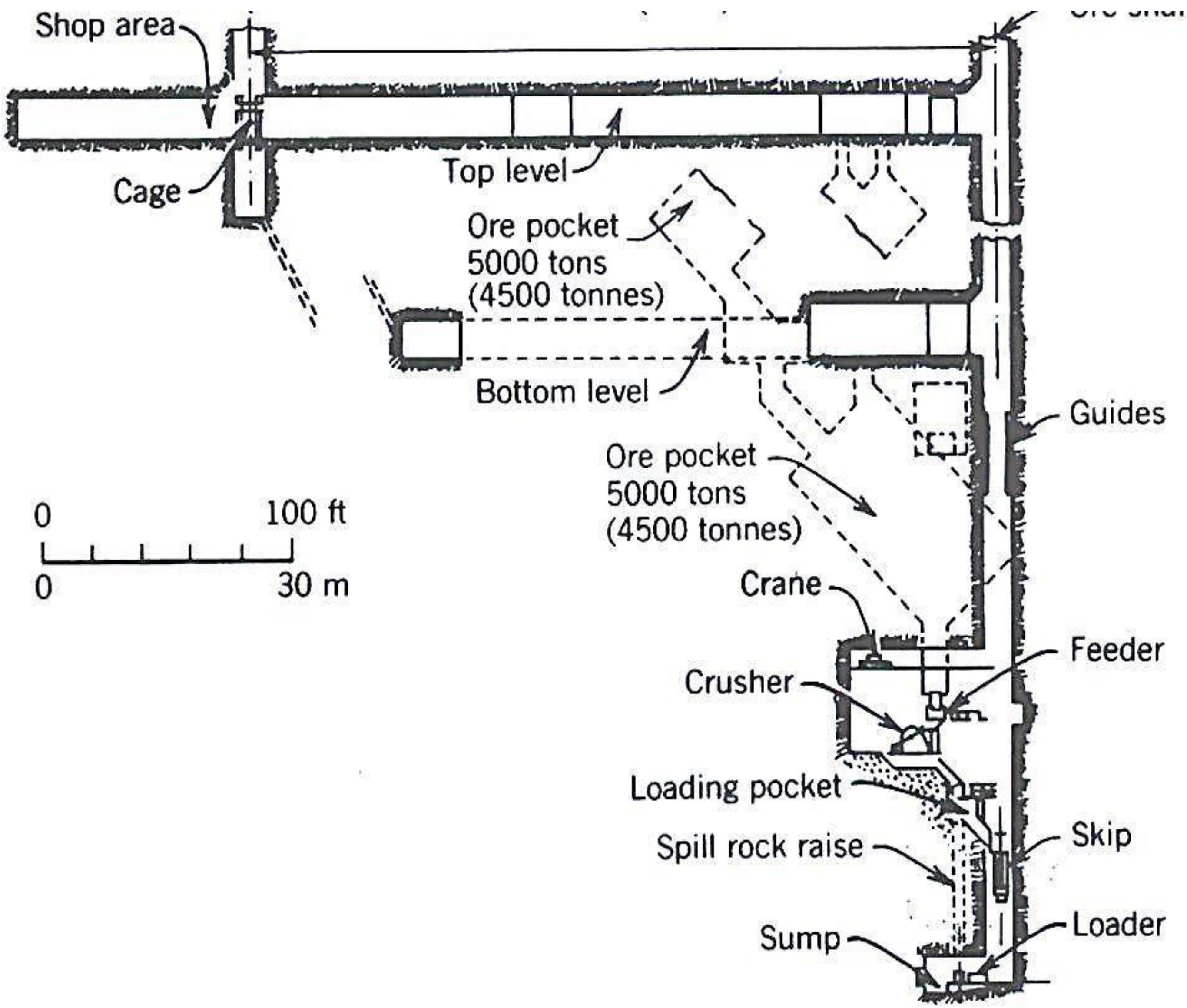
Draw point

Ore pass system

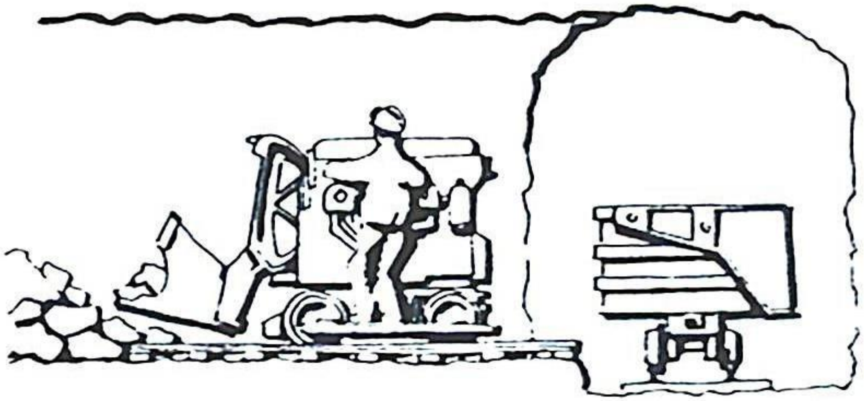
Ore passes are underground passageways for the gravity transport of broken ore, waste rock from one level of a mine to a lower level. Inclination of are pass vary widely from vertical to as low as and cross sections are mostly circular.

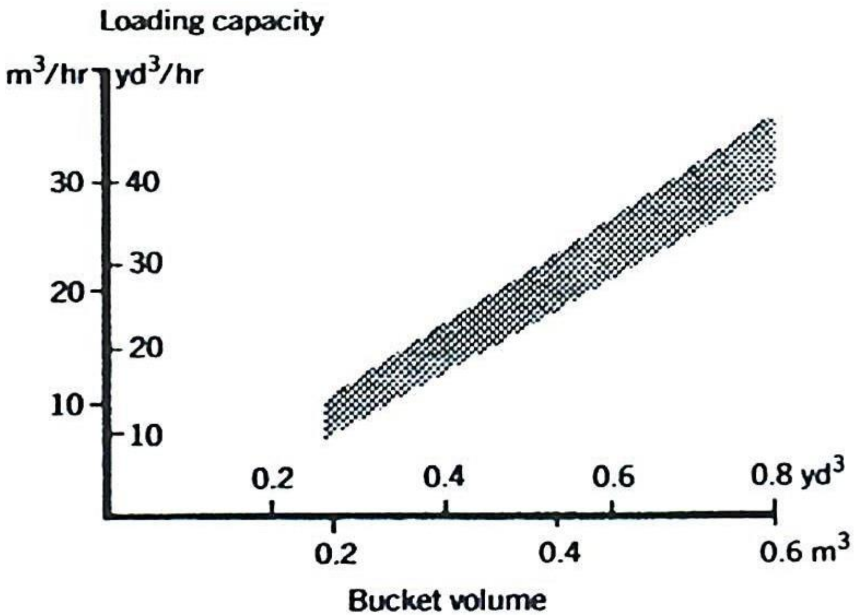
Besides transport of ore it also sometimes serves as a storage which is required for efficient mines operation.

Ore pass system include ore pass itself connecting two or more levels, tops end facility for material size and volume control such as grizzles, crusher and bottom end structures to control material flow.



Components of hoist plant installed with in a service shaft.





Unit Operations and equipment for development and exploitation in underground mining: loading by overhead loader/ Rocker shovel

Ore pass

- Ore pass systems are an integral part of the materials handling system in the majority of underground mines. Ore passes are developed using either mechanical (raise borer) or drill and blast techniques (Alimak, conventional raising and drop raising).

- Conventional and drop raises represent 29% and 5% of the sections, respectively. The dominance of Alimak raising is attributable to several causes. It ensures a reasonable degree of safety for the miners, while still allowing the installation of support.

- Furthermore, the ability to drive the Alimak pass from a single access (as opposed to raise boring, which requires that both the bottom and top accesses be developed) and a strong expertise of local mining contractors are also contributing factors.

Ore pass section length

There are several practical and financial considerations that influence the selection of an ore pass length.

- to minimize its capitalized development, it will end up driving short ore pass sections, going from one level or sub-level to the next.
- Quite often a mine that experienced problems when driving and operating long sections will subsequently opt for shorter sections when constructing new ore and waste passes.
- An excavation of greater length is more likely to intersect zones of poor ground. It also has a higher potential for problems and is harder to bypass.
- Longer sections may also result in higher material flow velocity in passes operated as flow-through.

Ore pass section inclination

- Ore pass inclination varies between 45° and 90°, with an average inclination of 70°. The choice for a particular inclination is dictated by the need to facilitate material flow. Shallow sections may restrict flow, especially if a high proportion of fine material is present, while steeper excavations result in higher material velocities and compaction. It should be noted that all vertical sections are shorter than 100 m. Generally steep ore passes (80º ± 8.3º) are advantageous because it ensures continuous material flow and limit hang-up occurrences.

Ore pass section shape

- The majority of excavated ore passes are square or rectangular.
- Circular sections are usually associated with raise boring methods but in some instances, circular sections were excavated using Alimak.
- Circular shape was used based on anticipated higher stress regimes.
- Ore pass size is an important factor influencing material flow. A common dimension of 2.0 m is widely used, however there are some mines where a relatively larger cross-sectional dimension of 2.5 ± 0.6 m have also been adopted.

Finger raises

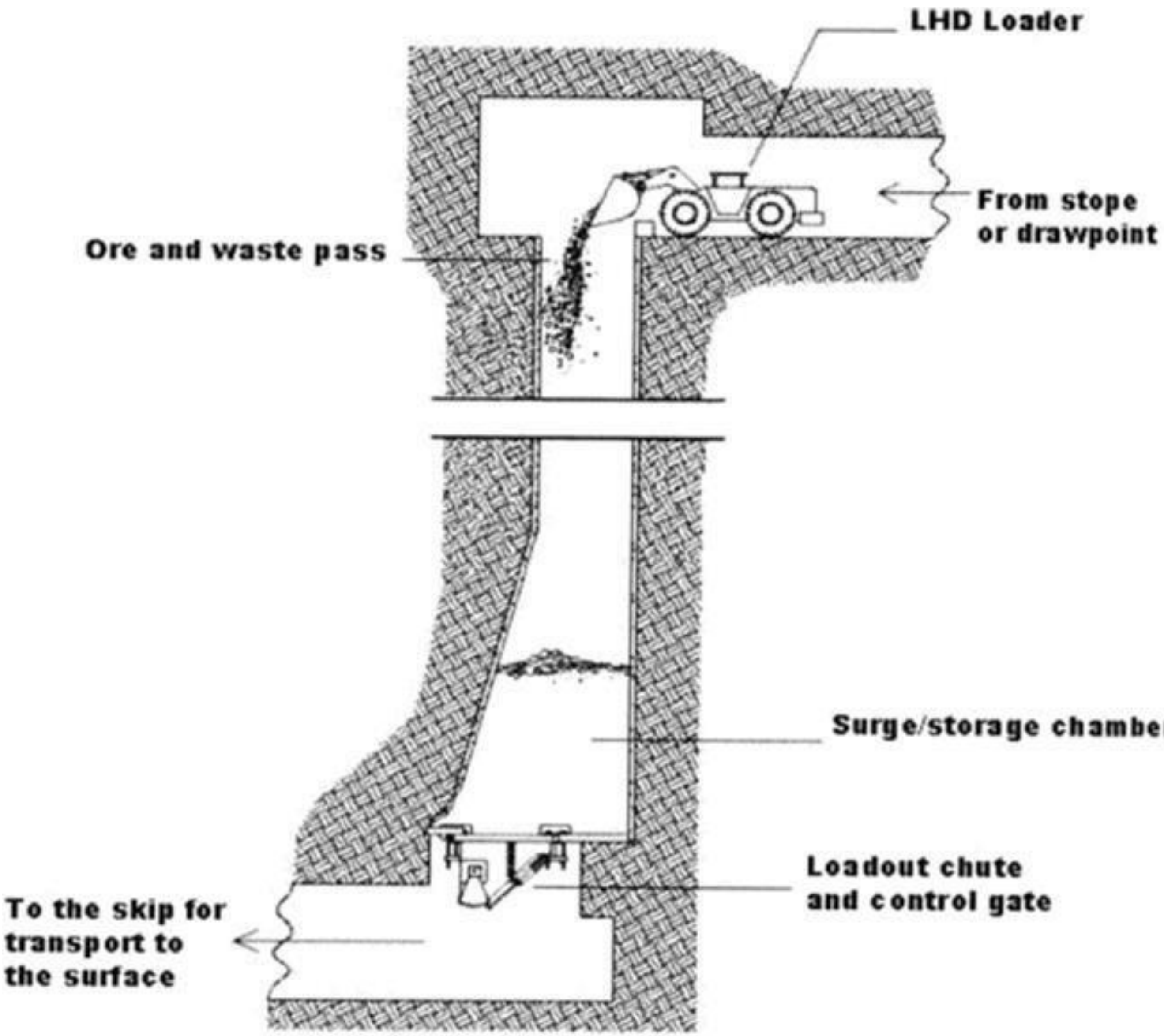
- Finger raises are used to funnel material into a pass intersecting two or more production levels. Typically, a finger raise is a square opening with a smaller cross-sectional area than the rock pass it feeds. The most common dimensions for a finger raise are 1.5 and 1.8 m. The majority of ore passes do not employ fingers or rely on a single finger. It is quite unusual to have more than 3 fingers leading into a section.

Screening of oversize material

- Oversize material dumped into the passes may lead to blockages or interlocking hang-ups. This can be avoided by either instructing the mucking crew or by installing the necessary infrastructure to restrict the entrance of the oversize material.

- The mechanical method of retaining oversized material at the mount of an ore-pass is by the installation of a grizzly.

  Sometimes mucking crews can be 'persuasive' in trying to push the block through the bars with the bucket. This practice damages both the bars and the scoop. Broken and missing bars are often the result of this practice. The ability of a grizzly to retain big blocks is therefore greatly diminished. In addition, the intrusion of a bar in the ore pass can lead to severe obstruction further down the system. Grizzlies are the best to keep big blocks out of the passes. Grizzlies require less maintenance than scalpers.


LHD Loader
From stope
or drawpoint
Ore and waste pass
Surge/storage chambe
Loadout chute
and control gate
To the skip for
transport to
the surface

Ore pass

Reinforcement

- Resin-grouted rebar constitutes the most popular reinforcement type for ore pass systems. Nevertheless, the most recently developed excavations are reinforced by resin grouted short cable bolts. An ore pass section is considered to have ‘failed’ if it had expanded to twice its initial volume as recorded in the original layout. It is suggested that liners should be considered for ground conditions where Q is less than 5.

Ore pass problems

- There is a relationship between the material unit weight and the degree of observed degradation of the walls of the ore pass.

- A qualitative assessment of the dominant degradation mechanisms include:
  - structural failures facilitated by material flow;
  - scaling of walls due to high stresses;
  - wear due to impact loading caused by material flow;
  - wear due to abrasion and blast damage caused by the hang-ups clearing methods.

- Wall damage attributed to impact loading is most often localized at the intersection of finger raises to the ore pass. It is most probable that the presence of structural defects in the rock mass accentuates the influence of impact loading, resulting in more pronounced degradation.

- Abrasion rate depends on the abrasiveness of the material and the ore pass walls' resistance to abrasion. In ore passes with relatively few fractures, wear of the walls did not seem to endanger the structural integrity of an ore pass.

Blockages

- Blockages are the most commonly encountered type of flow disruption in ore pass systems. Flow disruption near the chute may be due to blocks wedged at the restriction caused by the chute throat. Another source of problems is caused by the accumulation of fine or ‘sticky’ material in or near the chute, on the ore pass floor. This reduces the effective cross-sectional area and results in further blockages.

Material flow problems

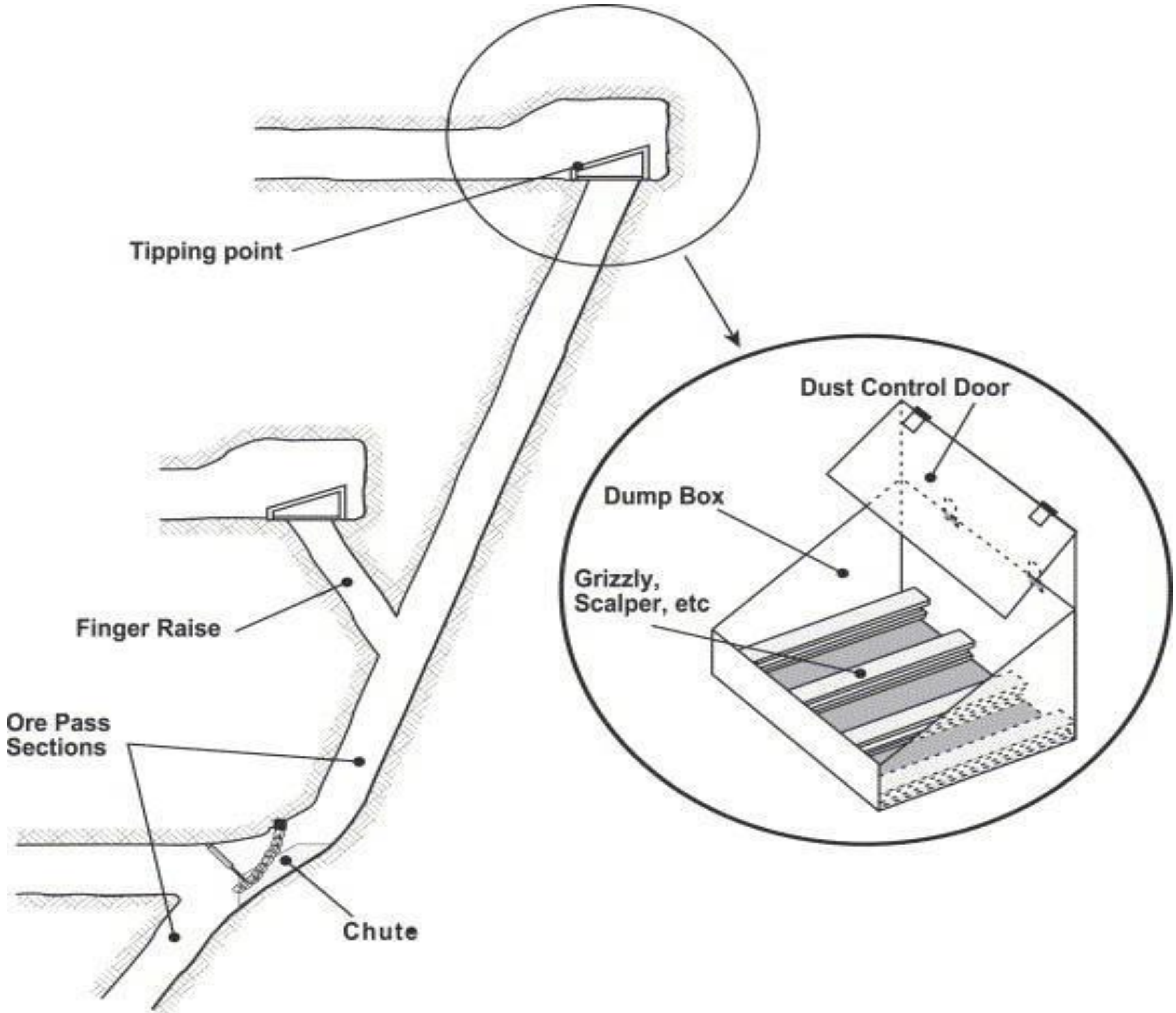
- Some types of material flow problems are reported in every mine operating an ore pass system. Sometimes the transfer of coarse material can result in hang-ups due to interlocking arches, while the transfer of fine material results in hang-ups due to cohesive arches,

Hang-ups

- Restoring material flow is a priority in operating mines. There are several methods to restore the material flow in case of a material hang-up with in the ore pass and they can be classified as those that employ water and those that rely on explosives,

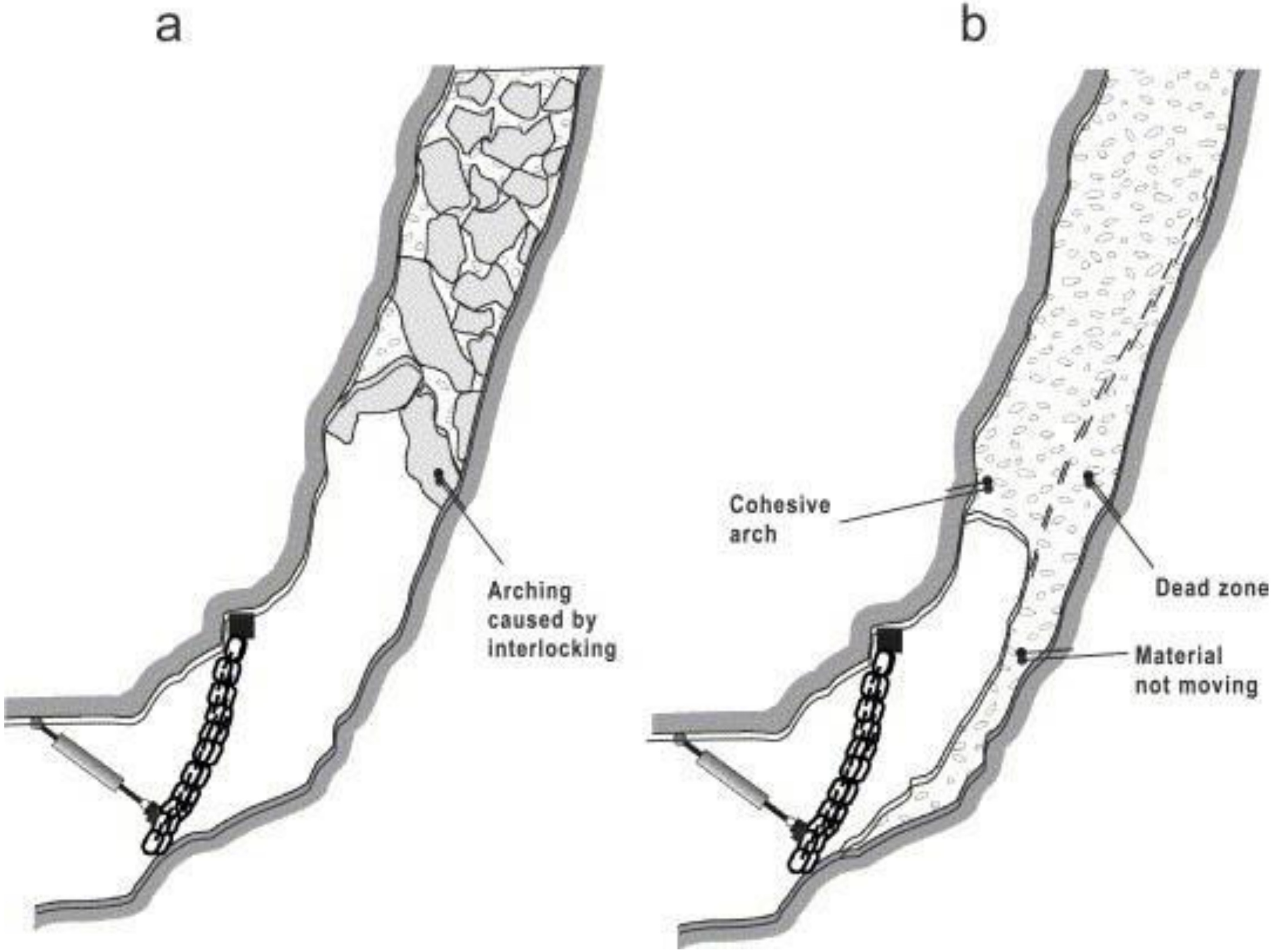
- Most hang-ups lower than 20 m are brought down by attaching explosive charges on wood or aluminium poles used to push the charge up to the hang-up. As a last resort, holes drilled toward the hang-up can be driven and explosive charges set inside the hole, near the supposed hang-up location.

- Cohesive hang ups are difficult to dislodge using explosives. Some operations resort to blowing compressed air through a PVC pipe raised up to the hang-up location or dumping a predetermined amount of water from a point above the hang-up. All mines have strict procedures about the use of water in order to avoid the risks of mud rushes.



Schematic of an ore-pass: tip section; discharge zones.

Hang-ups in an ore pass due to (a) interlocking; (b). cohesion arching,



Chapter 4: Rock mass response to stoping activity

The extraction of mineral resources involves rock excavations of different shapes, sizes, and orientation based on the purpose for which the excavation is made. And it changes the state of equilibrium and the redistribution of the stresses around the manmade structures is dependent on:

- the type of rock mass,
- size of the opening, and
- method of excavation.

Selection of a stoping activity is dependent on:

1. Ore body properties influencing mining method
2. Spatial distribution of the ore-body.
3. Disposition and orientation.
4. Geo-mechanical setting.
5. Ore body value and spatial distribution of value
6. Engineering environment.

Ore body properties influencing mining method

The strength of the rock mass around an ore-body in terms of near-field and far-field domains.

- In supported methods, mining increases the elastic strain energy stored in stress concentrations in the support elements and the near-field rock. The mining objective is to ensure that sudden release of the strain energy cannot occur. Such a sudden release of energy might involve sudden rupture of support elements, rapid closure of stopes, or rapid generation of penetrative fractures in the ore body peripheral rock. These events present the possibility of catastrophic changes in stope geometry, damage to adjacent mine openings, and immediate and persistent hazard to mine personnel.

- For caving methods, the mining objective is the prevention of strain energy accumulation, and the continuous dissipation of pre-mining energy derived from the prevailing gravitational, tectonic and residual stress fields.

2. Spatial distribution of the ore-body

- This property defines the relative dimensions and shape of an ore body.
- Veins, lenses and lodes are also generally extensive in two dimensions, and usually formed by hydrothermal emplacement or metamorphic processes. In massive deposits, the shape of the ore body is more regular, with no geologically imposed major and minor dimensions. Porphyry copper ore bodies typify this category. Both the ore body configuration and its related geological origin influence rock mass response to mining, most obviously by direct geometric effects.

3. Disposition and orientation

- These issues are concerned with the purely geometric properties of an ore body, such as its depth below ground surface, its dip and its conformation. Conformation describes ore body shape and continuity, determined by the deposit's post-emplacement history, such as episodes of faulting and folding. For example, methods suitable for mining in a heavily faulted environment may require a capacity for flexibility and selectivity in stoping, to accommodate sharp changes in the spatial distribution of ore.

4. Size

- Both the absolute and relative dimensions of an ore body are important in determining an appropriate stoping method. A large, geometrically regular deposit may be suitable for mining using a mechanized, mass-mining method, such as block caving. A small deposit of the same ore type may require selective mining and precise ground control to establish aprofitable operation. In addition to its direct significance, there is also an interrelation between ore body size and the other geometric properties of configuration and disposition, in their effect on mining method.

Geo-mechanical setting

- The response of a rock masses to a particular mining method reflects the mechanical and structural geological constitution of the ore body and the surrounding country rock. Rock material properties include strength, deformation characteristics (such as elastic, plastic and creep properties) and weathering characteristics. Rock mass properties are defined by the existence, and geometric and mechanical properties, of joint sets, faults, shear zones and other penetrative discontinuities. The pre-mining state of stress in the host rock is also a significant parameter.

5. Ore body value and spatial distribution of value

- The monetary value of an orebody, and the variation of mineral grade through the volume of the orebody, determines both mining strategy and operating practice. The critical parameters are average grade, given various cut-off grades, and grade distribution

6. Engineering environment

- Mine interaction with the external environment involves effects on local groundwater flow patterns, changes in the chemical composition of groundwater, and possible changes in surface topography through subsidence. Different mining methods interact differently with the external environment, due to the disparate displacement fields induced in the far-field rock. In general, caving methods of mining have a more pronounced impact on the mine external environment, through subsidence effects, than supported methods.

Summary of factors for selection of

Factors to Consider

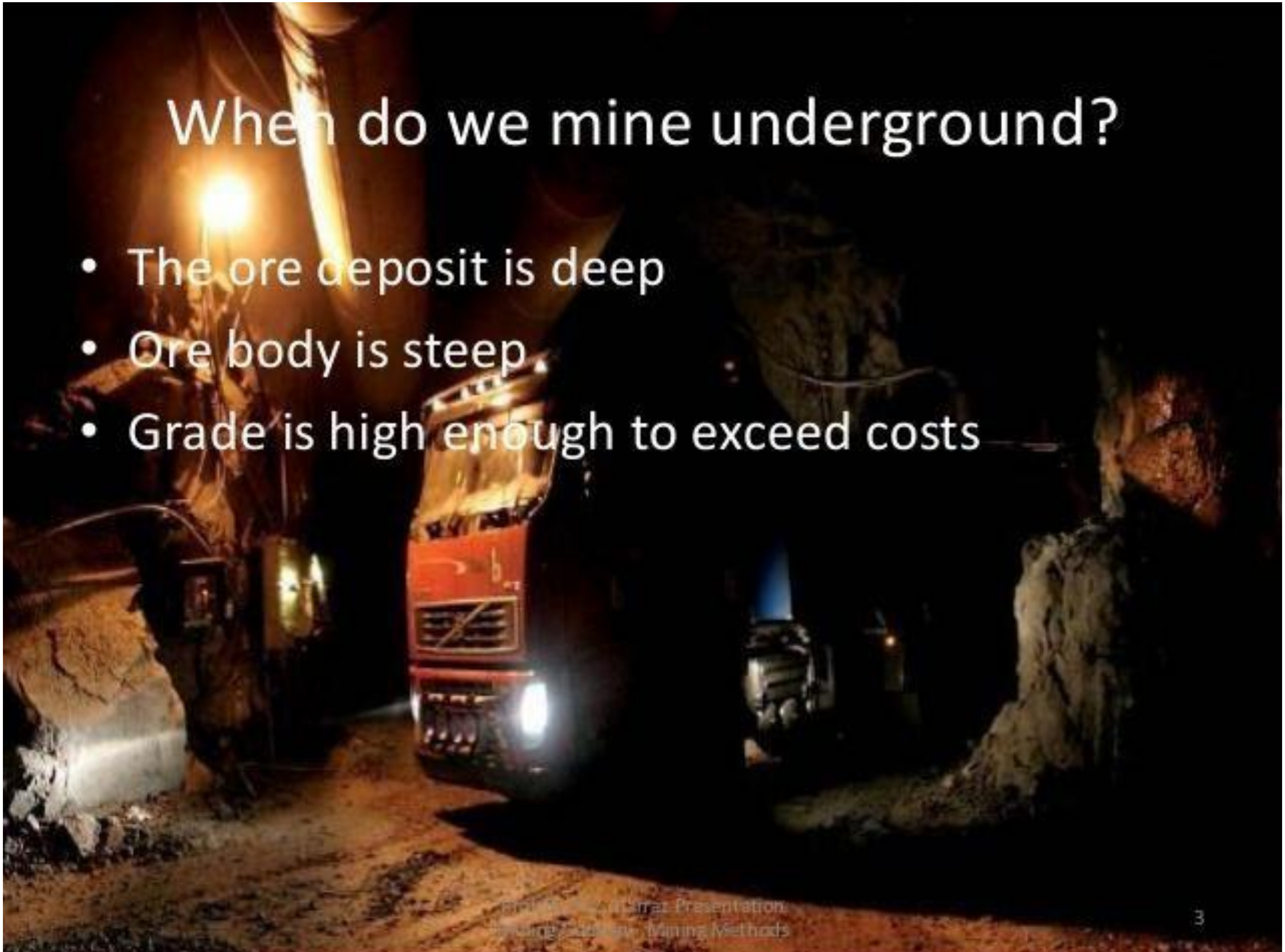
- **Geological and Geotechnical Considerations**
  - **Strength of Ore**
  - **Strength of host rock**
  - **Stress field**
  - **Structural Geology (faults, contacts, joints, folds, etc.)**
  - **Dimensions of orebody (thickness, strike length, height)**
  - **Orientation (dip, plunge)**
  - **Depth**

Factors to Consider

- Economic and Logistical
  - **Availability of Skilled Labour**
  - **Availability of Equipment**
  - **Availability of backfill**
  - **Legacy issues**
  - **Health and Safety factors**
  - **Economics**
    - **Production Requirements**
    - **Value of ore**
    - **Operating Cost**
    - **Capital cost**
    - **Processing cost**

When do we mine underground?

- The ore deposit is deep
- Ore body is steep
- Grade is high enough to exceed costs



INTRODUCTION TO UNDERGROUND MINING

Currently, mining in underground presents production volumes significantly lower than the open pit mining.

However, underground mines:

- still occupy a key position in the mining industry worldwide;
- not should decrease your application.

Reasons for the continuation of underground mining:

- depletion of deposits in the open and the consequent search for deeper deposits;
- less environmental impact;
- constant improvements in subsurface equipment

- All Underground mining methods involve:

drilling a pattern of holes into the rock.

  - Charging (filling) the holes with explosive.
  - Blasting the rock.
  - Bogging (digging) it out.
  - Ground support
  - Transporting it to the surface.

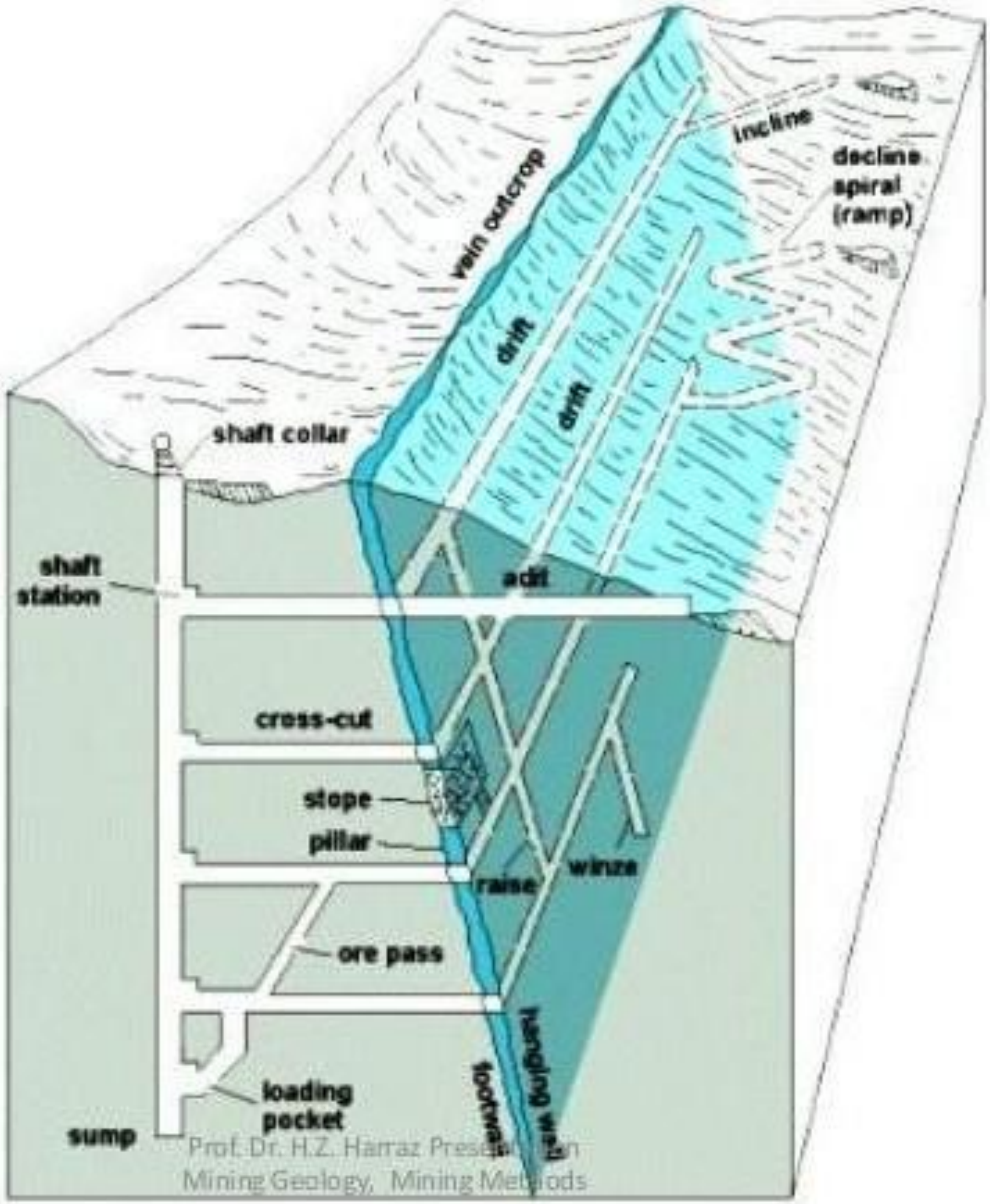
- ***Design issues:***
  - *Geometry of underground mining.*
  - *Ground support.*
  - *Shaft location.*
  - *Logistics of underground materials.*

Terminology

- **Stopes** are openings from which ore is mined. They may be backfilled with cemented waste materials.
- **Drifts** are horizontal passageways used for access.
- **Ore passes** are sub-vertical chutes for movement of ore.
- **Declines or ramps** are spiral or inclined drifts.
- **Output**: In general for underground mines:
    - **small output mines** have output of < 4,000 tpd. Hauling is done on several levels, tonnage handled on each level is small, and light equipment is used.
    - **high output mines** have output of > 4,000 tpd. A main haulage level is used and all ore is dropped to that haulage level via ore passes.
- **Levels** include all the horizontal workings tributary to a **shaft** station. Ore excavated in a level is transported to the shaft to be hoisted to the surface.

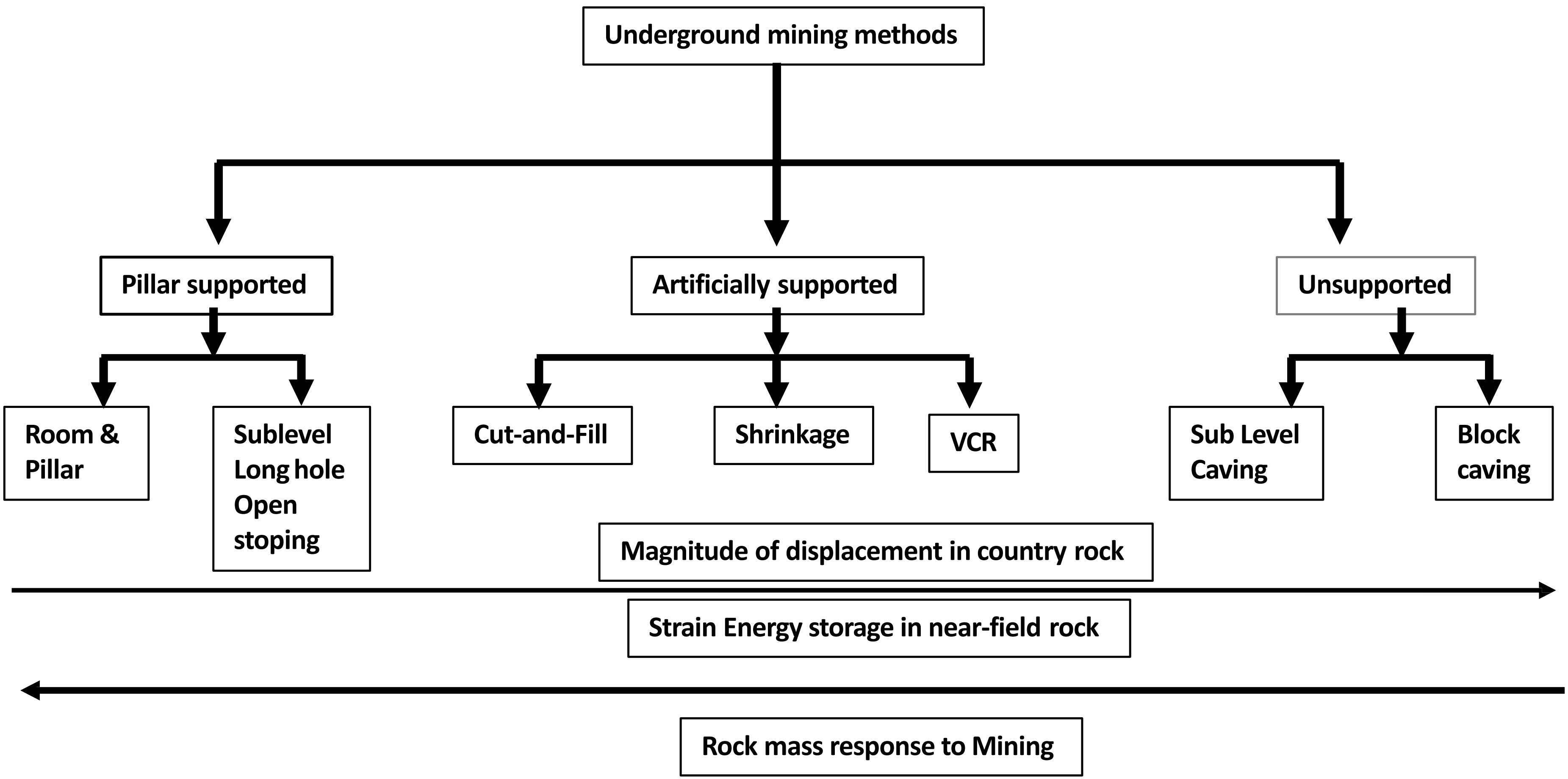
Some terms used in underground mining

- **Back** or **Roof** - ceiling or inner surface of an underground excavation (synonymous with roof);
- **Bell** - shaped excavation funnel formed in the top of a raised comminuted material to move by gravity into a stope of a drawPoint;
- **Capping** - waste material overlying the mineral deposit;
- **Crosscut** - gallery oriented perpendicular to the strike of a deposit that has inclination to the horizontal;
- **Pillar** - not mined portion of a deposit that serves as support for the roof or hood;
- **Crown pillar** - an overlying portion of an excavation and left intact in the form of pillar deposit. Can also be the mainstay of the above drawPoint;
- **Sill pillar** - behind an excavation and left intact in the form of pillar support portion;
- **Dip** - tilt angle of a deposit measured from the horizontal (synonymous with attitude);
- **Slope** - inclined plane, connecting the surface to the underground workings;
- **DrawPoint** - point loading fragmented ore located at the bottom of the stope and uses gravity to drain fragmented material for a kick or loading equipment;
- **Drift** - gallery oriented parallel to the strike of a deposit that has diving;
- **Finger** raise - approximately vertical opening used to transfer ore from a stope for drawPoint (point of load);
- **Floor** - floor or bottom surface of an underground excavation;
- **Footwall** - footwall of a deposit;
- **Hanging wall** - cover a deposit;



Mining layout-
terminology

Chapter 5 Mining Methods



1. Room-and-Pillar stoping method

Naturally Supported Method- Room-and-Pillar Mining

- **Conditions**
  - Ore strength: weak to moderate
  - Host rock strength: moderate to strong
  - Deposit shape: tabular
  - Deposit dip: low (<15 degrees), preferably flat
  - Deposit size: large extent – not thick
  - Ore grade: moderate

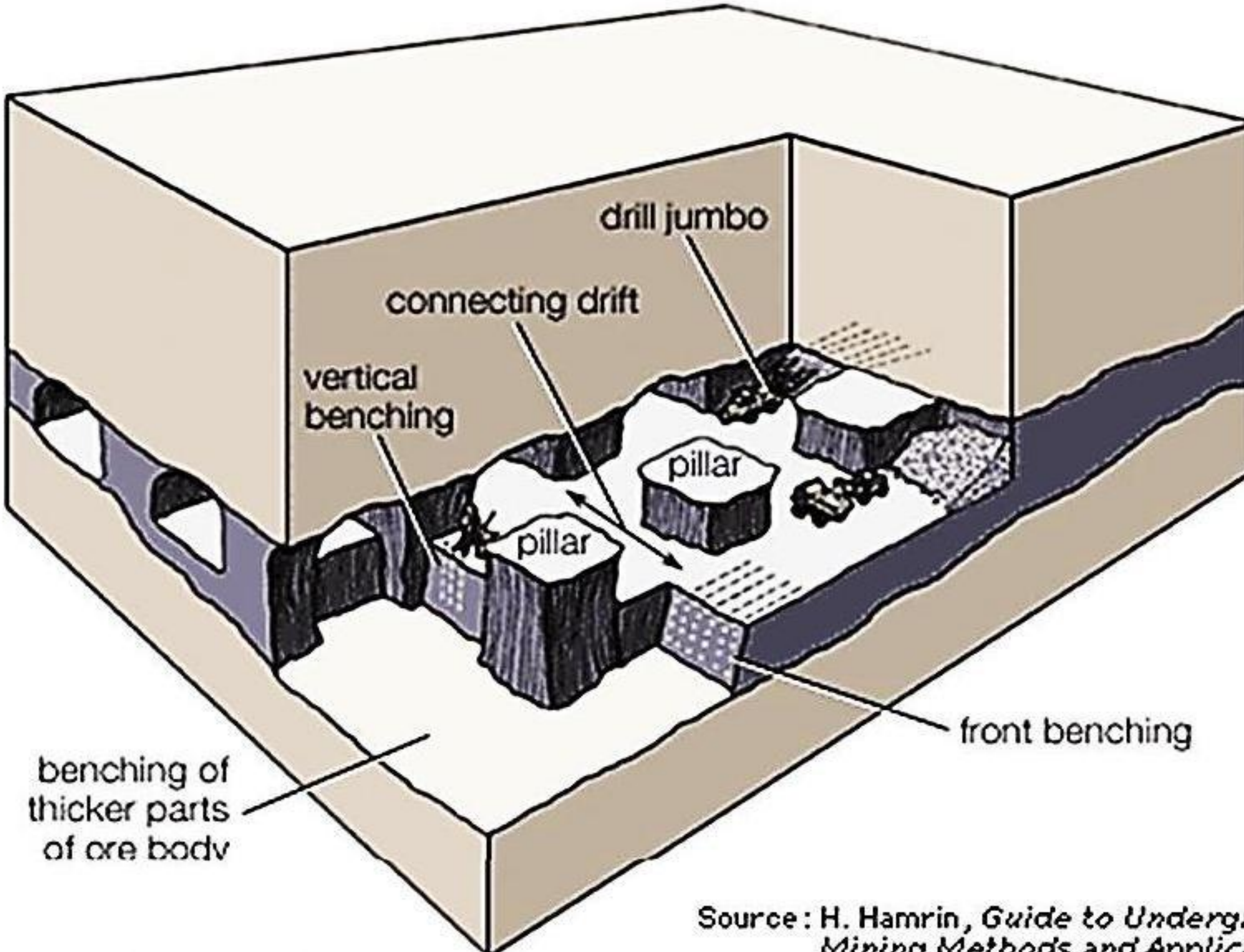
- **Features**
  - Generally low recovery of resource as pillars need to be left (40-60%)
  - Moderately high production rate
  - Recovery can be improved with pillar extraction (60-80%) but caving and subsidence will occur
  - Suitable for total mechanisation, not labour intensive
  - High capital cost associated with mechanisation
  - Versatile for variety of roof conditions

Applications

  - Bord and pillar – Coal mining region of Ipswich, Queensland
  - Room and pillar mining – MacArther River – North Queensland
  - Variation: Stope and pillar mining

Method:

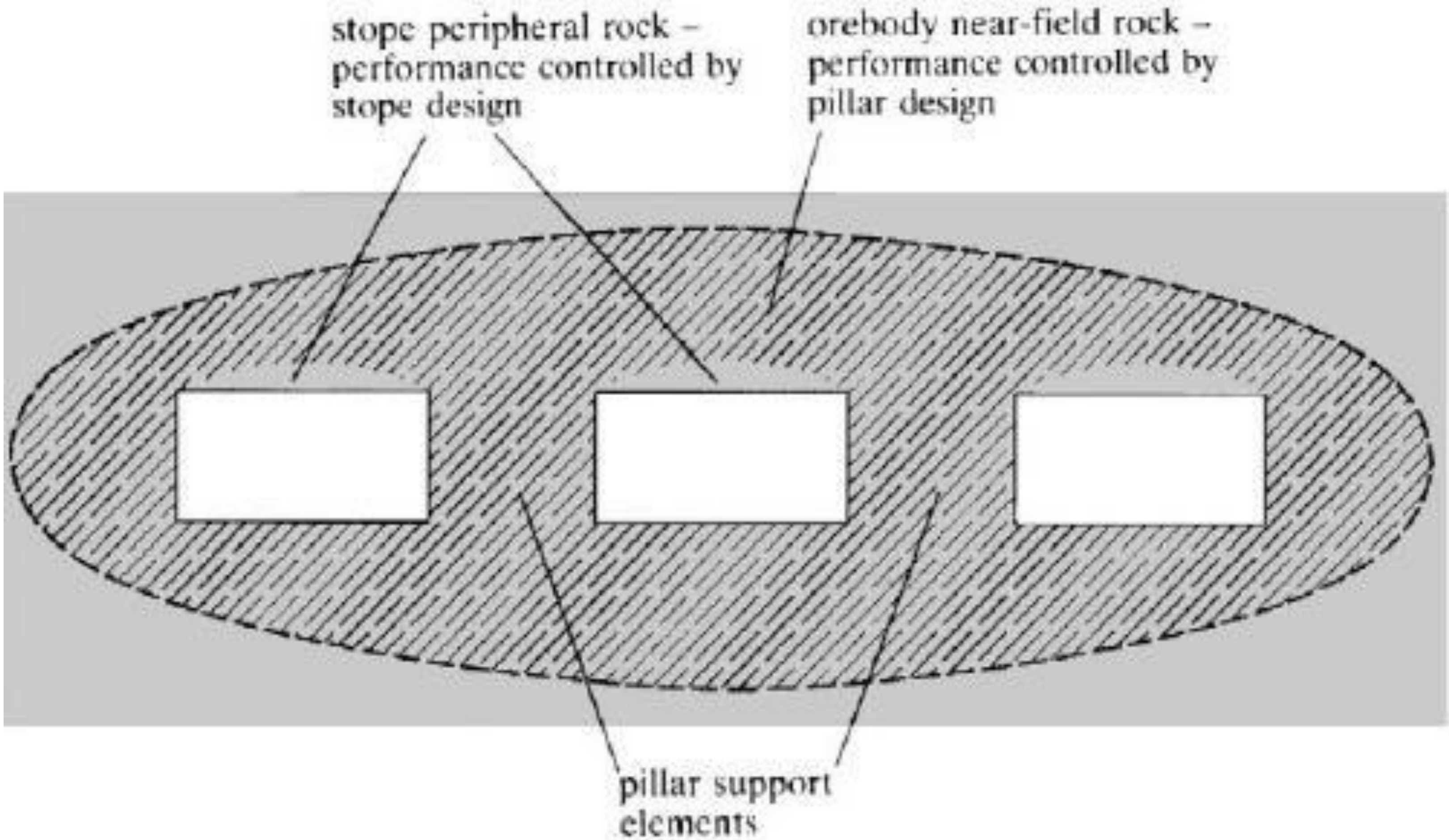
- The *room and pillar mining* method is a type of open stoping used in near horizontal deposits in reasonably competent rock, where the roof is supported primarily by pillars.
- Ore is extracted from rooms or entries in the ore body, leaving parts of the ore between the entries as pillars to support the hanging wall or roof.
- The pillars are arranged in a regular pattern, or grid, to simplify planning and operation. They can be any shape but are usually square or rectangular.
- The dimensions of the rooms and pillars depend on many design factors such as:
  - stability of the hanging wall and the strength of the ore in the pillars,
  - thickness of the deposit, and the depth of mining.



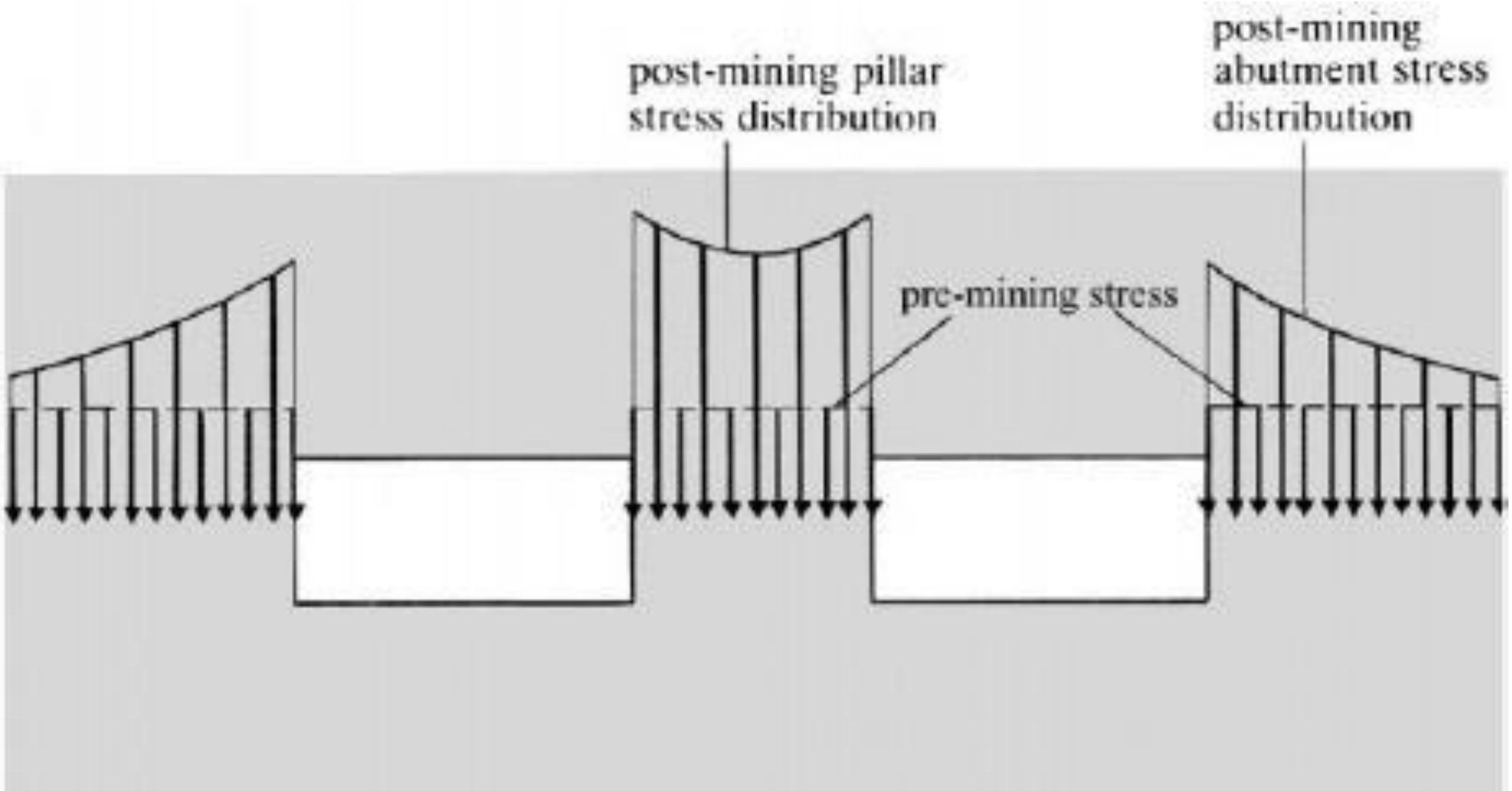
Source: H. Hamrin, *Guide to Underground Mining Methods and Applications* (Stockholm: Atlas Copco, 1980)

Analysis of Pillar support system in Room-and – Pillar stoping

- A mining method based on pillar support is intended to control rock mass displacements throughout the zone of influence of mining.
- Stopes may be excavated to be locally self-supporting. Near-field ground control is achieved by the development of load-bearing elements, or pillars, between the production excavations.
- Effective performance of a pillar support system can be expected to be related to both the dimensions of the individual pillars and their geometric location in the orebody.
- An economic design of a support system implies that ore committed to pillar support be a minimum.



Schematic illustration of problems of mine near-field stability and stope local stability, affected by different aspects of mine design.



Redistribution of stress in the axial direction of a pillar

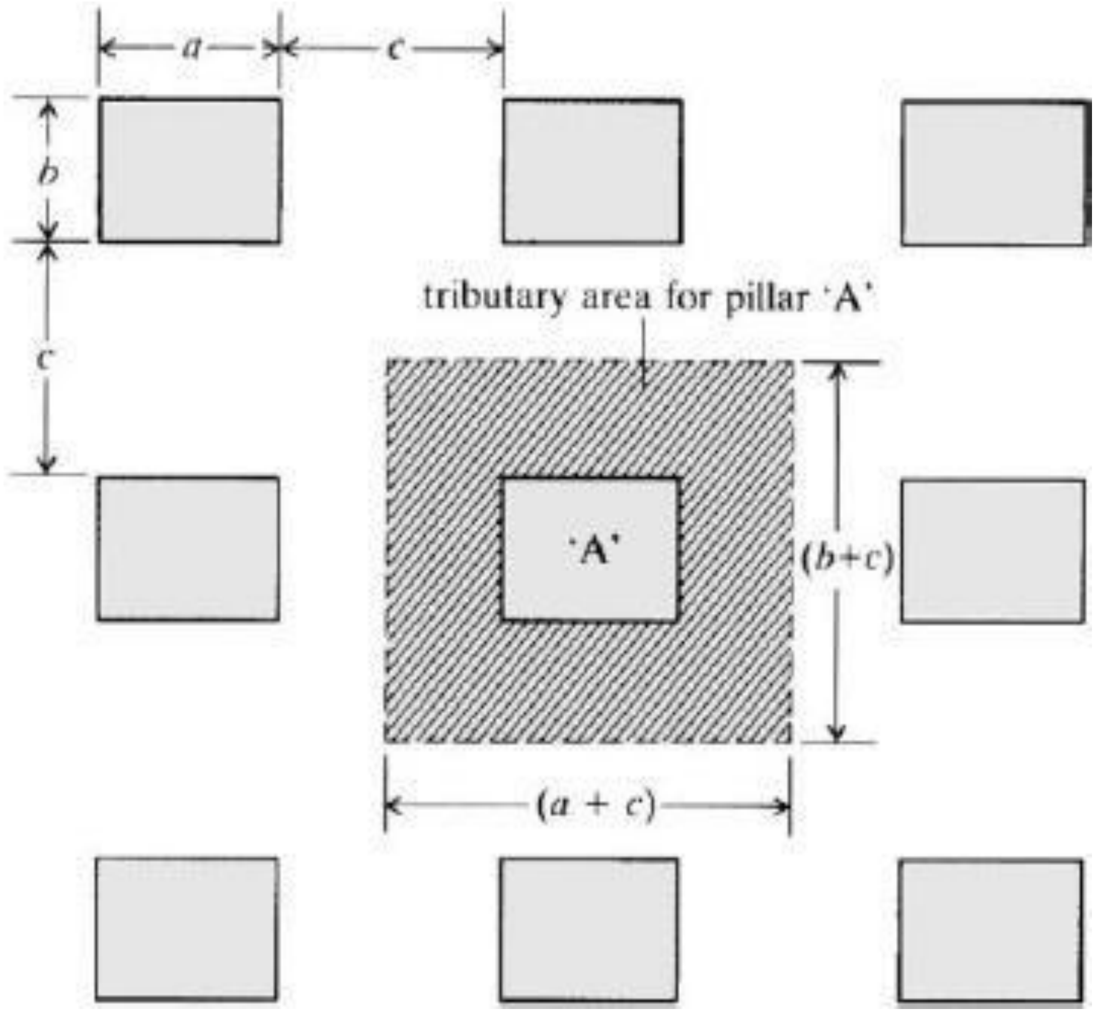
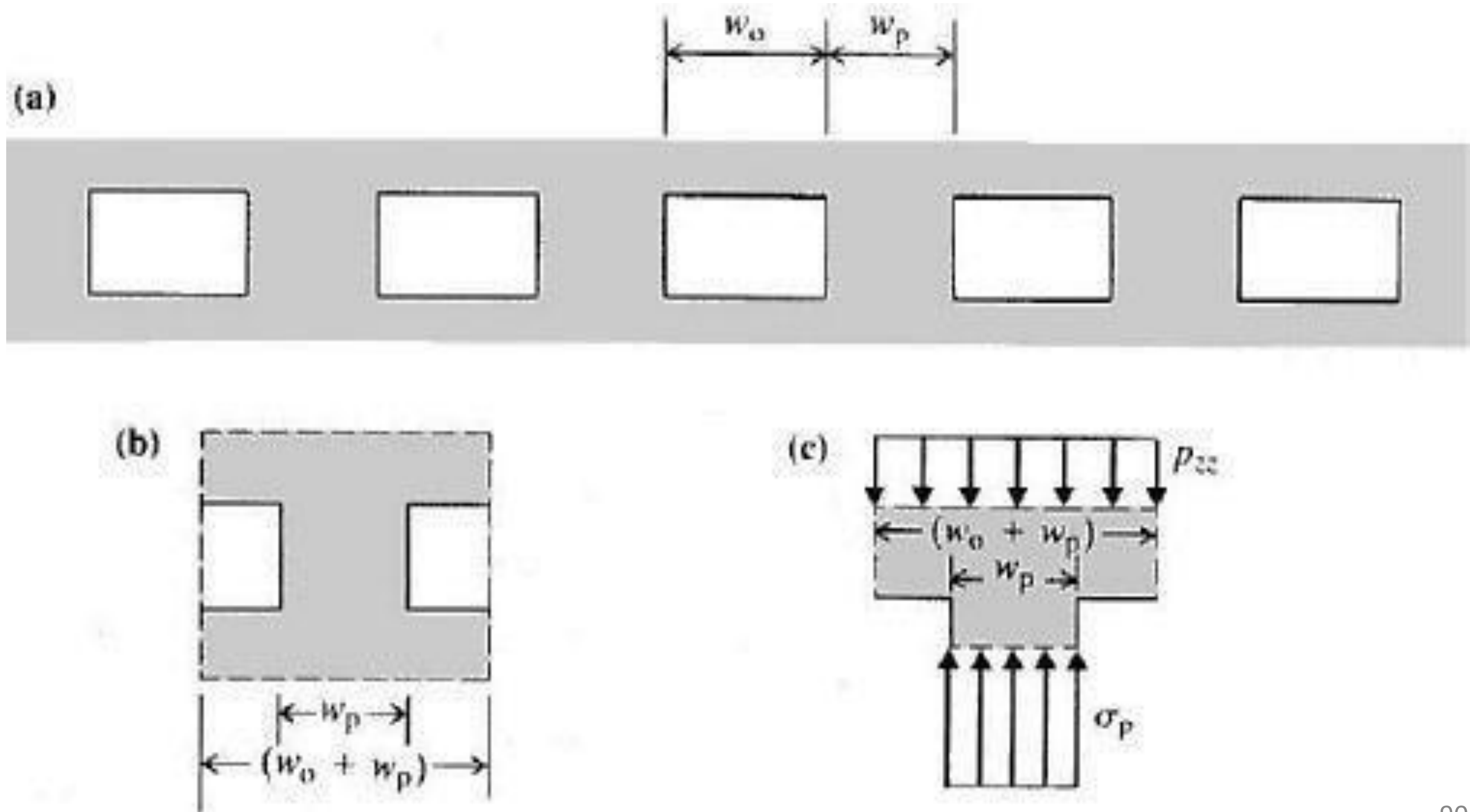

a
c
b
c
tributary area for pillar 'A'
'A'
(b+c)
(a + c)

Figure below shows a cross section through a flat-lying orebody, of uniform thick-ness, being mined using long rooms and rib pillars. Room spans and pillar spans are W_o and W_p respectively.



On considering equilibrium,

( )

Or

( )

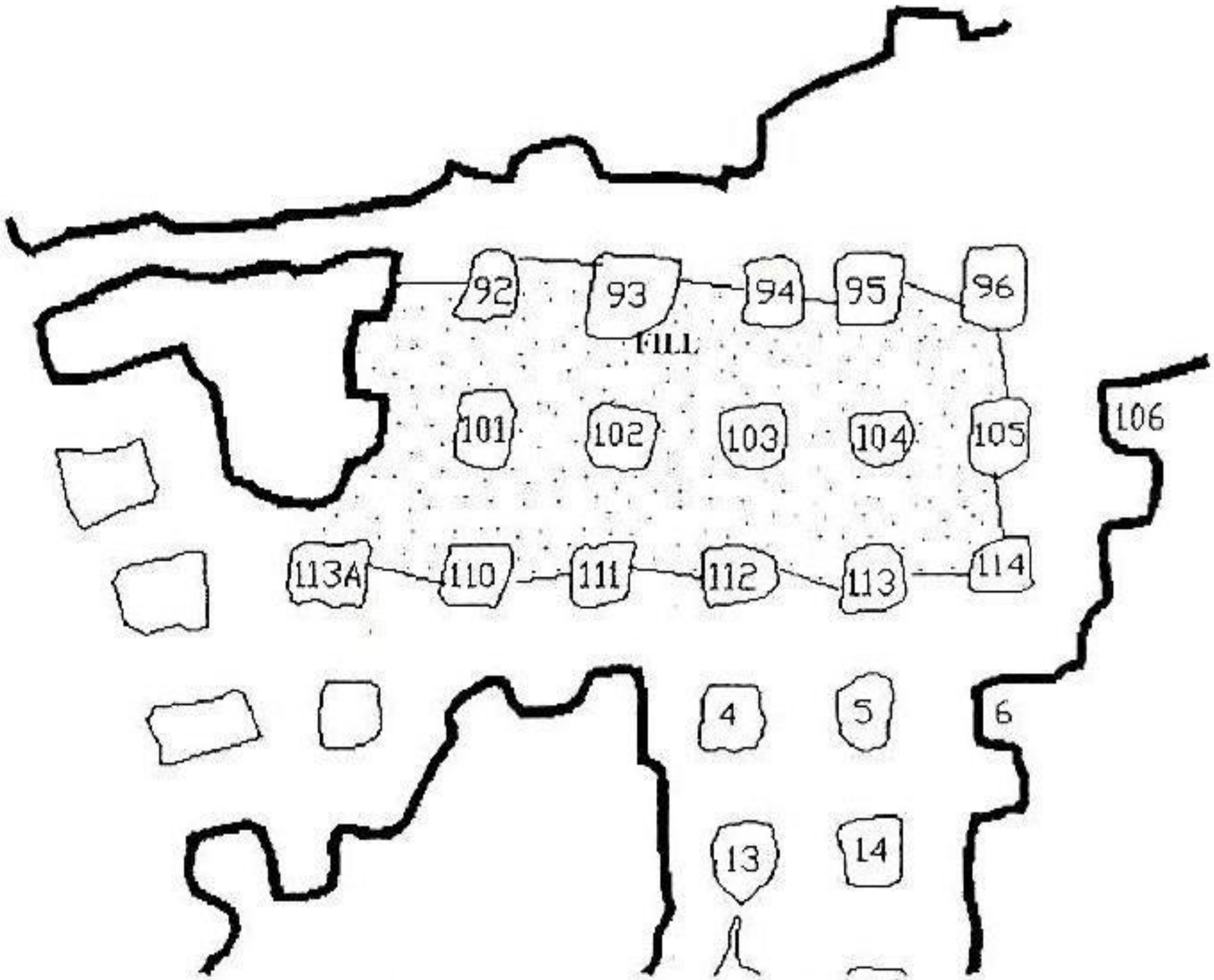
- The average axial pillar stress and is the vertical normal component of the pre-mining stress field.
- The width (of the representative free body of the pillar structure is often described as the area which is tributary to the representative pillar.

The area extraction ratio, R, defined as the ratio of area mined to total area of ore body. The area extraction ration is also defined by

So that

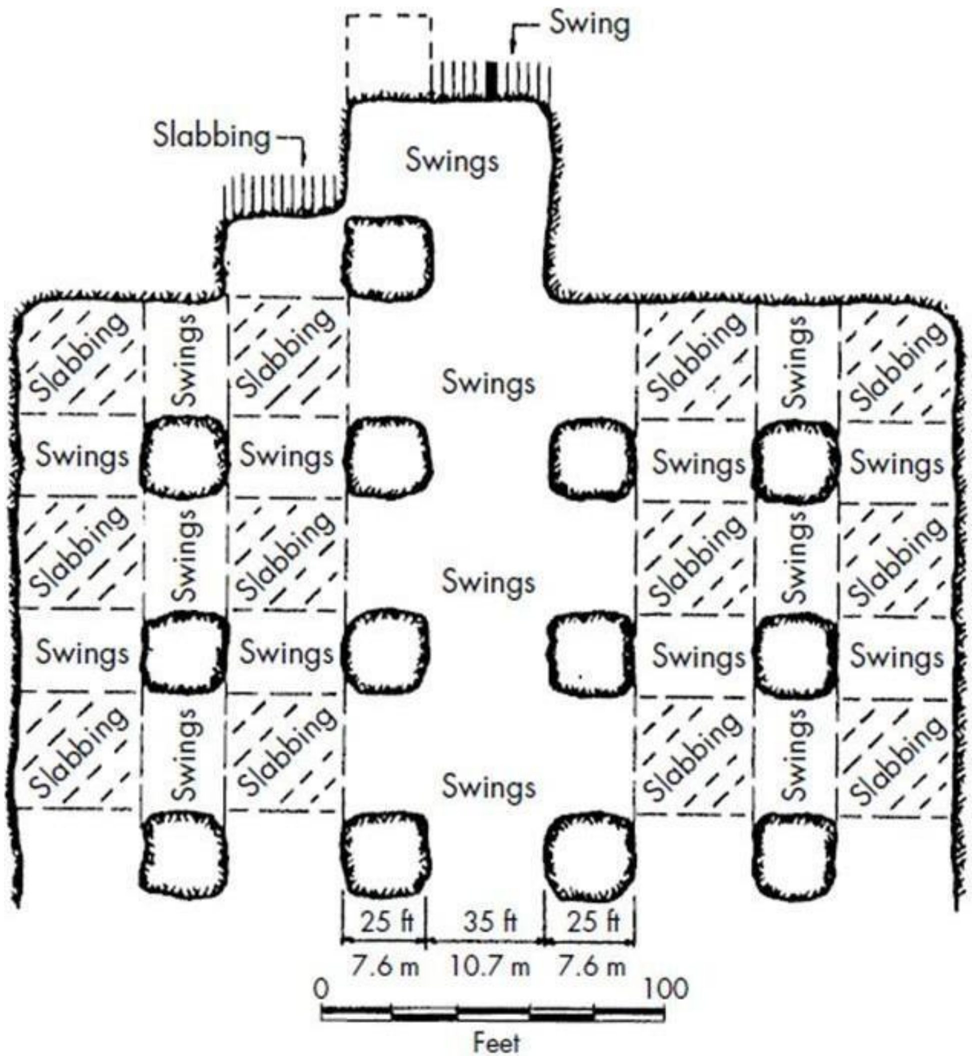
Insertion of this expression in the above equation, yields:

For a square pillar, of plan dimension W_px W_p, are separated by rooms of dimension W_o, the equation is



Plan view of Room-and-pillar stope

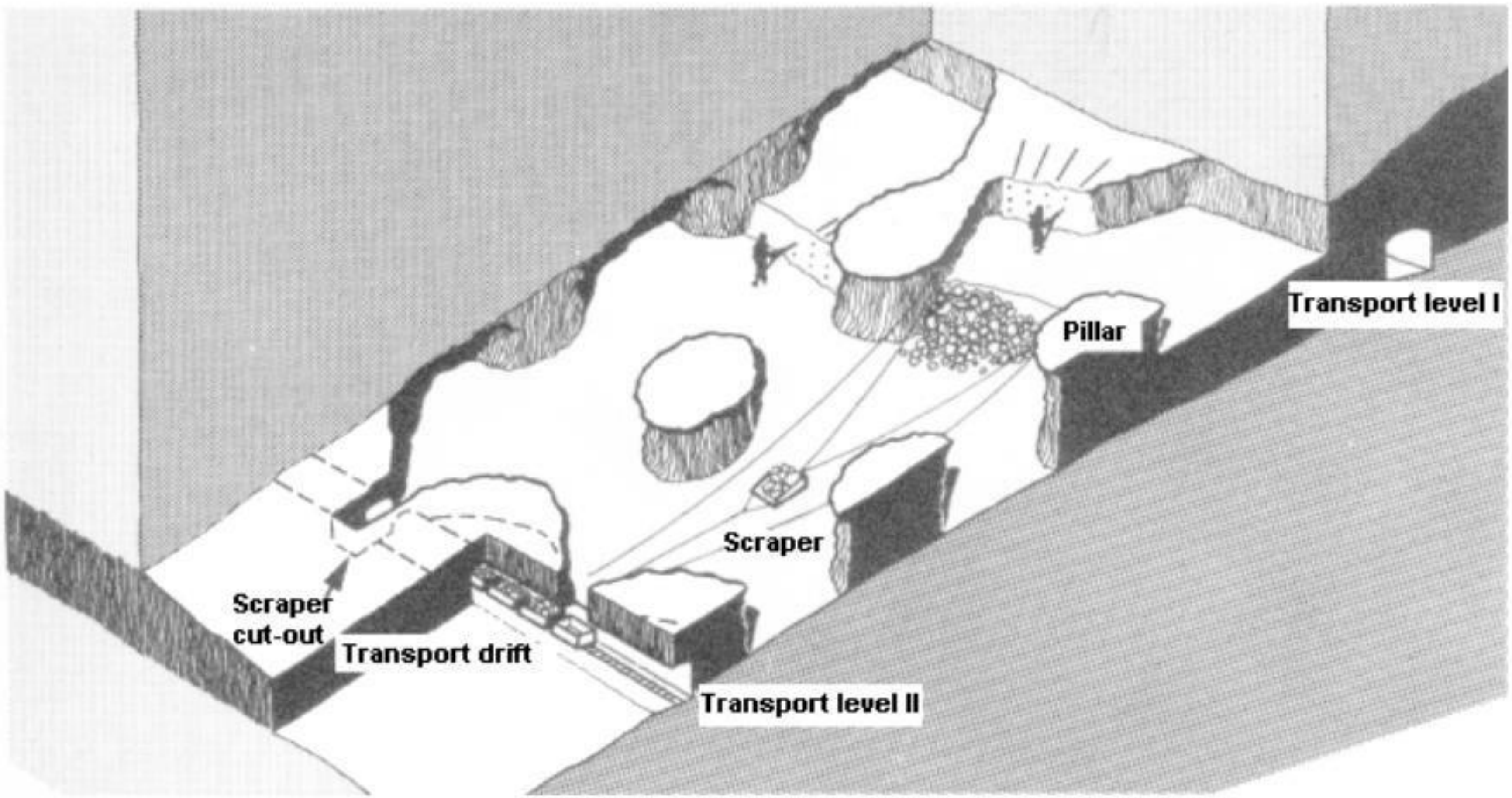
Drilling and blasting in Room-and-pillar stoping



The initial advance in room and pillar mining uses a cut pattern when there is only one free face open. The burn cut is the most common drilling pattern in metal mines(drives). The next type of blasting used in room and pillar is known as slabbing. This type of round is used once a free face has been established so that there is a group of drill holes parallel to an open face. This free face allows the fragmentation of the rock to be the same as a swing with less explosives which leads to lower costs.

Jumbo Drill machine

Inclined Room and Pillar



Room and Pillar

Room and Pillar

Room and Pillar Features

- Summary of Applications
  - relatively flat orebodies
  - limited thickness
  - competent hanging wall and ore
- Advantages ...
  - good productivity
  - moderate cost
  - flexible method, amenable to mechanization
  - Selective
  - minimal early development
  - No backfill required
- Disadvantages ...
  - possible ground control problems
  - Medium to low recovery, ore lost in pillars

2. Sub-level Open Stoping method - SLOS

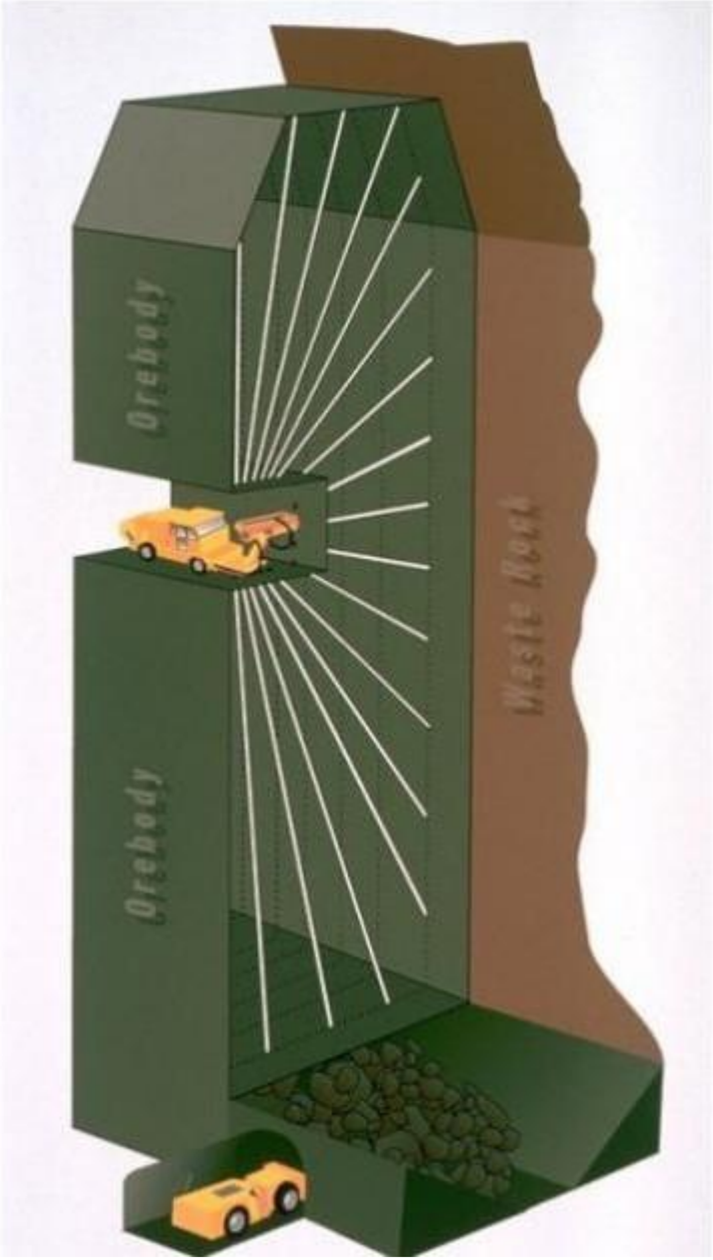
Sublevel Stoping Methods

- Sublevel stoping is also known as "blasthole stoping" or "longhole stoping".
- vertical or steeply dipping ore bodies with regular boundaries
- mined from levels at predetermined vertical intervals
- drilling/blasting from sublevels (overcut or undercut), mucking from undercut
- ore pillars between stopes for support, may be recovered later
- The orebody is divided into sections up to 100 m high and further divided laterally into alternating stopes and pillars. A main haulage drive is created in the footwall at the bottom, with cut-outs for draw-points connected to the stopes.
- Long hole blasthole and stoping uses longer and larger diameter blastholes than sublevel stoping, thus requiring less drilling than sublevel stoping. Greater drilling accuracy is required

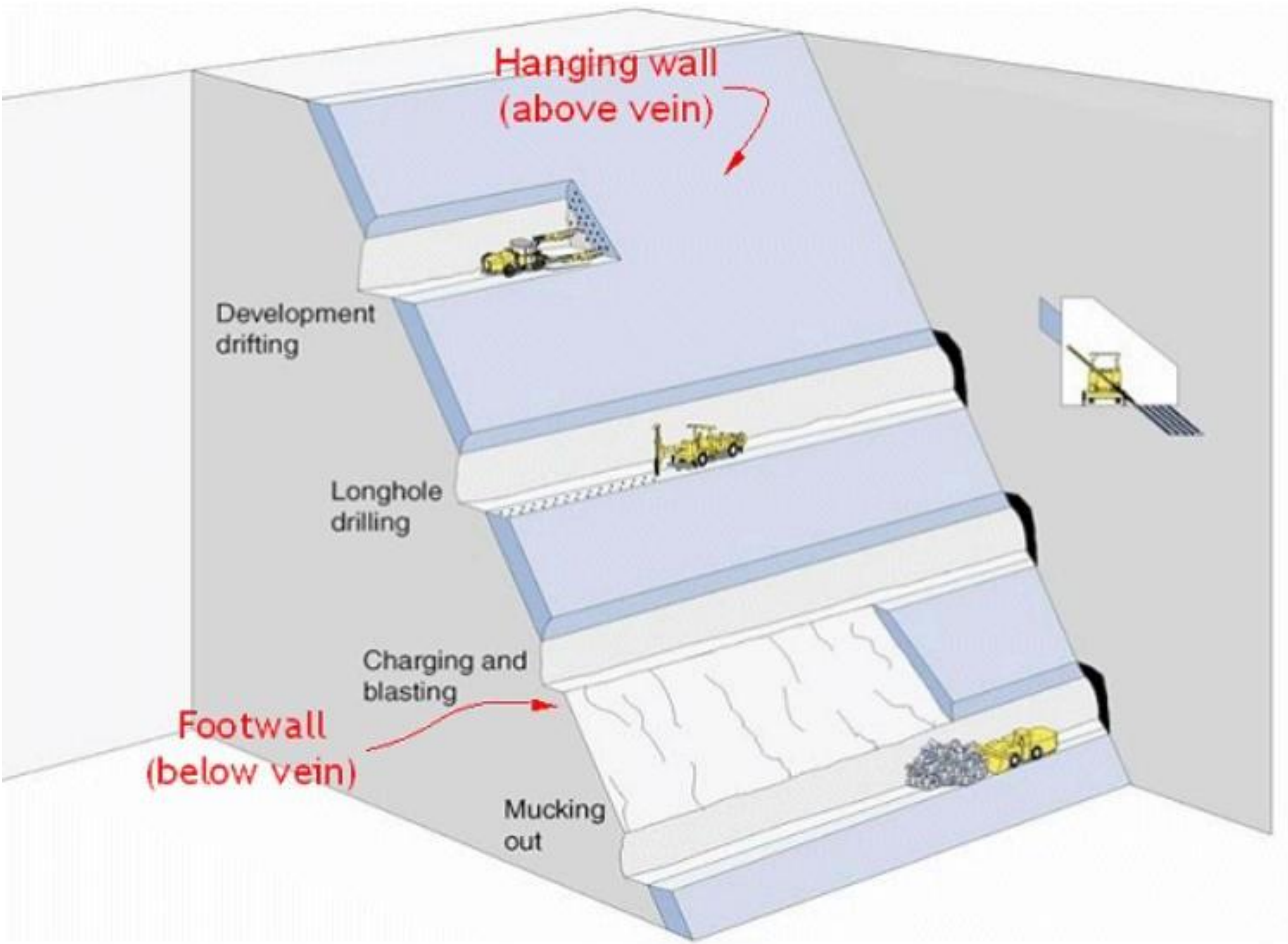
Sublevel Stoping Methods

- minimum orebody width 2m
- tabular or massive shape
- Can be mined transverse or longitudinal
- dip >50°
- large stopes (non-entry)
- limited selectivity, orebody should be regular
- No Backfill
  - pillar size considerations similar to room and pillar
  - competent footwall, ore zone and hanging wall
  - dilution a potential problem
- With Backfill
  - pillar size must be suitable for recovery
  - stress on pillars should be low
  - fill material must allow recovery of pillars with minimum dilution

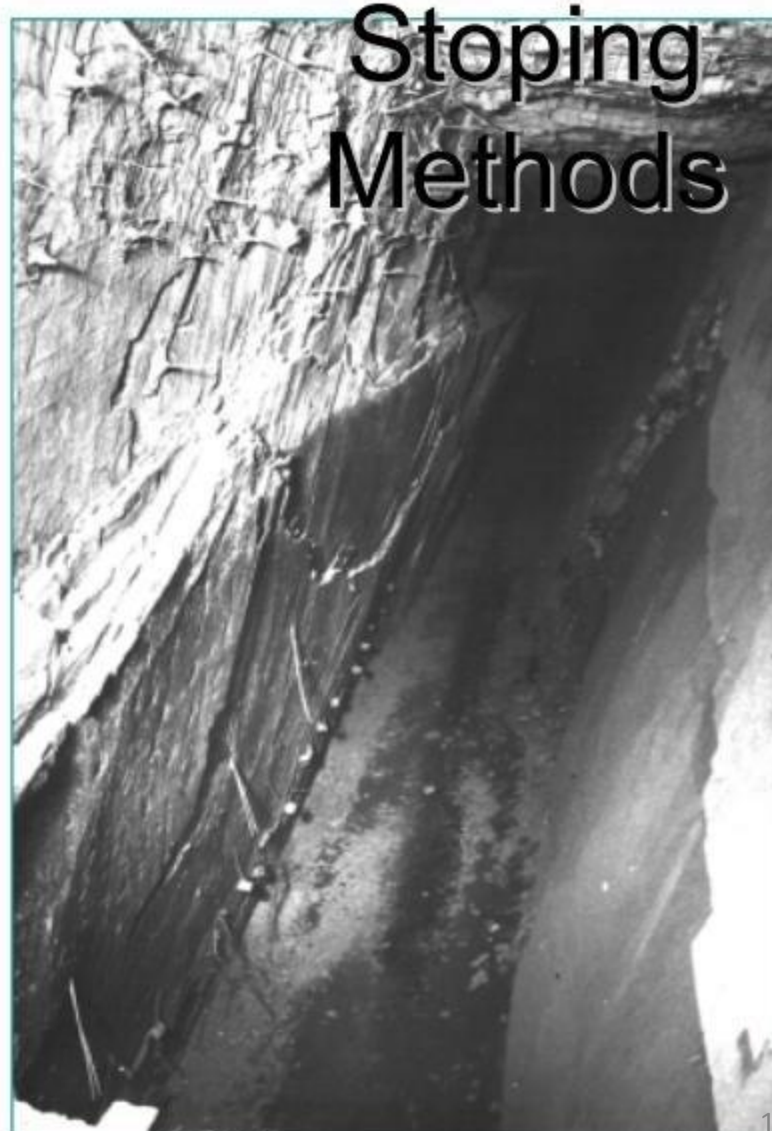
Sublevel Stoping Methods

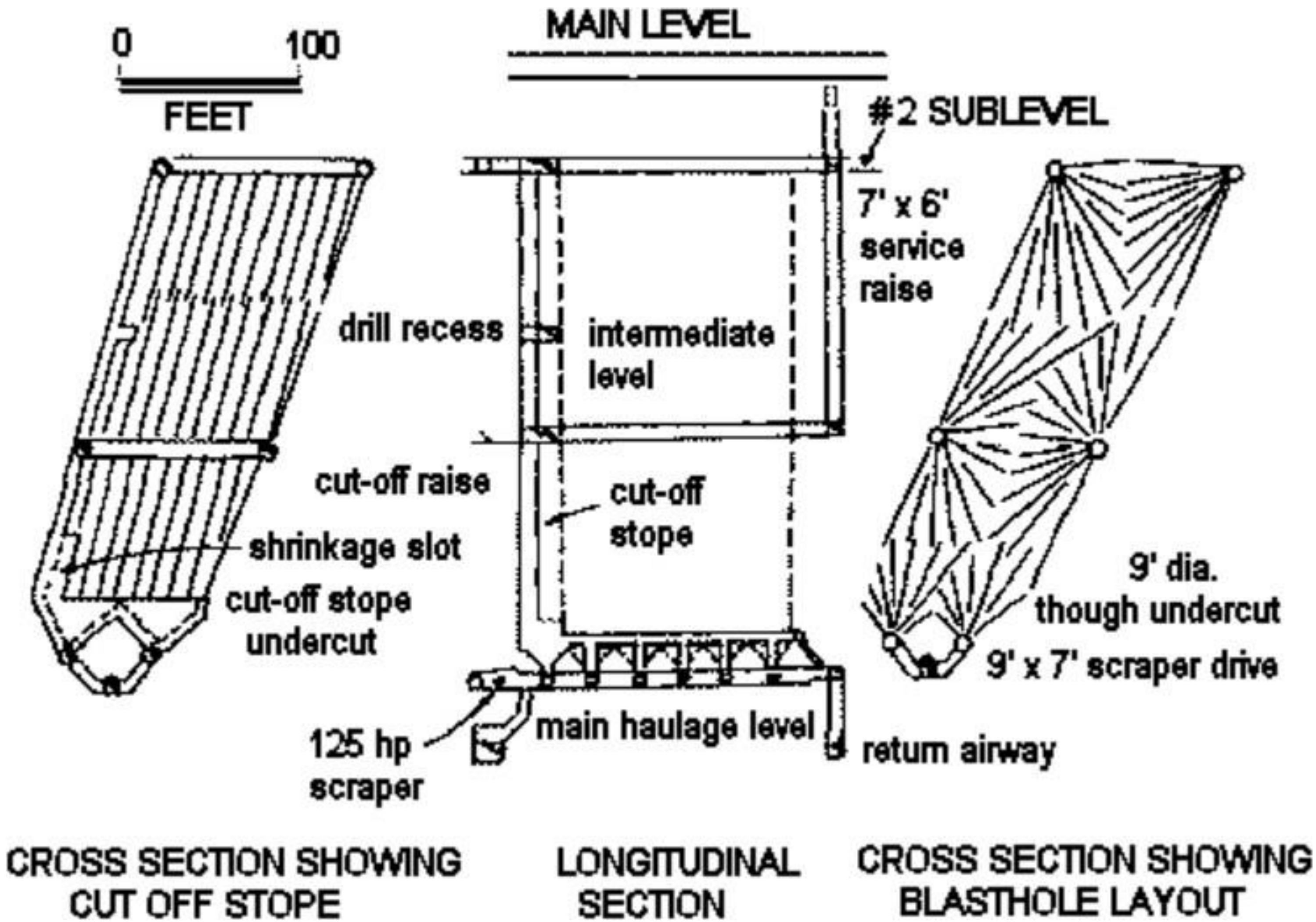


Sublevel Stoping Methods

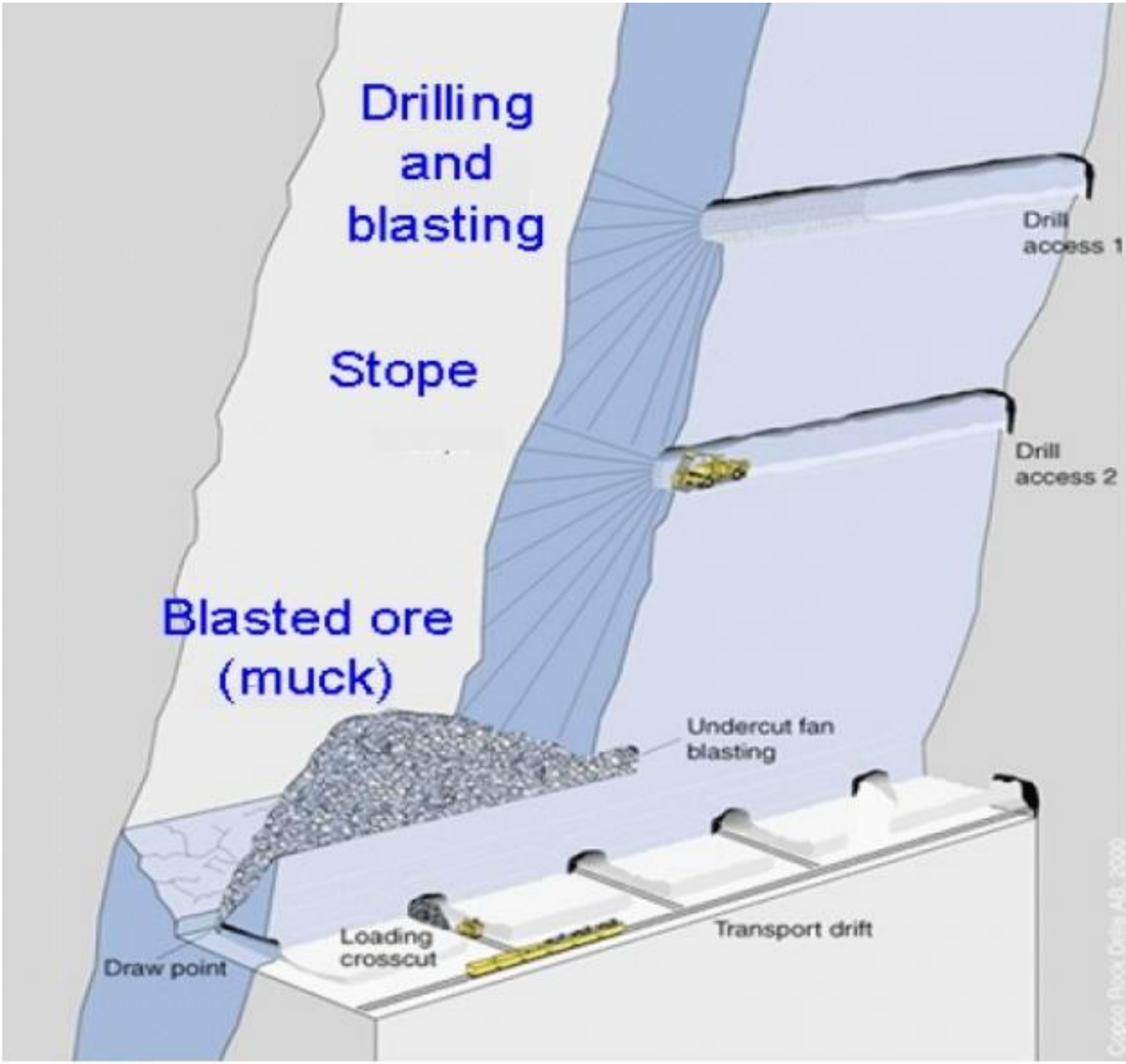


Sublevel Stoping Methods

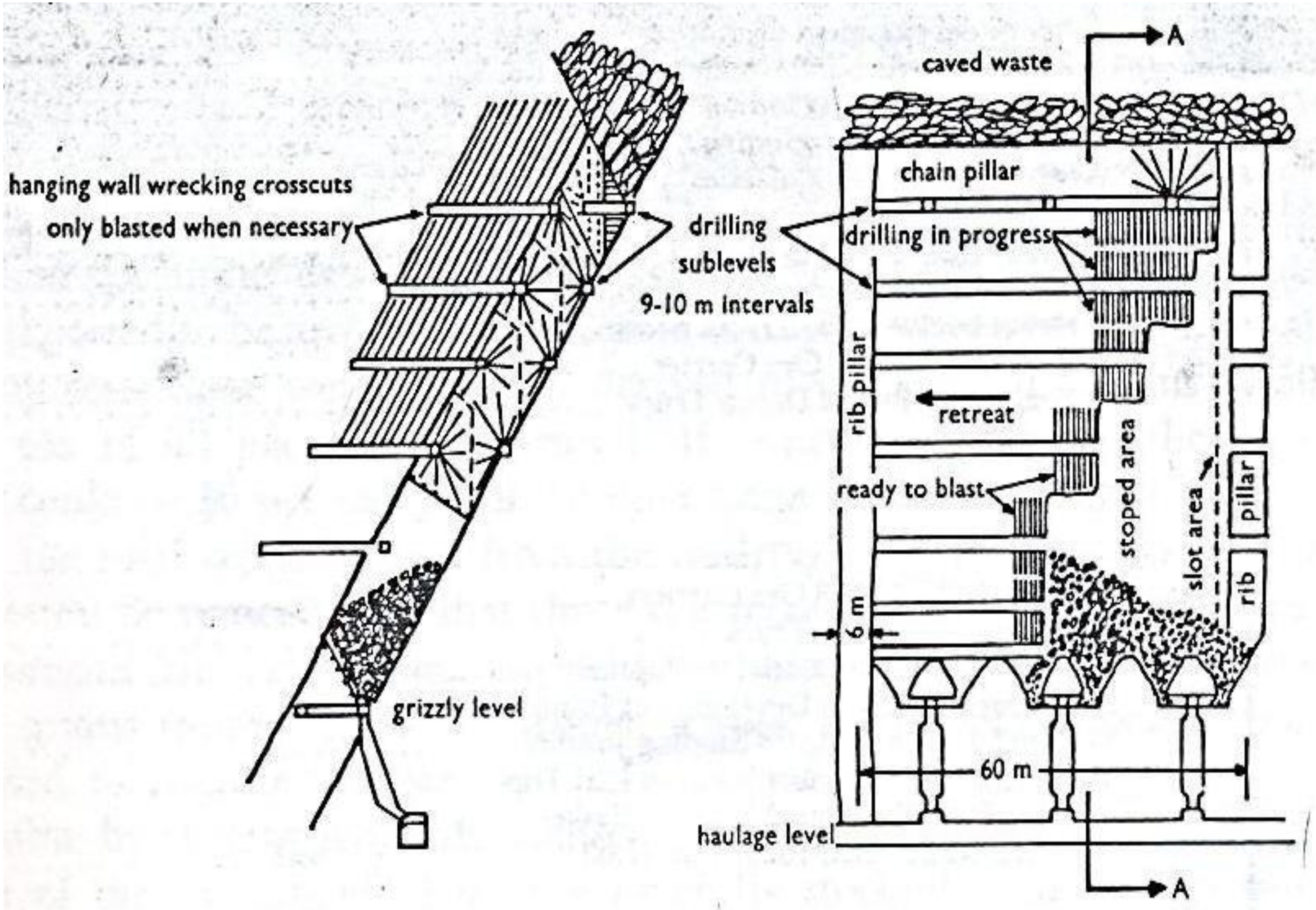




Drilling and Blasting in Sub-level Stoping method

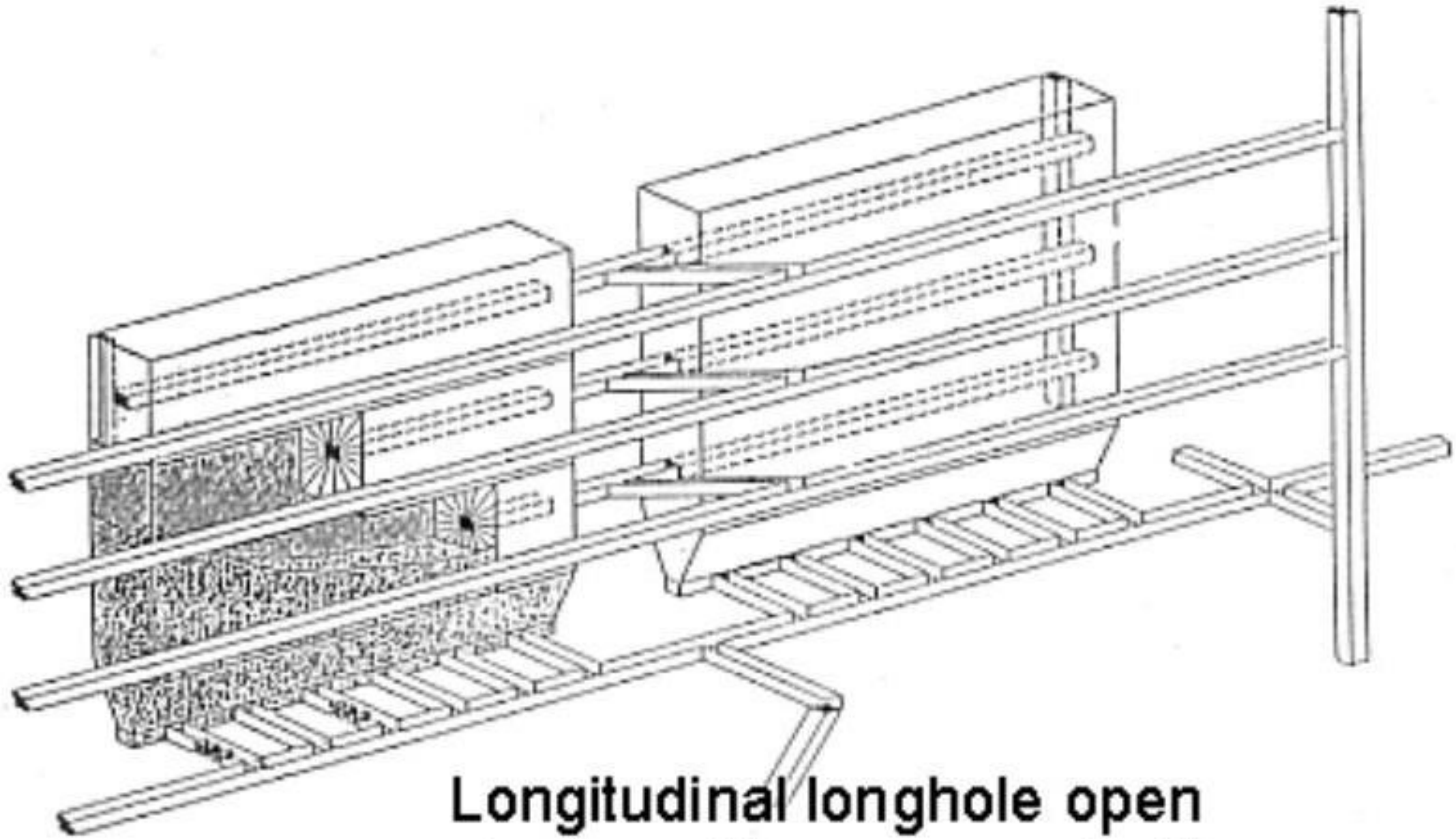


Sublevel stoping



Transverse and longitudinal sections of sub-level stoping method

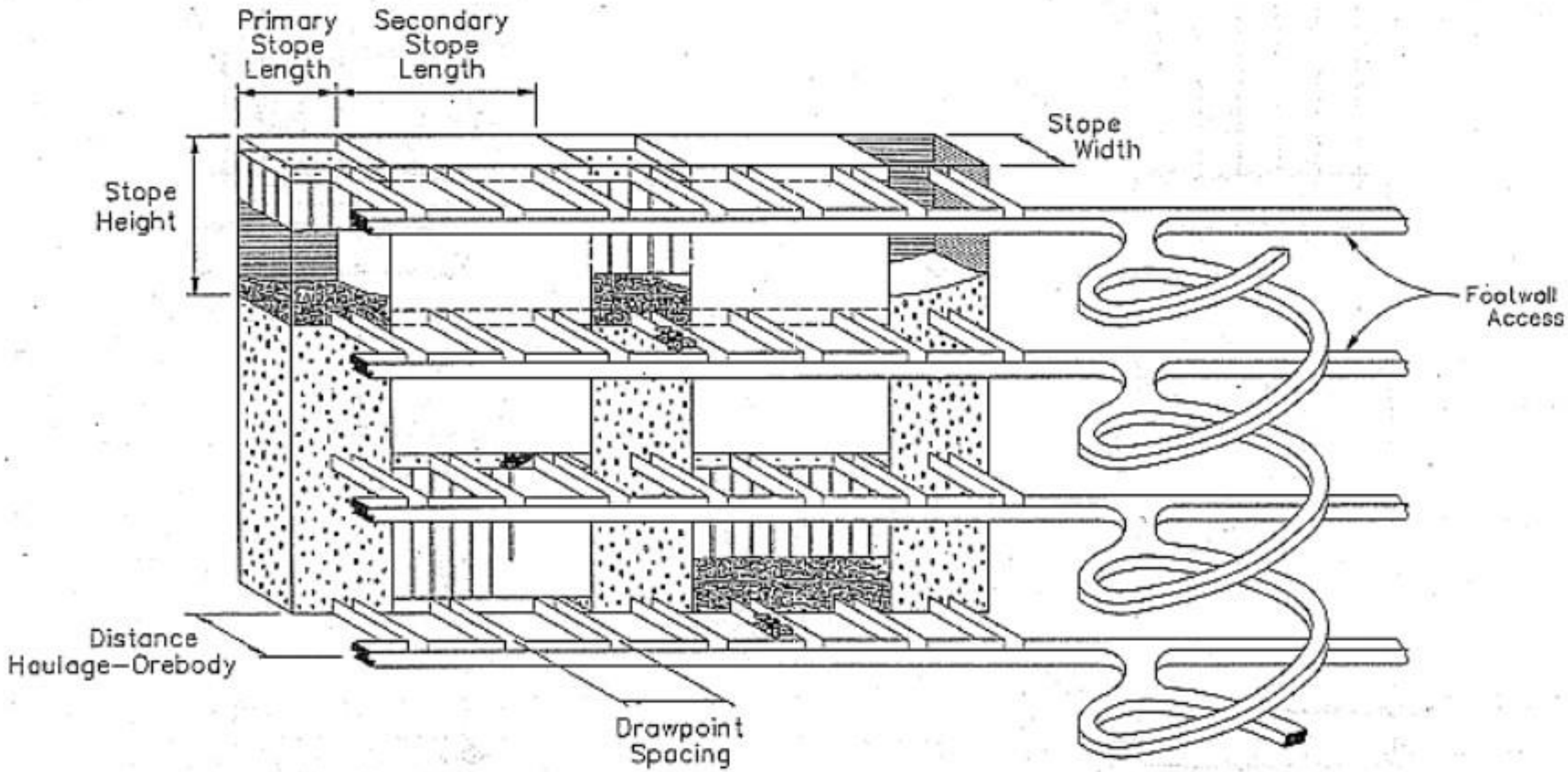
Sublevel Stoping Methods



Longitudinal longhole open stoping with permanent pillars (Potvin et al, 1989)

Sublevel Stoping Methods

SLOS Primary/Secondary with Transverse Drilling and Extraction

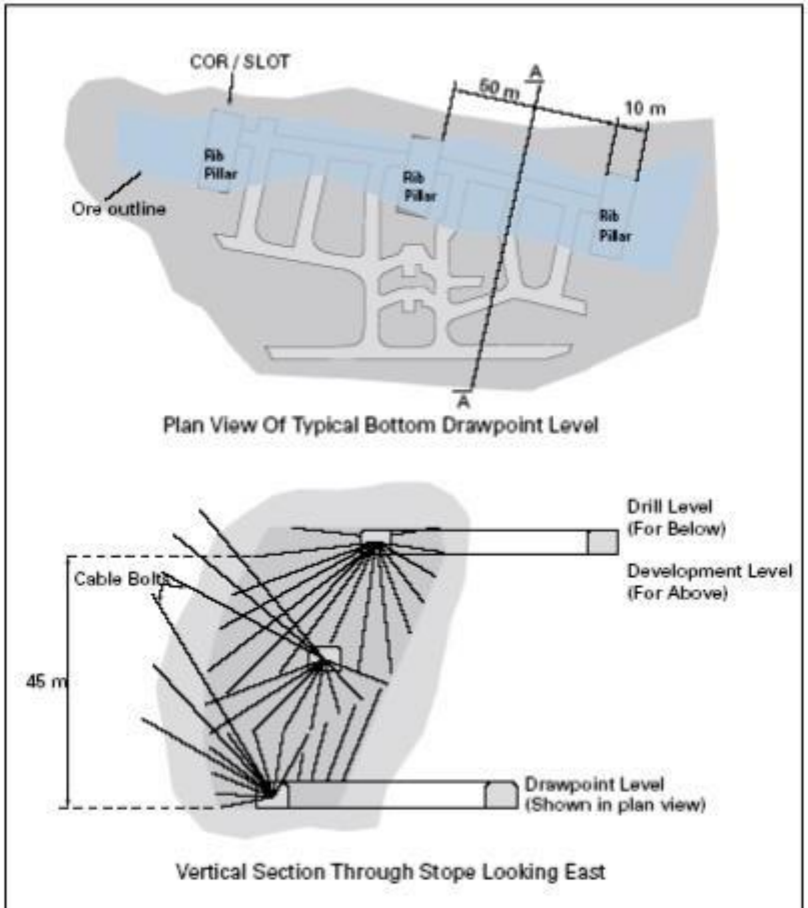


Development for open stope mining (Potvin et al, 1989)

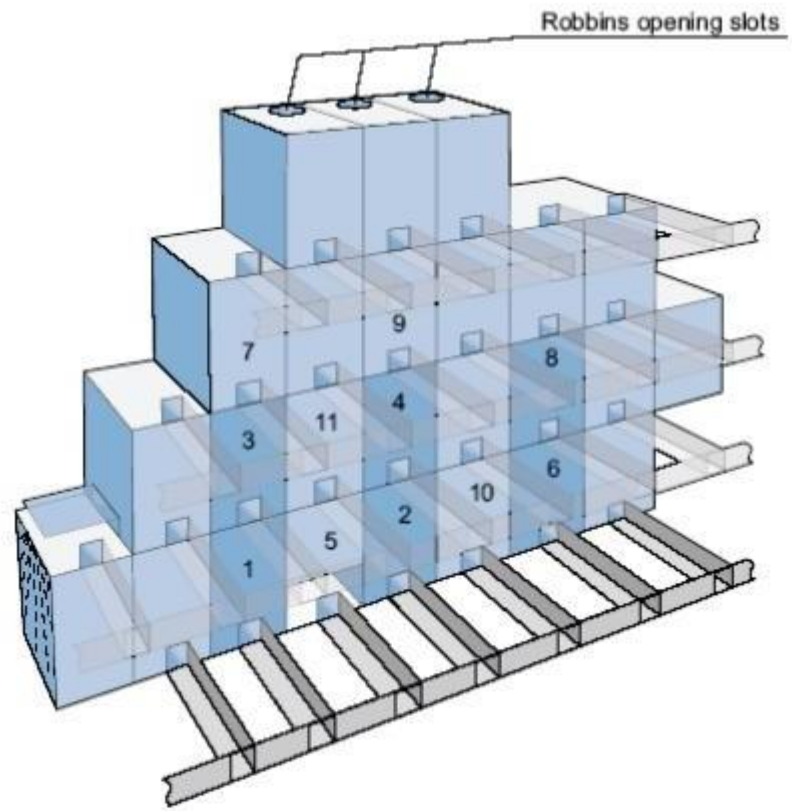
Sub-level Stope

Sublevel Stoping Methods

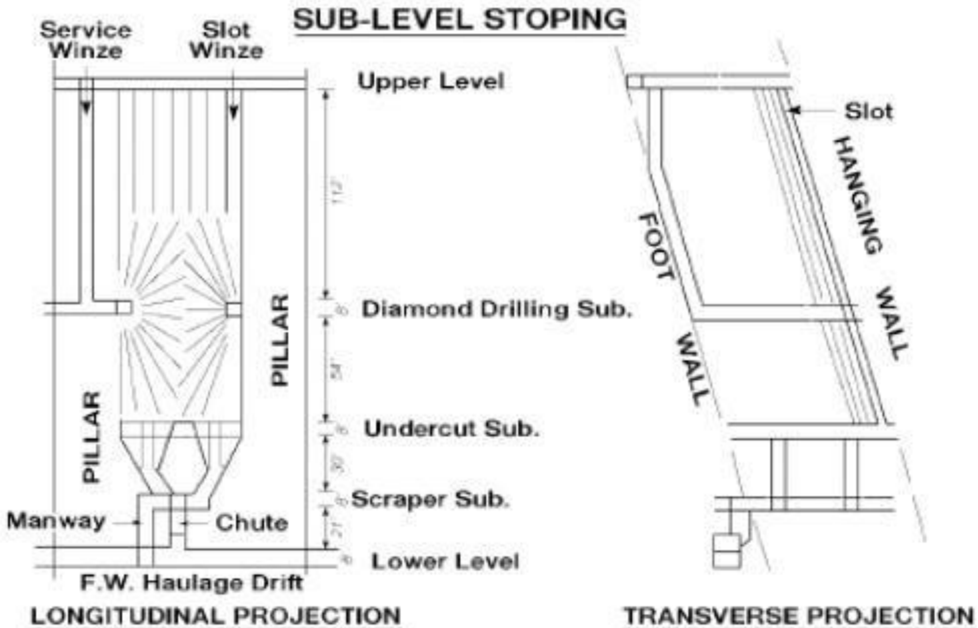
Stope drilling and cable bolting.

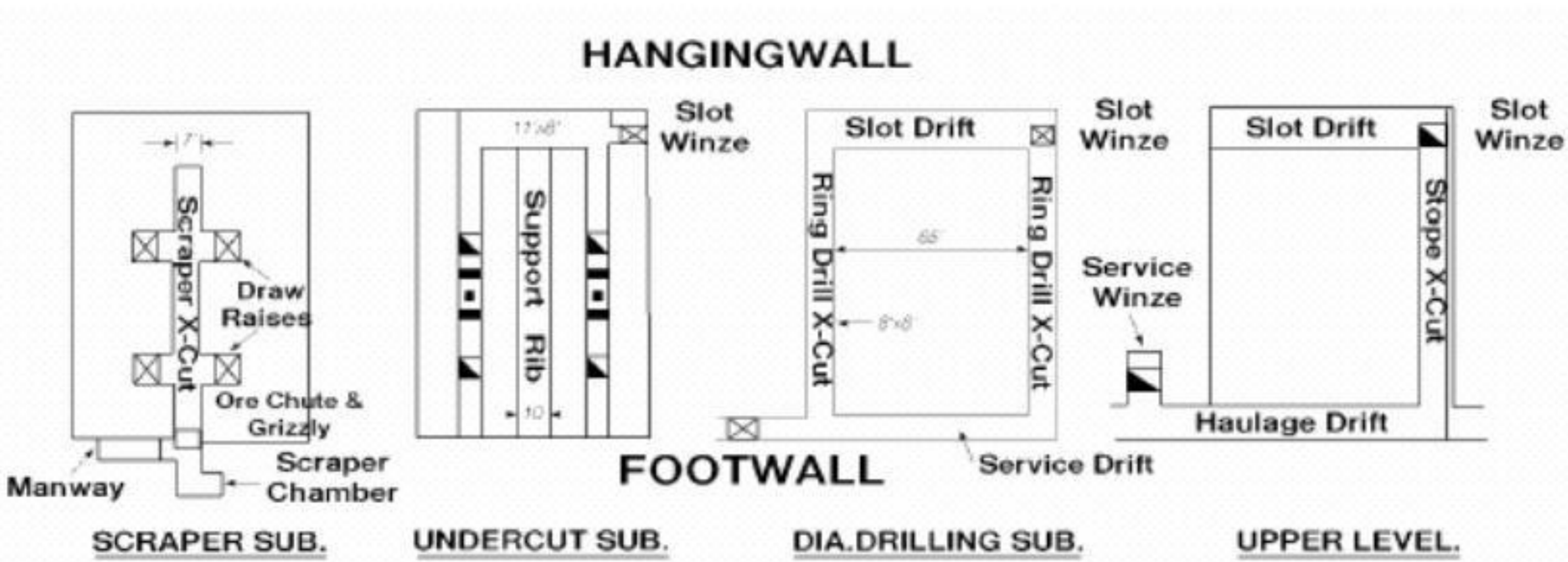


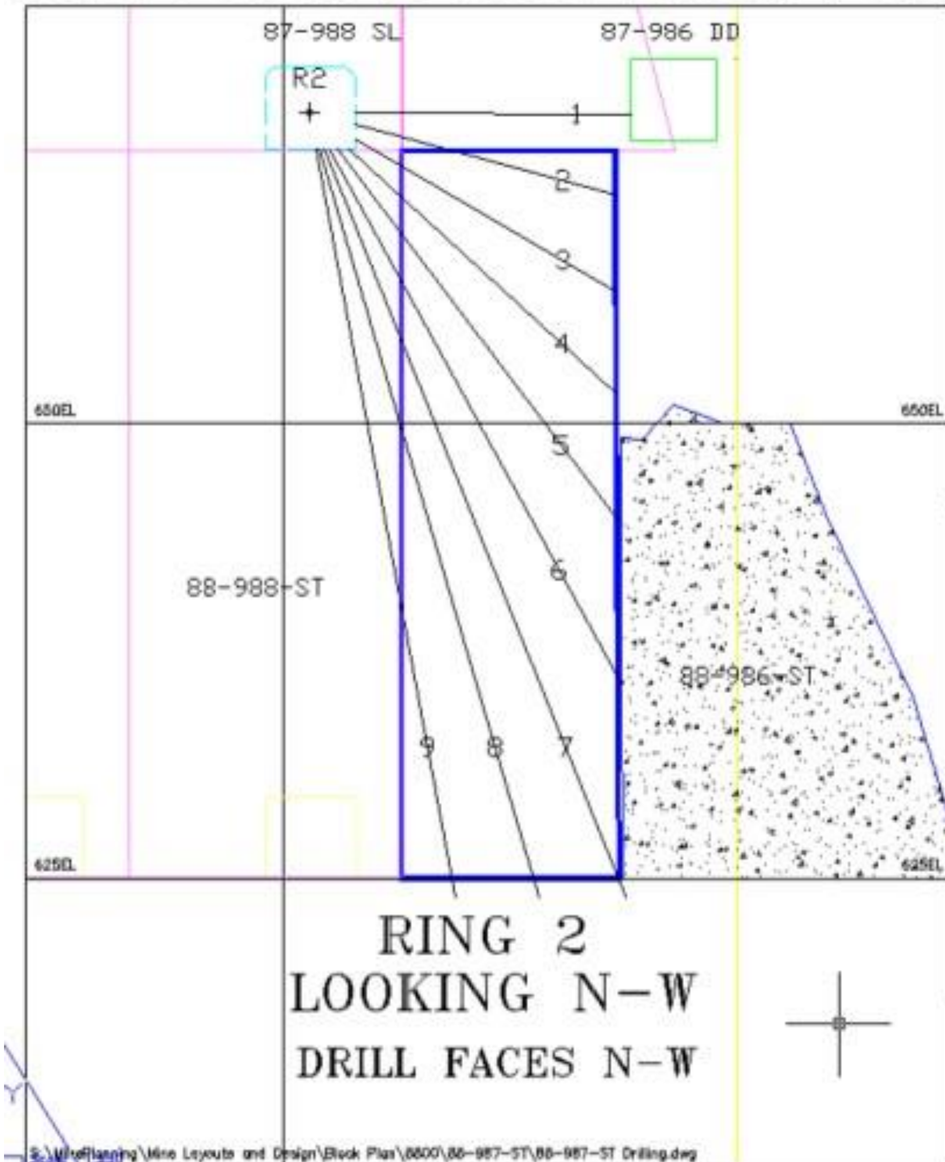
Schematic of stoping sequence.



Sublevel Stoping Methods







SOLO-114mm				DRILLING			LOADING			COMMENTS
SET UP	HOLE ID	DUMP	DIP	m	FT	Actual	From (m)	To (m)	CAP	
R2	1	0°	0°	15.2	50					Guard BT 87-986 DD
R2	2	0°	15°	14.8	49					
R2	3	0°	30°	16.6	54					
R2	4	0°	42°	20.0	65					Poss BT in Paste
R2	5	0°	53°	25.6	84					BT in Paste
R2	6	0°	61°	33.2	109					BT in Paste
R2	7	0°	68°	44.3	145					BT in Paste
R2	8	0°	74°	42.8	140					
R2	9	0°	79°	41.8	137					
			TOTAL	254.2	834					

ITH-114mm				DRILLING			LOADING			COMMENTS
SET UP	HOLE ID	DUMP	DIP	m	FT	Actual	From (m)	To (m)	CAP	
R2	1	-90°	0°NE	15.2	50					Guard BT 87-986 DD
R2	2	-90°	-15°NE	14.8	49					
R2	3	-90°	-30°NE	16.6	54					
R2	4	-90°	-42°NE	20.0	65					Poss BT in Paste
R2	5	-90°	-53°NE	25.6	84					BT in Paste
R2	6	-90°	-61°NE	33.2	109					BT in Paste
R2	7	-90°	-68°NE	44.3	145					BT in Paste
R2	8	-90°	-74°NE	42.8	140					
R2	9	-90°	-79°NE	41.8	137					
			TOTAL	254.2	834					

Dump Angle: 0°   Scale: 1:250

Stope Block: 88-987-ST	SECTION LOOKING: North-West		Tonnes: 4265 / Meters: 254.2
Work Place: 87-988 SL	Level & Sub 87 -0	R-2	T/m: / Density: 3.00 / Burden: 3.0

S:\MinePlanning\Mine Layouts and Design\Block Plan\8800\88-987-ST\88-987-ST Drilling.dwg

Ring Blasting Hook up Plan in Sub-level stoping method

Sublevel Stoping Methods

- Summary of Application…
  - method became popular after development of large diesel LHD's in the last 40 years
  - efficient in drilling, blasting and loading
  - high utilization of mechanized equipment
  - limited selectivity with irregular orebodies
- Advantages
  - good productivity
  - moderate cost
  - amenable to mechanization
  - safe operating conditions
  - good recovery; moderate dilution
- Disadvantages…
  - Expensive initial development
  - inflexible / non-selective

The following disadvantages:

- rate of penetration slows down with longer holes due to energy attenuation at a larger number of steel junctions (with the commonly used drifters and prevalent air pressure a maximum hole length of 30 m is desirable)
- hole deviation may become significant
- with a larger sublevel interval the number of holes in a ring increase in order to maintain the required toe burden which results in crowding of the holds at the cellar.
- open space required at the undercut level to accommodate the swell of blasted ore increases with increased sublevel spacing.
- Length of stope ranges from as small as 20m to as large as 150m depending on ground pressure and rock characteristics. Rib pillars vary from 6 to 10 m length.

SLOS Stoping:

- Stoping starts from a slot at one end of the stope sometimes a slot is made at the centre of the stope, but this is desirable in relatively long stopes which is possible in relatively strong ground. The slot is made by stripping a slot raise from wall to wall by parallel long holes drill from cross-cuts it the ends of the upper sublevels. Rings of long holes are then drilled from the sublevels and blasted into the slot.

- Rings of 45 to 65 holes (52 & 57 mm holes are most prevalent) are usually drilled. Burden on rings is generally kept at 30 times hole diameter while a larger toe spacing 50 times hole diameter is adopted between holes in a ring. This should however, be varied depending on rock structure and strength and fragmentation desired based on experimental stope blasts. Blasting efficiency requires a correct maintenance of the drilling pattern through rigorous control of hole direction and deviation.

- Charging of holes also needs careful planning to ensure efficiency in blasting and good fragmentation. Holes should be charged to different distances from the collar in order to maintain a uniform charge spacing as far as practicable. Charging pattern must be worked out in the planning office and supplied to the face.

SLOS contd.,,,,

- Parallel hole drilling is superior to ring drilling. It ensures lower specific drilling and blasting compared to ring drilling. However, for safety it is desirable to drill the parallel holes from a cross-cut rather than from a bend. With narrow holes this loads to a large burden on holes and hence poor fragmentation in addition to the need for driving narrow cross-cuts at very close intervals. Use of large diameter blast holes however, has made parallel hole drilling a superior proposition. This will be dealt with further under blast-hole stoping.

3. Shrinkage stoping method

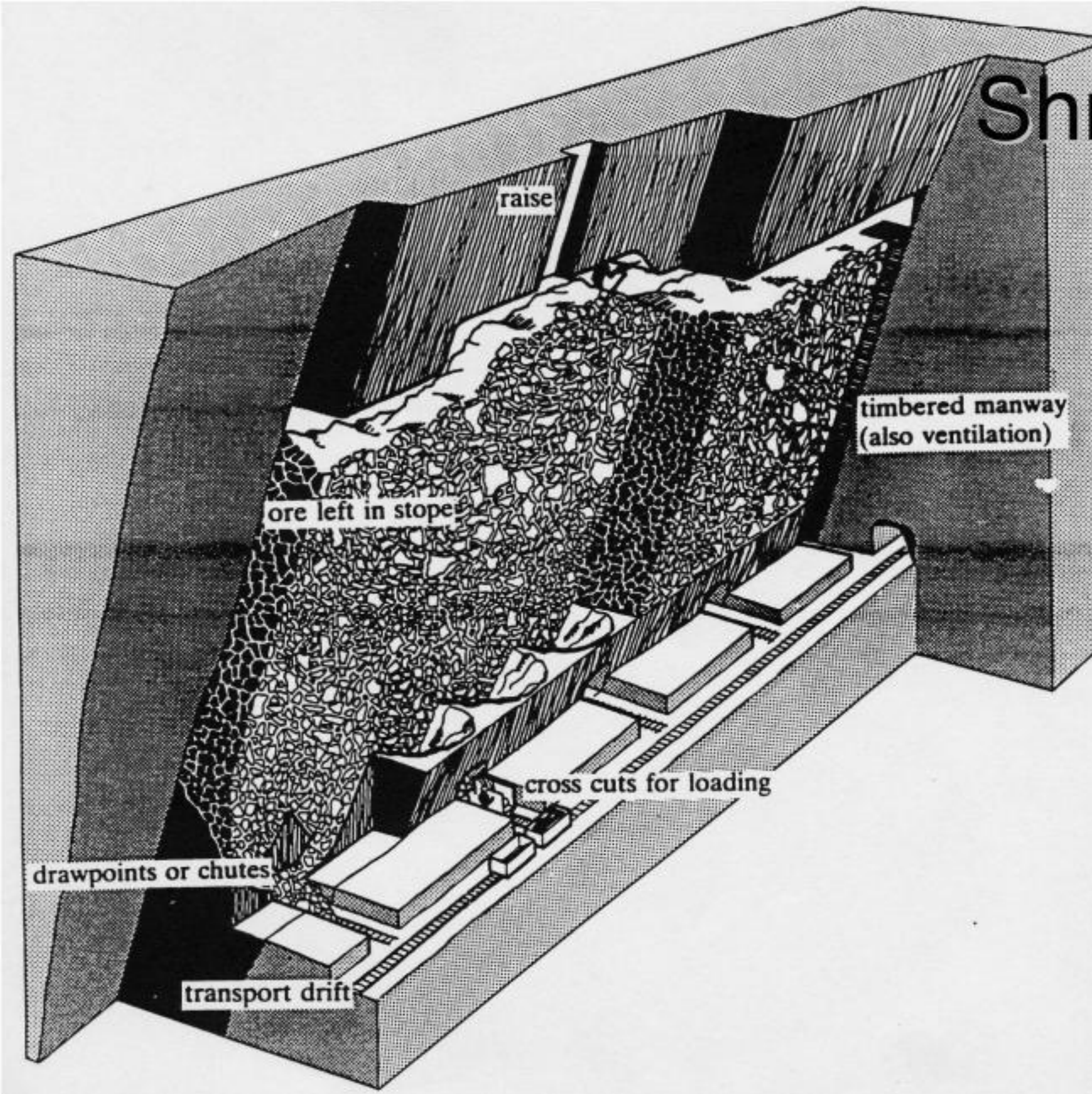
Shrinkage

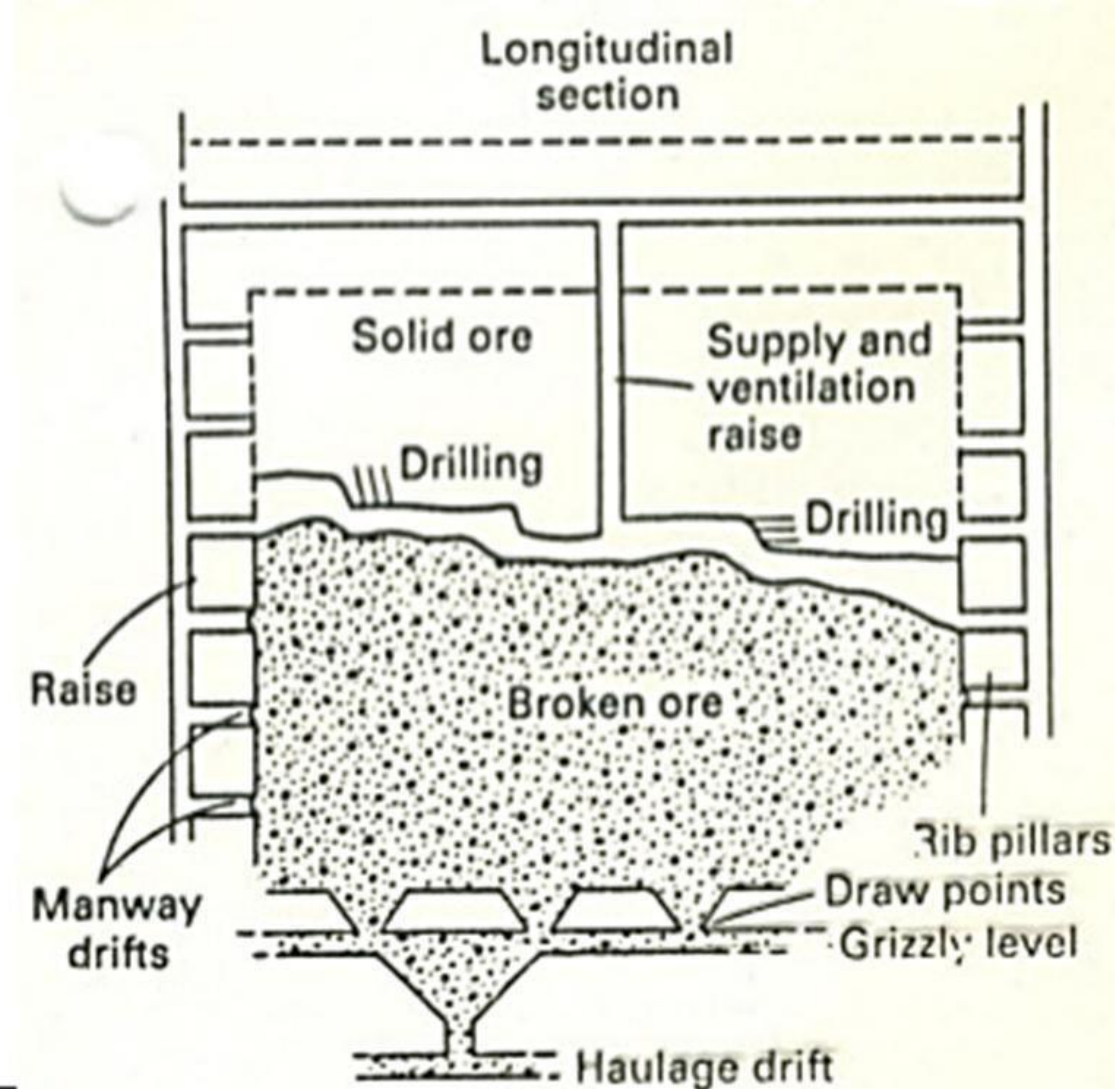
- Ore is broken in horizontal slices working upwards.
- Sufficient ore withdrawn at the bottom after each slice to accommodate swell (30% - 40%)
- Remainder stays in the stope to provide a working platform ... removed at the end.
- Stopes separated by intermediate (recoverable) pillars

Shrinkage

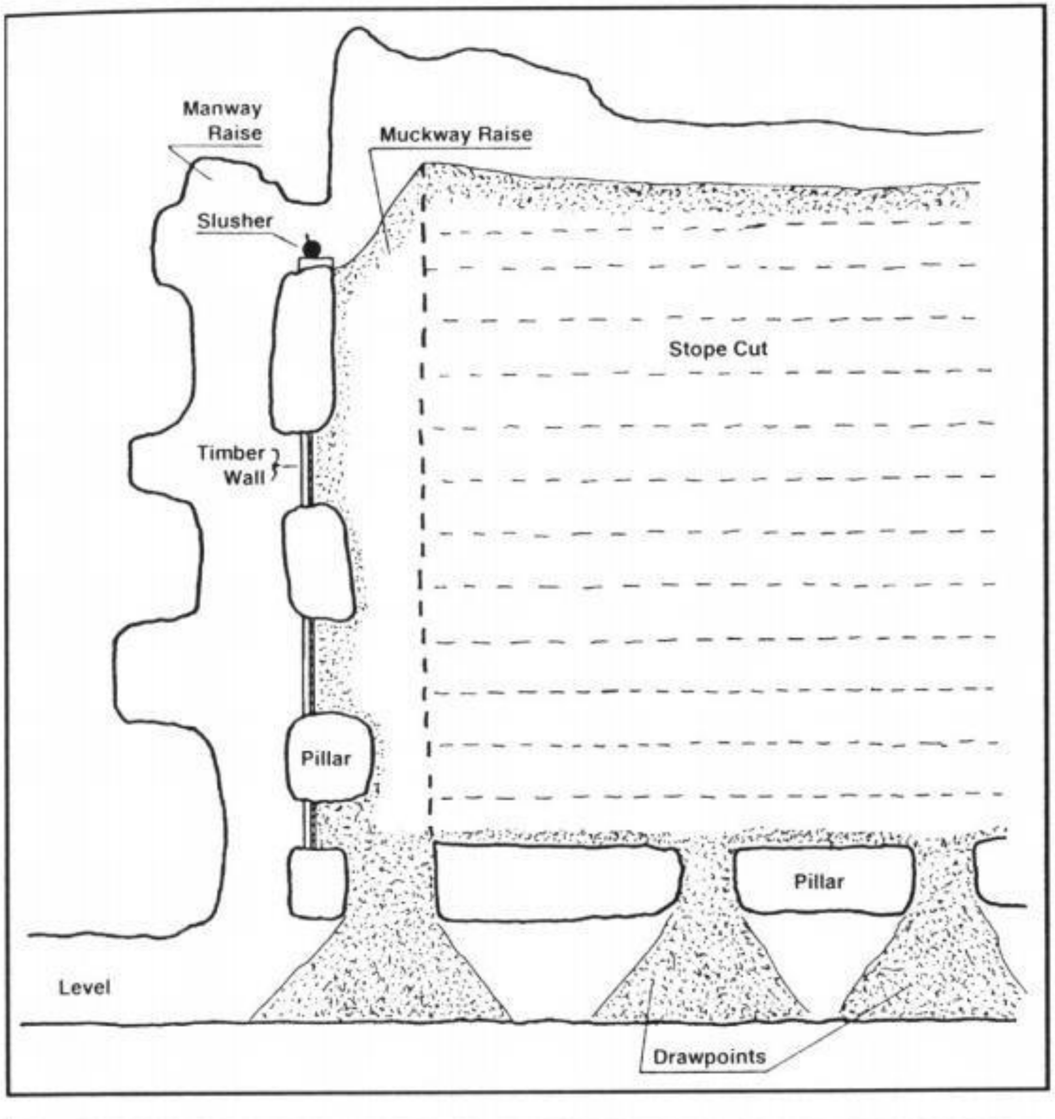
- orebody width 1.2m - 30m
- tabular orebody; regular boundaries
- dip >50°
- stable hanging wall and footwall
- uniform draw down important
- dilution generally low
- Ore must be unaffected by storage in stope
- Labour intensive method, limited scope for mechanization

Shrinkage


raise
timbered manway
(also ventilation)
ore left in stope
cross cuts for loading
drawpoints or chutes
transport drift



Shrinkage stope



Shrinkage stoping

Shrinkage

- Summary of Application…
  - Shrinkage not a common method ... too labour intensive
  - Employed only where mechanization not possible.
  - Maintaining stope full of muck increases possible stope spans and minimizes dilution .. support and development costs reduced.
  - Limited production capacity and bulk of ore tied up for a long time.

- Advantages…
  - moderate production rate.
  - draw down by gravity
  - conceptually simple (small mine usage)
  - low capital investment
  - minimal support in stope
  - moderate development
  - good recovery, low dilution

- Disadvantages…
  - low productivity
  - moderate to high mining cost.
  - labor-intensive
  - dangerous working conditions
  - ore tied up in stope
  - ore subject to oxidation, packing in stope

4. Cut-and-Fill Stoping

Cut-and-Fill stoping

- In this method the ore is excavated in horizontal slices starting from the bottom of the stope and advancing upwards. The broken ore is loaded and completely removed from the stope. When ore slice of the ore has been excavated the corresponding volume is filled with waste material. The filling is conducted integrally with the mining cycle and not after the completion of the entire mining operation

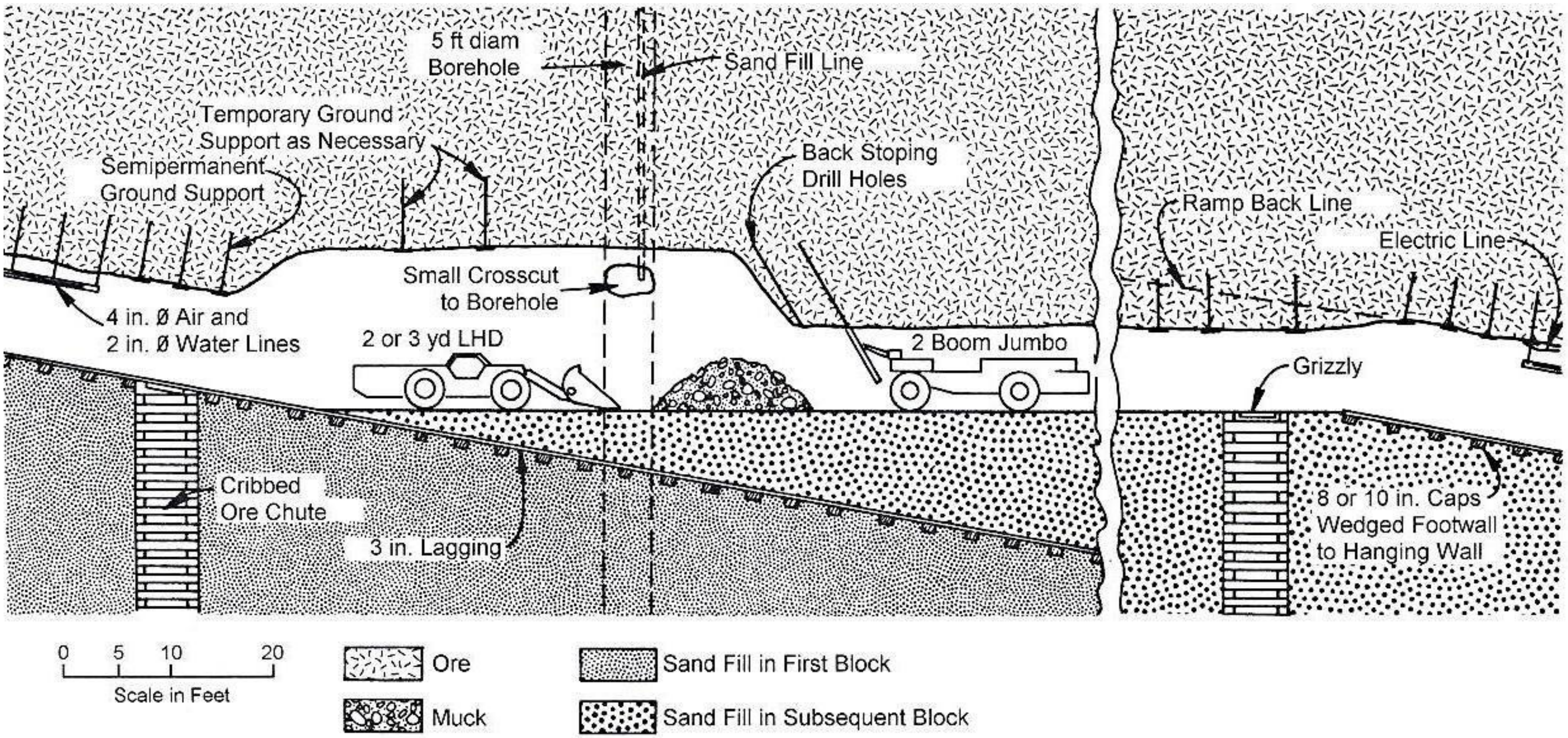


Fig Cut-and-Fill stoping operation

Cut and Fill

- Summary of application
  - **orebody width 2m - 30m**
  - **tabular shape ... good for irregular orebodies**
  - **orebody dip 35^{o} - 90^{o}**
  - **good for low strength / high stress regions**
  - **requires safe, stable back for man entry**
  - **Expensive, generally high grade ore required for this method to be economic**
- **Selective mining and minimum dilution**

Application :

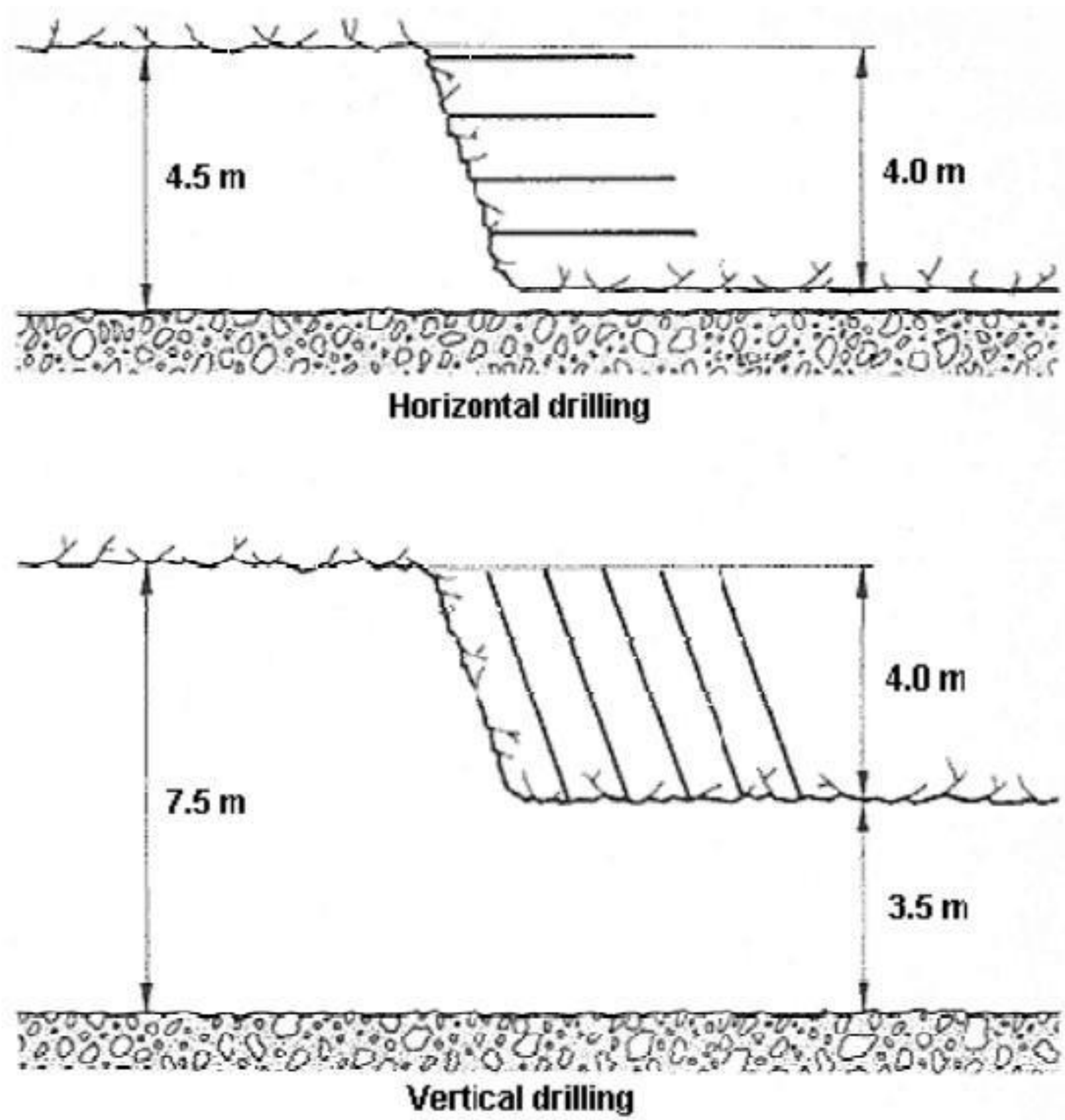
This method can be used with steeply dipping ore bodies with reasonably firm ore. The condition can be stated as:

- Ore strength : moderate to strong, maybe less competent than with un-supported method.
- Rock Strength : Weak
- Deposit Shape : tabular, can be irregular
- Dip : moderate to fairly steep can accommodate flatter deposit if ore passes are steeper than angle of repose
- Deposit Size : narrow to moderate width
- Ore grade : fairly high
- Depth : moderate to deep

Cut and Fill

Type of Stope	Drilling Equipment	Mucking Equipment
Breast (Narrow Vein)	Jackleg	Slusher
		0.4 m^3 LHD
Breast (Wide Vein)	Jackleg	Slusher
	2-boom Jumbo	0.8-3.8 m^3 LHD
		Rubber tired overshot mucker
Post-Pillar	Jackleg	0.8-3.8 m^3 LHD
Drift and Fill	2-boom Jumbo	0.8-3.8 m^3 LHD
Back	Stoper	Slusher
	Stope Jumbo	0.8-3.8 m^3 LHD
	2- or 3-boom Jumbo	
	Crawler	
	Mounted Drifter	
Undercut	Jackleg	Slusher
	2-boom Jumbo	0.8-3.8 m^3 LHD

Drilling and Blasting in Cut-and-Fill stoping method



Cut and Fill

- Advantage…
  - **moderate production and scale**
  - **good selectivity**
  - **low development cost**
  - **adaptable to mechanization**
  - **flexible method**
  - **excellent recovery with low dilution**
  - **tailings can be disposed of as fill**
- **Disadvantage…**
  - **high production cost**
  - **fill complicates cycle**
  - **requires stope access for mechanized equipment**
  - **labour intensive**
  - **ground settlement/instability risk**

Advantages :

- Moderate productivity
- Moderate production rate
- Permits good selectivity, sorting possible
- Low development cost
- Adoptable to mechanization
- Recovery is high, low dilution
- Waste revised as fill
- Good safety record.

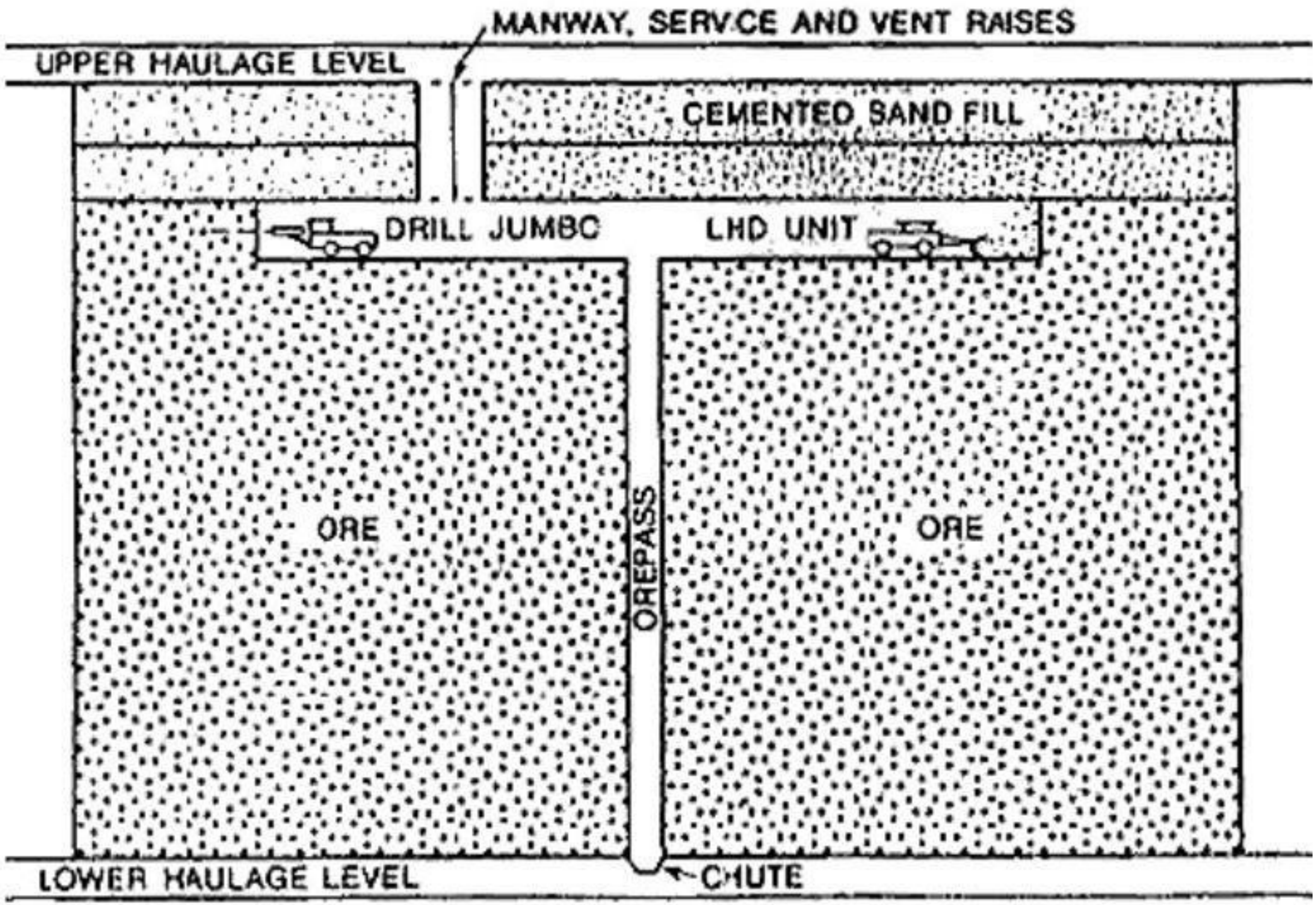
Disadvantage :

- Fairly high mining cost
- Handling of waste – extra cost
- Filling complicates cycle of operation causing discontinuous production
- Must provide stope access for mechanized equipment
- Compressibility of fill risks some ground settlement

Cut and Fill Variations

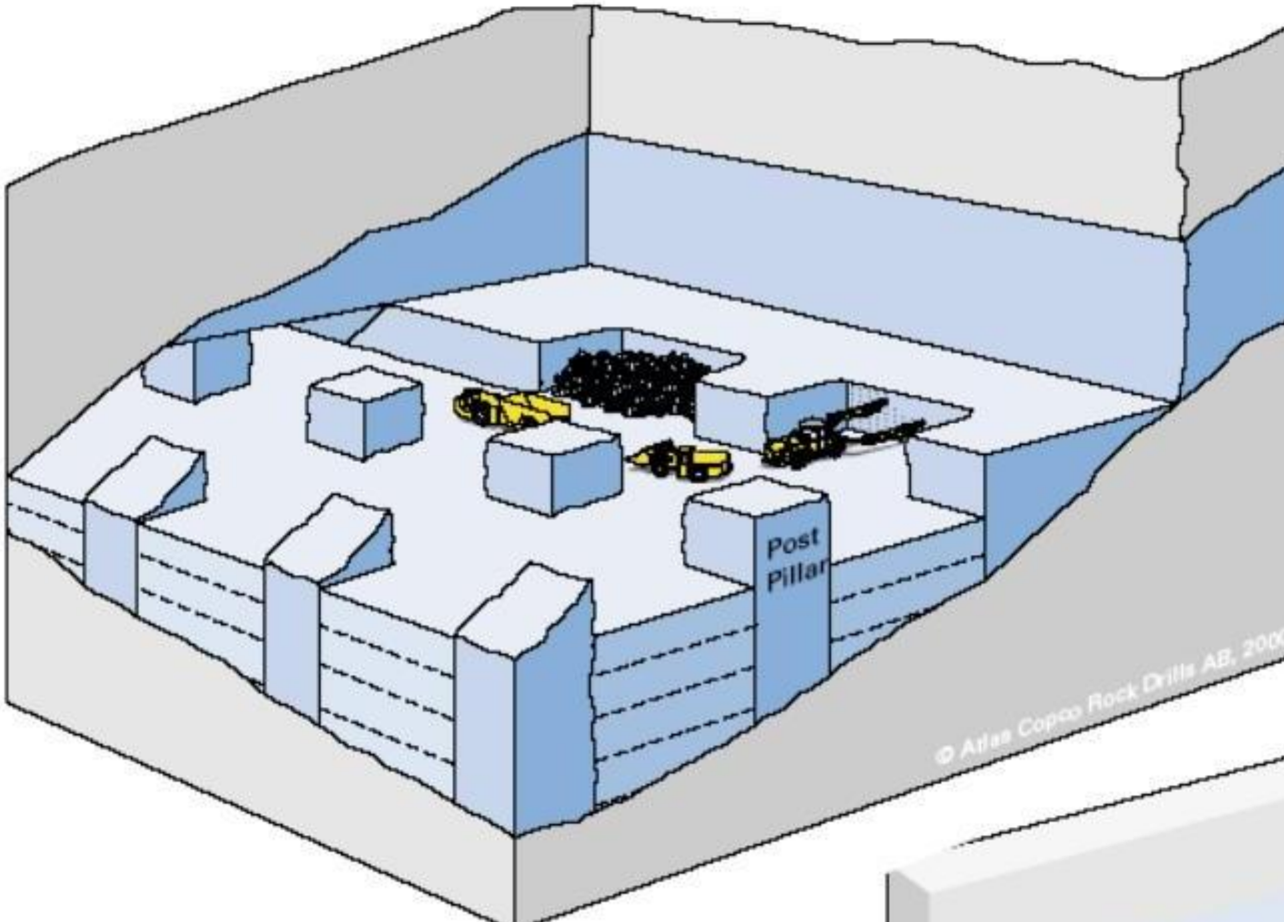
- Underhand Cut and Fill or Undercut and Fill
  - **Developed to recover pillars or to mine low strength ore bodies**
  - **Mining top down and placing a cemented/reinforced mat over the working area ... enabling mining below.**

- Drift and Fill
  - **Used to mine wide, flat, thin (<6m) orebodies with poor hanging wall conditions. Mining involves a series of parallel drifts with an access heading driven along the hanging wall contact. Each mined drift is filled with cemented sand fill ... providing back support for the next drift.**
- Post Pillar
  - **Hybrid between room and pillar and cut and fill**
  - **moderately thick, flat, tabular ore bodies**
  - **moderate to low strength back**



Underhand Cut-and-Fill stoping method

Post Pillar Cut and Fill

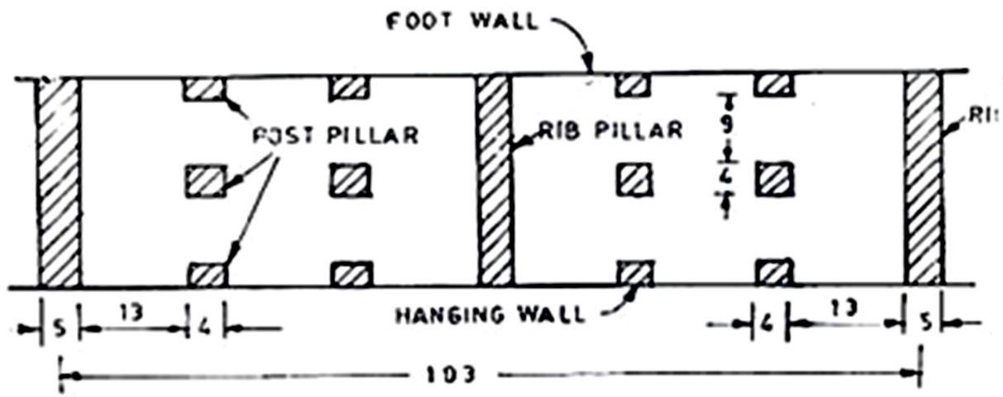


Post pillar mining layout.

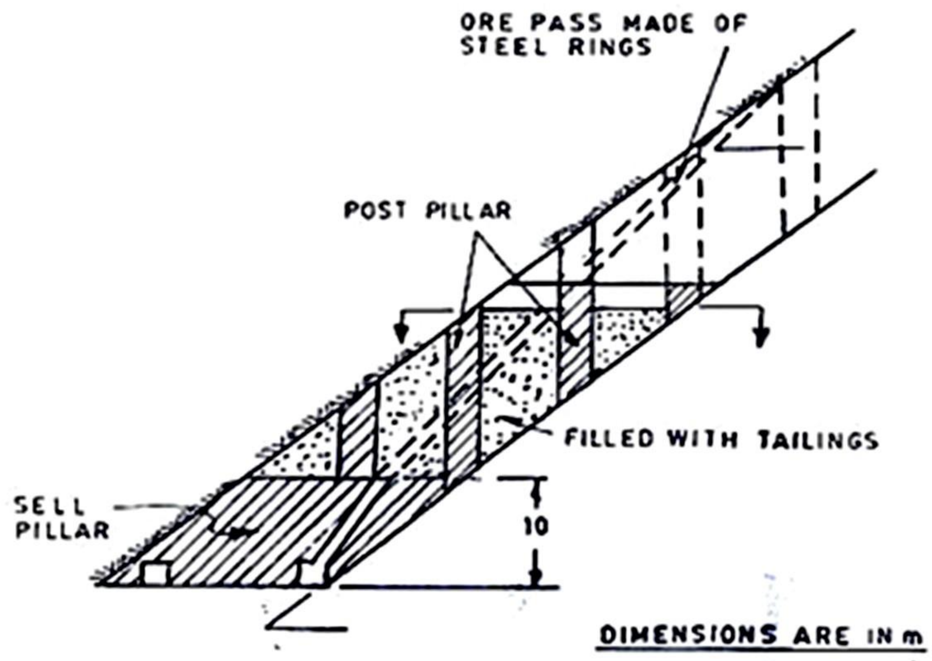
Post Pillar Stoping:

- **Post Pillar Cut-and-Fill stoping** is adopted in such cases where the width and/or inclination of the ore-body or the condition of hanging wall, stope back or induced stresses are such that ordinary methods of rock bolting and fill would not give sufficient support to the stope back.

- The rock mechanics aspect of the mining method is that post pillars are expected to yield under the fill and have the ability to take load in the post-failure condition, most of the super-incumbent load being transferred to the abutments.
- The pillars, however, surrounded by the backfill must still have sufficient strength to support the immediate roof structure.
- The role of the fill in this situation is to prevent any further disintegration or unravelling so that pillars can continue to support the immediate stope back strata rather than the total overlying strata.

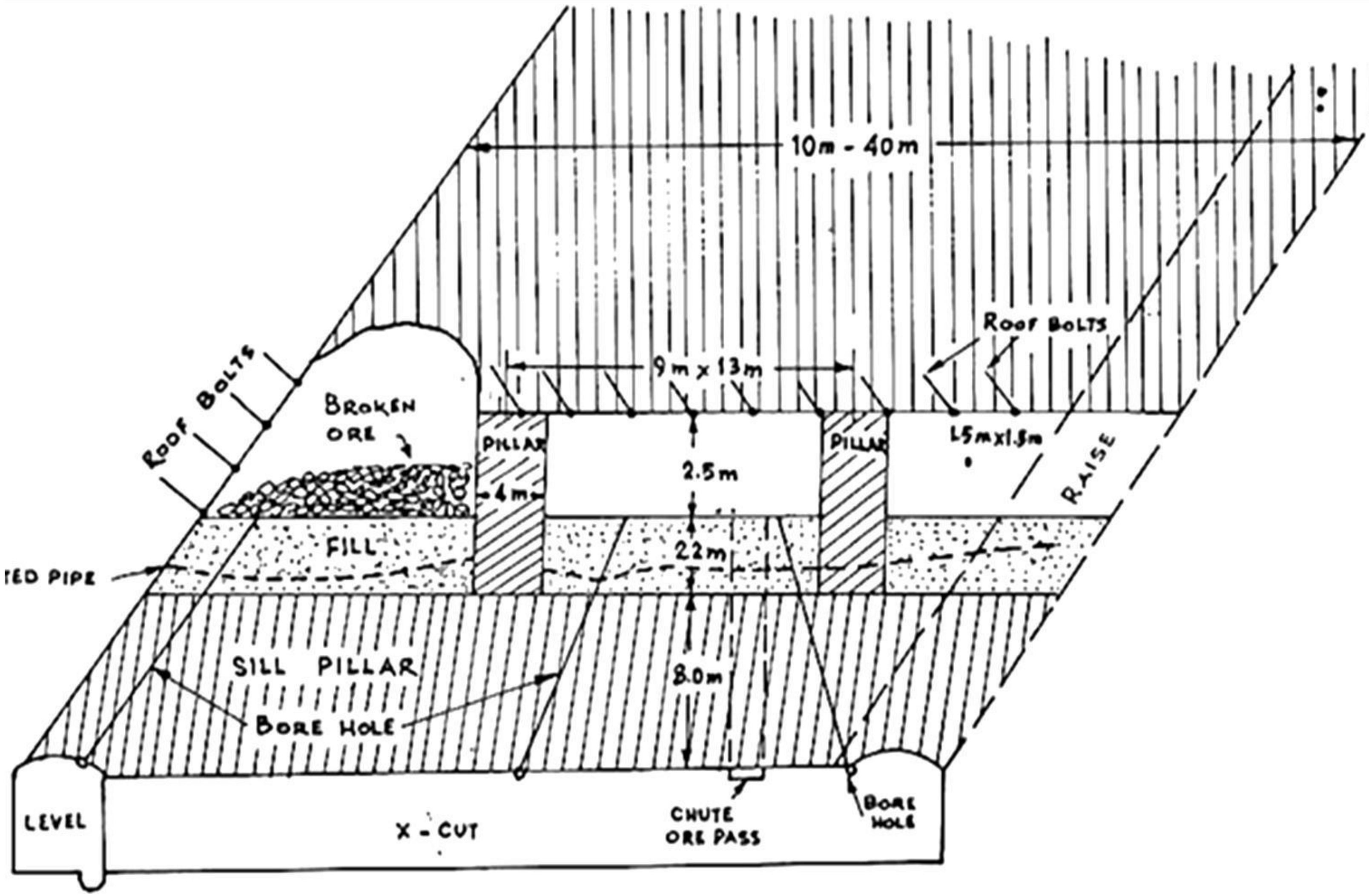


PLAN OF THE STOPE FLOOR



SECTION

Post pillar
Cut-and-fill
stope

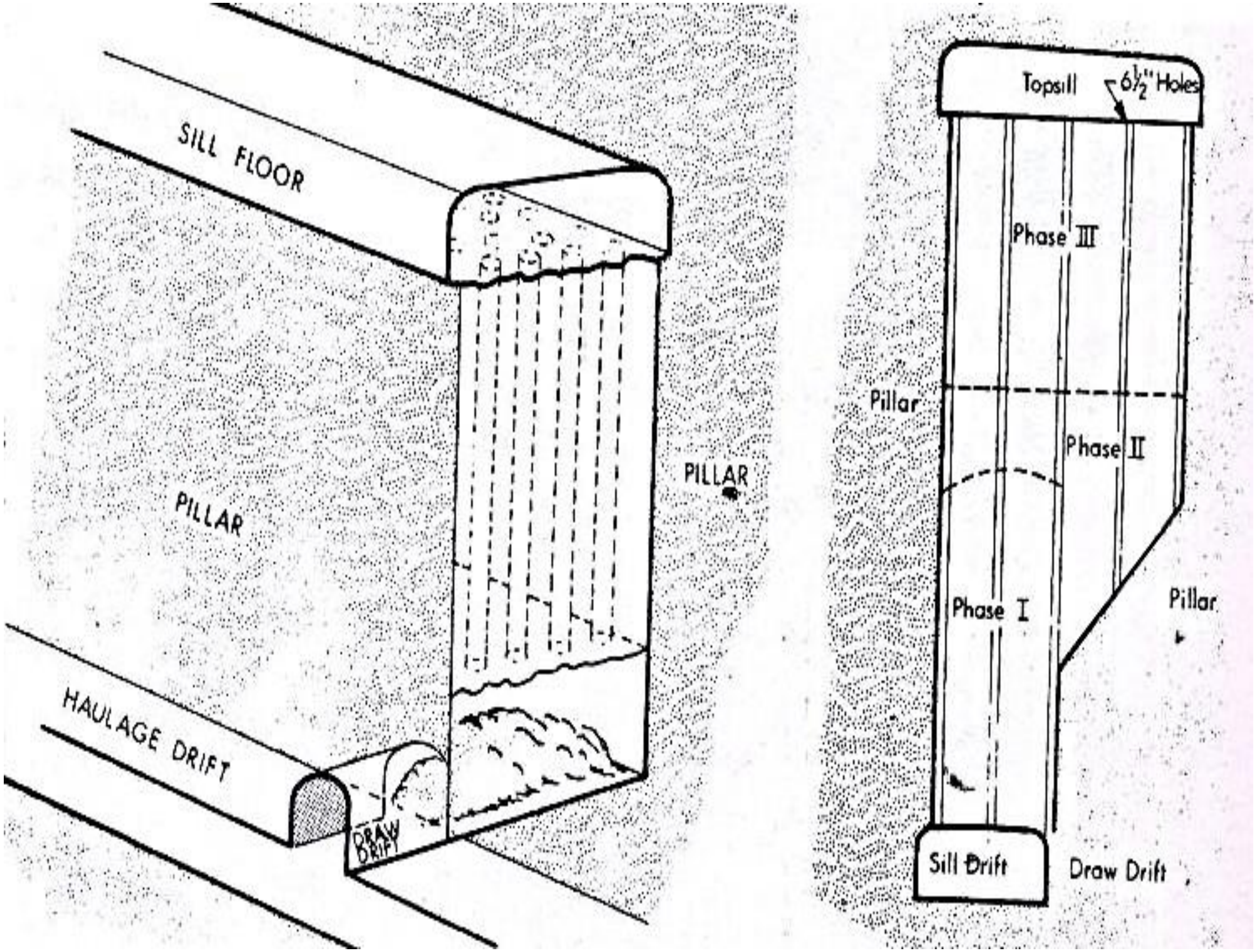


Post pillar Cut-and-fill stope

5. Vertical Crater Retreat method

VCR stoping

- VCR stoping is applicable in many cases where conventional shrink stoping is feasible, although narrow ore body widths (less than about 3 m) may not be tractable. The method is also particularly suitable for mining configurations in which sublevel development is difficult or impossible. These geometric conditions arise frequently in pillar recovery operations in massive ore bodies.


SILL FLOOR
PILLAR
PILLAR
HAULAGE DRIFT
DRAW DRIFT
Topsill
6½" Holes
Phase III
Pillar
Phase II
Phase I
Pillar
Sill Drift
Draw Drift

VCR stoping

Mechanics of Crater Formation:

- The method of VCR mining utilizes concentrated or spherical charges as opposed to conventional cylindrical charges.
- A charge is considered to be spherical if its length-to-diameter ratio does not exceed 6 to 1. Thus for a hole of 165 mm diameter, a slurry package of 165 mm diameter and 990 mm length would form a spherical charge.
- The geometrical configuration of a spherical charge limits its weight to approximately 35 kg in a 165 mm hole. These spherical charges are placed in vertical or near-vertical parallel blast-holes at an optimum distance from the bottom of the hole.

Mechanics of Crater Formation:

- The optimum distance (also called the depth of burial) is defined as the distance from the free surface to the centre of gravity of the charge and is so chosen that the maximum volume of rock is broken to an excellent fragmentation size. When the charge is detonated, it produces a crater (surface cavity) in the surrounding rock. As gravity works with the explosives breakage process and as the explosive energy in spherical charges is used at optimum confinement conditions, the resultant crater depths normally exceed the top of the explosives charge location and the muck produced is very – well fragmented for an efficient handling.

The Stoping Method:

- The VCR method requires large diameter holes, usually of 165 mm diameter, to be drilled in a parallel pattern from a top drilling drive in the roe (called an over cut) down to an undercut on the level below.

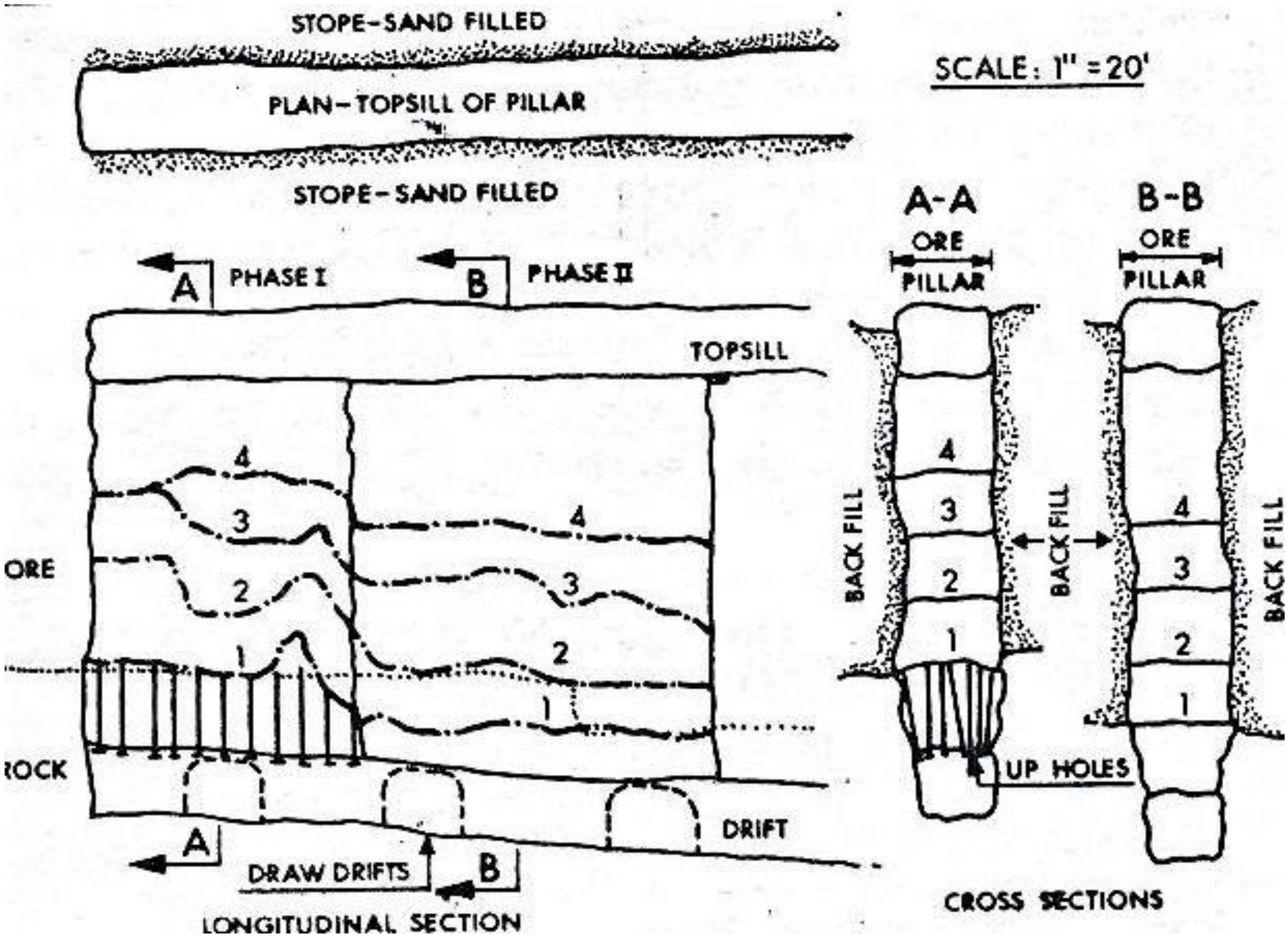
- The bottom of each hole is blocked off and charged with 'spherical' slurry bags placed in the hole at an optimum depth of burial. Horizontal slices of ore up to about 5 m thick, are then blasted into the undercut.

- The 'swell' of broken ore is then drawn off (as in shrinkage stoping) from draw points by LHD equipment, prior to the next blast being taken.

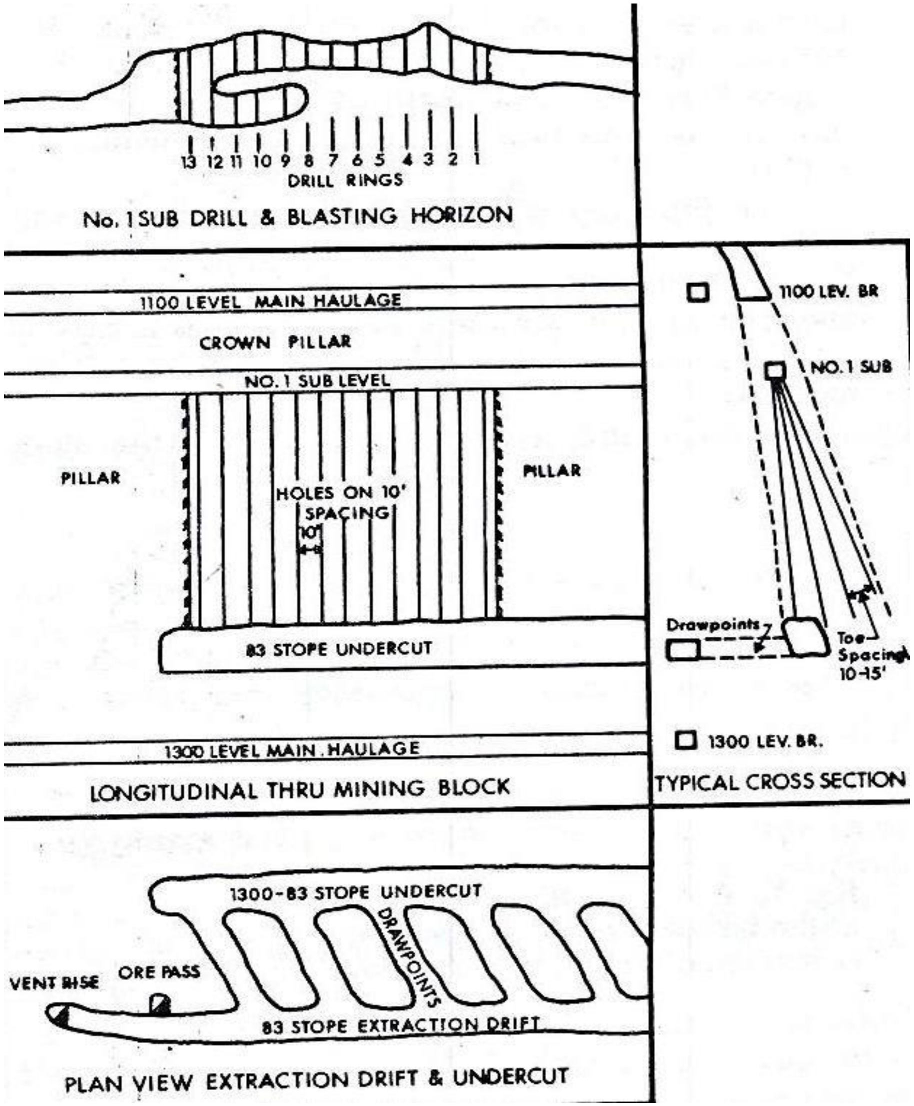
- After each blast has been drawn off, the space between the top of the broken ore and the face of the stope is measured which forms the basis for determining the thickness of the next slice to be blasted.
- Repeating this loading and blasting procedure, mining of the stone or pillar retreats in the form of horizontal slices in a vertical upwards direction until the entire block is crater-blasted.

- The VCR method necessitates the use of water jel or aluminized slurry explosive having high densities, high detonation velocities and high bulk strengths. ANFO, because of its low density has not been used in VCR blasting, despite its attractive cost and safety characteristics.

- Several patterns of millisecond delays for blasting the slices of the ore body are used but the preferred method isto first blast a burn cut out of the centre of the pattern while the remaining holes are then blasted concentrically around the burn. This method gives each hole two free faces into which it can break, laterally into the burn and downwards into the horizontal stope back.


STOPE-SAND FILLED
PLAN-TOPSILL OF PILLAR
STOPE-SAND FILLED
SCALE: 1" = 20'
A
PHASE I
B
PHASE II
TOPSILL
ORE
ROCK
4
3
2
1
4
3
2
1
A
DRAW DRIFTS
B
DRIFT
LONGITUDINAL SECTION
A-A
ORE
PILLAR
BACK FILL
4
3
2
1
UP HOLES
B-B
ORE
PILLAR
BACK FILL
4
3
2
1
BACK FILL
CROSS SECTIONS

VCR stoping



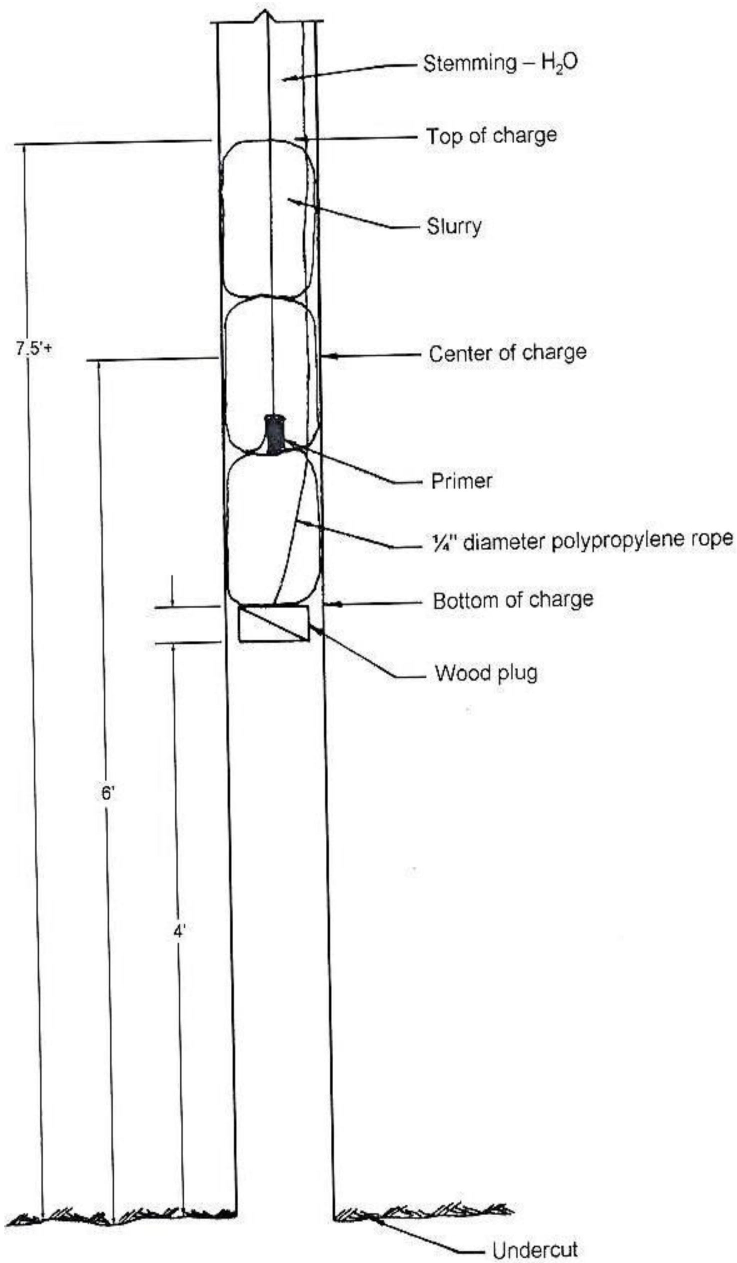
13 12 11 10 9 8 7 6 5 4 3 2 1
DRILL RINGS
No. 1 SUB DRILL & BLASTING HORIZON
1100 LEVEL MAIN HAULAGE
CROWN PILLAR
NO. 1 SUB LEVEL
PILLAR
HOLES ON 10' SPACING
10'
PILLAR
83 STOPE UNDERCUT
1300 LEVEL MAIN HAULAGE
LONGITUDINAL THRU MINING BLOCK
1100 LEV. BR
NO. 1 SUB
Drawpoints
Toe Spacing 10-15'
1300 LEV. BR.
TYPICAL CROSS SECTION
1300-83 STOPE UNDERCUT
DRAWPOINTS
VENT RISE
ORE PASS
83 STOPE EXTRACTION DRIFT
PLAN VIEW EXTRACTION DRIFT & UNDERCUT

VCR stoping

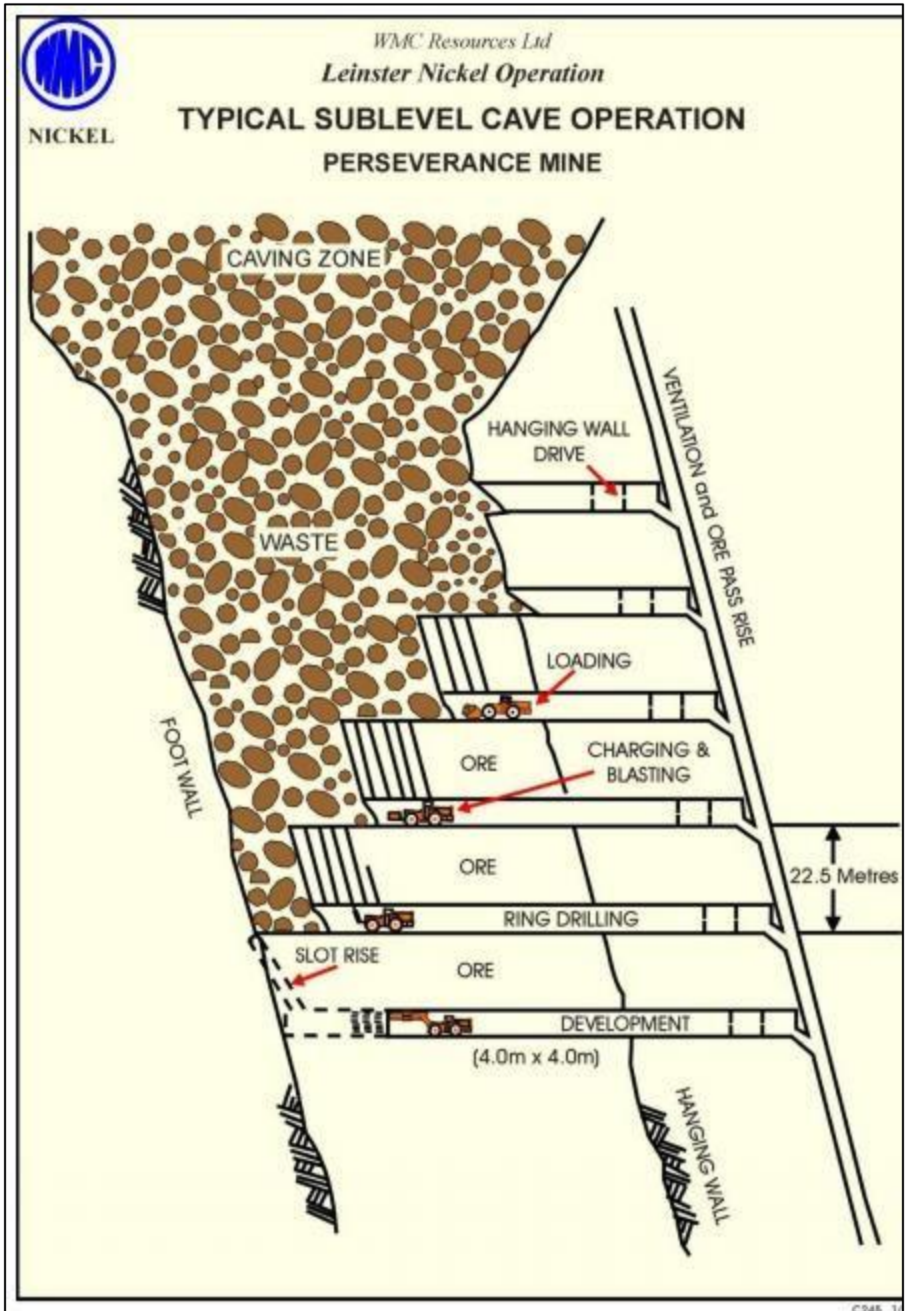
Advantages:

VCR method has gained popularity both as a stoping method and for pillar extraction, in conditions where suitable ore blocks are available and the rock mechanics aspects are favourable. The VCR stopes have been used both as sublevel and shrinkage stopes. The method has also been used in drop raising. The main advantages of this method include:

- (i) Higher tonnage per day and lower stoping cost.
- (ii) Lower development cost since it eliminates raise boring and slot-cutting.
- (iii) Increased safety of operations because drilling and blasting are
- carried out from above and there is no need for the miner to enter the actual stope.
- (iv) Improvement in fragmentation (the method yields lowest powder
- factor).
- (v) Reduced labour requirements and drilling and charging time.
- (vi) Reduced dilution and over break.
- (vii) Elimination of up-hole drilling and up-hole loading of explosives.

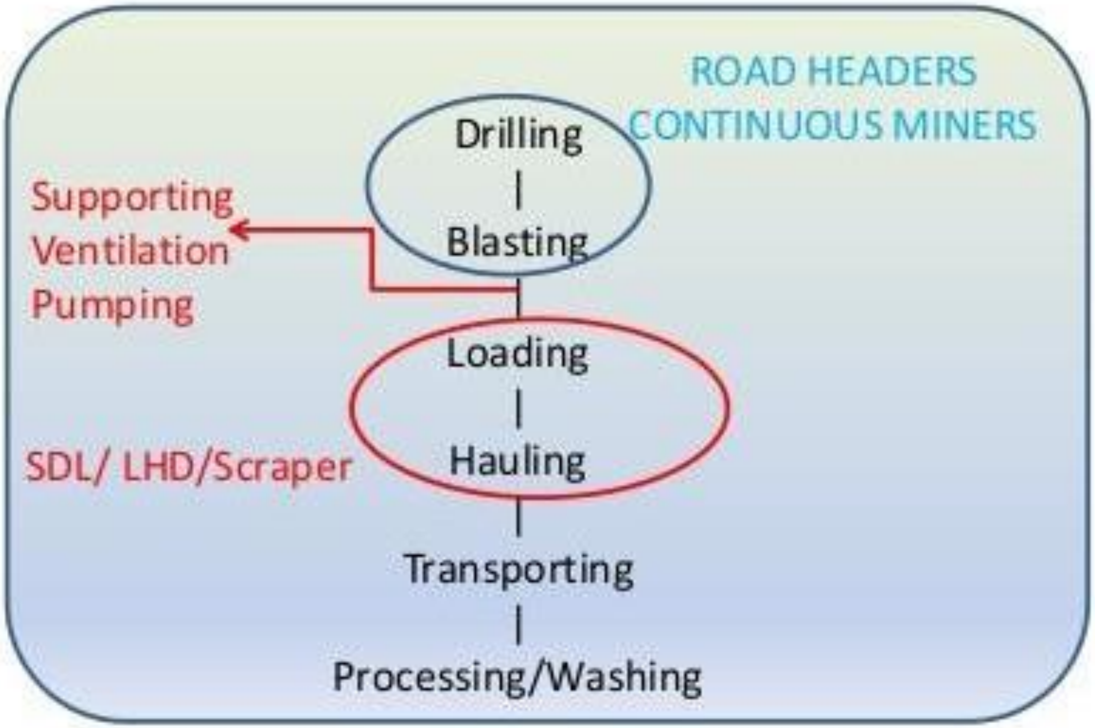


- The term cratering is applied to the formation of a surface cavity in a material through the action of detonating an explosive charge within the material. A crater blast is a blast when a spherical charge is detonated beneath a surface that extends laterally in all directions beyond the point where the surrounding material would be affected by the blast.



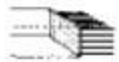
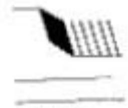
Sub-level Caving method

Mining Process used in Underground Mining methods

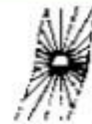


Drill
|
Permitted explosives
|
Manual/ SDL/ LHD/Scraper
|
Manual/ SDL/ LHD/Scraper
|
Tubs, Conveyors, ..etc
|
Washeries

Drilling

Mining Method	Room and Pillar Miing		Cut and Fill Stoping		Shrinkage Stoping	
Drilling and blasting technique	 drifting and slashing  frontal benching	 vertical or downward benching	 roof drilling or overhand stoping	 frontal stoping, breasting	 overhand stoping	 frontal stoping, breasting
Applicable drilling equipment	 mechanized drifting jumbo	 mechanized airtrack drill	 mechanized light wagon drill	 mechanized drifting jumbo	 hand-held stoper drill	 hand-held airleg drill
Drilling data						
Hole diameter, mm	38 - 48	64 - 76	33 - 38	38 - 48	29 - 33	29 - 33
Hole depth, m	3.0 - 5.5	as required	3.0 - 4.0	3.0 - 4.0	2.0 - 2.5	2.0 - 3.5
Production capacity						
With pneumatic rock drill m/h	60 - 75	15 - 25	20 - 40	60 - 70	8 - 12	10 - 15
With hydraulic rock drill m/h	90 - 110	(25 - 35)	--	90 - 110	--	--
Drilling - blasting						
Output, m^3 rock per drilled metre	1.5 - 2.0	3.0 - 4.0	0.9 - 1.2	1.0 - 1.4	0.7 - 0.9	0.7 - 0.9

Drilling

Mining Method	Sublevel Caving	Sublevel Stoping		Sublevel and Vertical Retreat Stoping	
Drilling and blasting technique	 fan drilling	 ring drilling		 parallel drilling	
Applicable drilling equipment	 mechanized fan drill	 bar-and-arm rigging	 mechanized ring drill rig	 track drill rig DTH hammer and high pressure	
Drilling data					
Pneumatic rock drill	48 - 57 (64)	48 - 51	48 - 57	105 - 115	152 - 165
Hydraulic rock drill	48 - 75 (89)	--	48 - 76 (89)	--	--
Normal hole length m.	10 - 20	10 - 20	10 - 25	30 - 50	40 - 60
Production capacity m/shift					
With pneumatic rock drill	160 - 240	50 - 60	100 - 120	25 - 50	25 - 50
With hydraulic rock drill	240 - 300	--	120 - 180	--	--
Drilling - blasting					
Output, m^3 rock per drilled metre	1.8 - 2.3	1.5 - 2.5	1.5 - 2.5 (5.0)	8 - 10	14 - 18

Drill – Development Jumbo

Drill – Development Jumbo