



Unit 16

Mine Development

About This Unit

In this unit, you will learn how a Mine is developed for production, how a shaft is sunk, how lateral headings and raises are mined.

Objectives

After completing this unit, you should be able to:

- **Explain the methods of "opening a deposit"**
- **Lists the steps of shaft sinking**
- **Lists the type of shafts**
- **Big Hole Drilling**
- **Ground Freezing**
- **Shaft Linings**
- **Lateral Development & Ramps**
- **Track versus Trackless**
- **Design and function of Lateral Headings**
- **Laser Control**
- **Raises**

Mine Development

When a promising mineral deposit has been found, production is the next thing to consider. All mines require considerable development before actual ore production can begin.

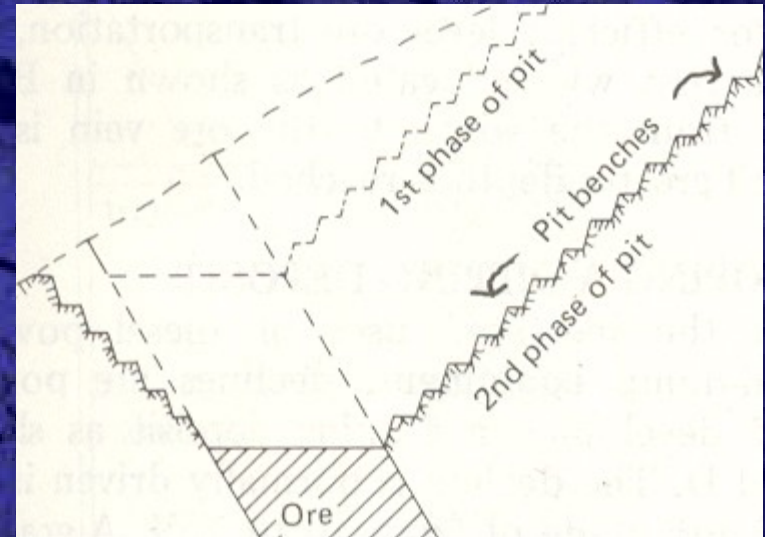
The orebody is "opened up" by excavation. In opening a mine, a small mining company usually digs any ore that is showing. The revenue from the sale of the ore keeps the venture going and finances further development. After the ore body has been delineated and defined, a company may make several feasibility studies to determine the best way to mine the ore.



Opening a deposit

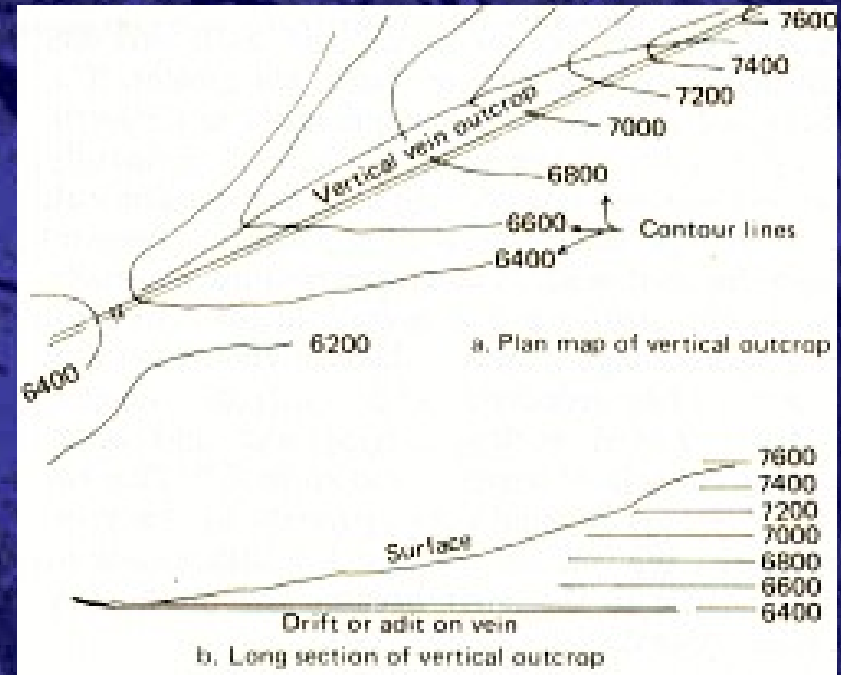
A) Open Pit

Stripping the overburden is always a problem. The wider and richer the vein the deeper the pit. The availability and production capability of surface equipment makes open-pit mining a very attractive choice.



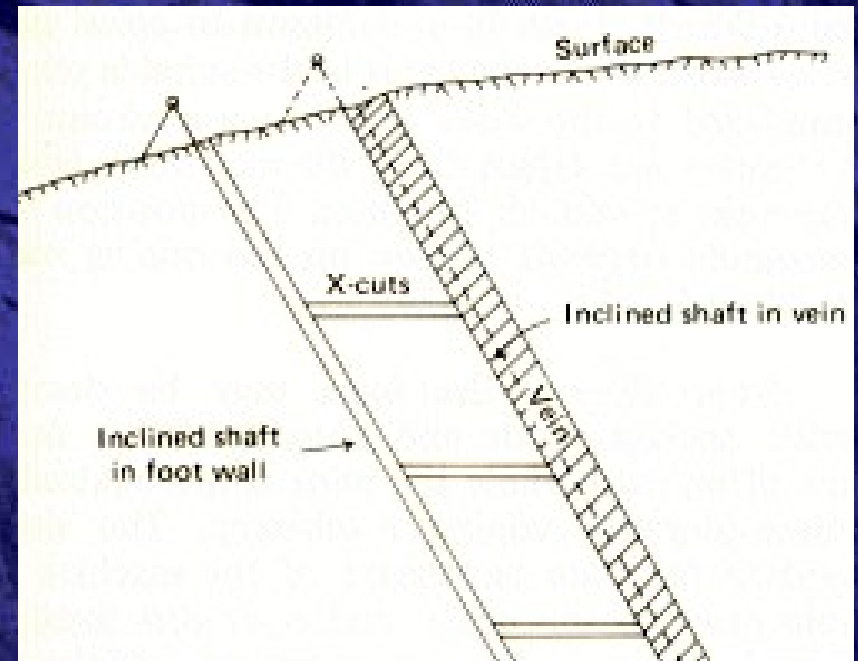
B) Drift Mining

If the ore vein is narrow and the terrain is favourable, a drift or adit on the vein is often used. The drift is mined into the vein at an almost flat elevation.



C) Inclined Shaft

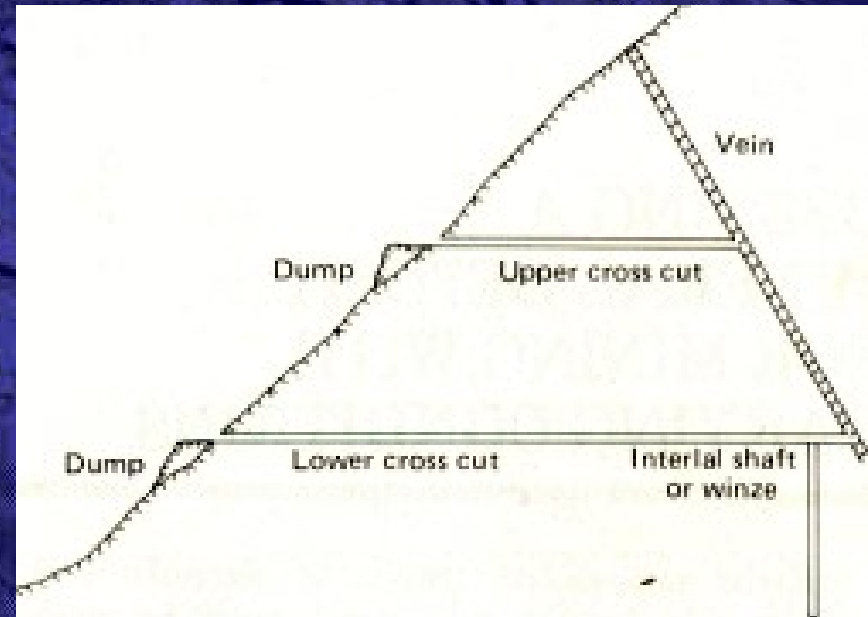
In flat terrain, a shaft is almost always required in a narrow vein. The shaft runs parallel to the orebody in the footwall for stability. Normally the footwall is used for ground stability. Cross-cuts or levels run out to intersect the ore vein.



C) Crosscuts to Veins

In steep mountainous terrain, crosscuts to veins can be used.

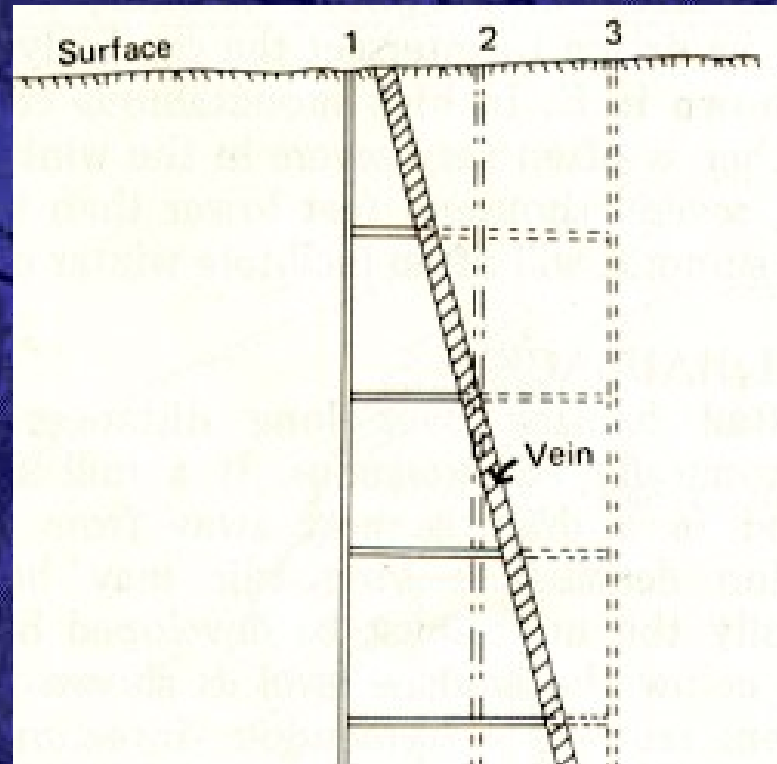
Crosscuts have the advantage of draining water and hauling ore on a near level horizon.



D) Vertical Shaft Mining

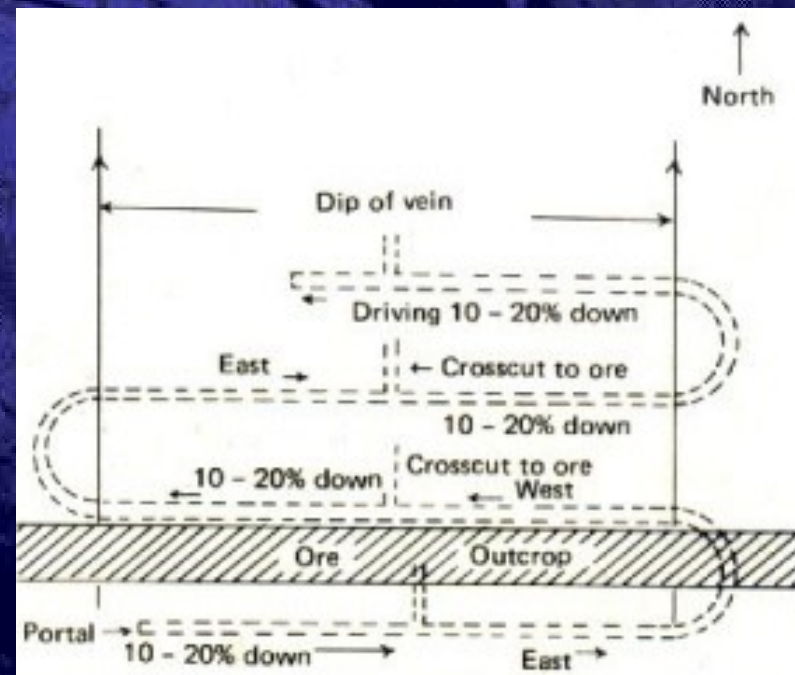
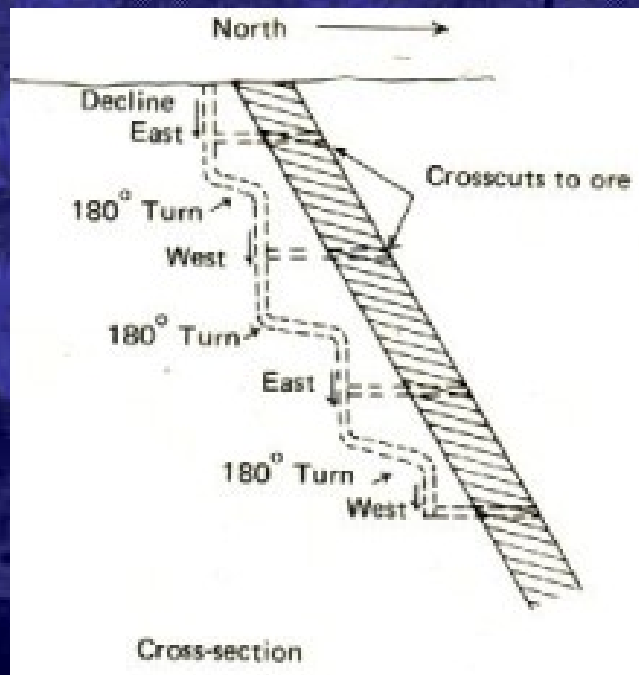
Many mines use vertical shafts for narrow veins.

Location 1 is preferred over 2 and 3 but may require increasingly longer cross-cuts to reach the orebody as the depth increases.



E) Ramps

With the increased uses of diesel powered LHD units, ramps are becoming popular ways of developing dipping deposits.



Shaft Sinking

Of all the headings driven in hard rock mines, shafts are the most costly and time consuming. Moreover, the shaft sinking procedure is intricate and arduous. While a few shafts are advanced by big-hole drilling methods, the great majority use the traditional "drill and blast" cycle.

Shafts for smaller mines have traditionally been sunk rectangular and relied on timber for support. Larger mines have typically employed circular shafts lined with concrete poured in place as the sinking advances.



On the surface of an underground mine, a collar is required for a shaft or raise entry, while a portal refers to the entrance for an adit, decline, or ramp.

Collar

Collars are also required for ventilation shafts, service shafts, and for all raises that reach surface. Constructing collars in a rock outcrop or in shallow overburden is relatively straightforward; however, if the soil overburden is deep and especially if it is water bearing, collar construction can become a major project. Shaft and raise collars are normally lined with concrete.



Portals

Portals may be left open to the elements in tropical zones; however, the entrance is often enclosed with a weather-tight structure in temperate or arctic climates. This structure was once often built with timber or reinforced concrete, but now miners usually employ **corrugated metal archways** similar to those used for large highway culverts. Portals for ramps and declines usually incorporate a reverse slope at the start to prevent surface water from running into the mine.



Today, independent mining contractors sink most shafts. While there have been significant technical advances, no world records have been broken for rate of shaft-sinking advance in hard rock since 1962.

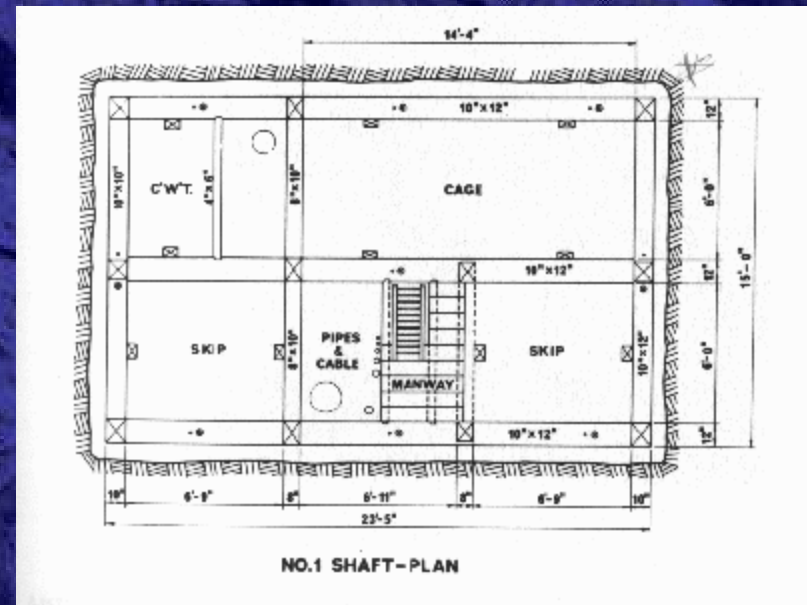
Except at great depth, shafts sunk in hard rock mines do not normally require special considerations to maintain wall stability. A few shafts require the ground freezing method to traverse a waterbearing horizon.



Types of Shafts

Shafts sunk today in hard rock mines are mostly limited to the standard three-compartment timber shaft and the circular concrete shaft.

The standard three-compartment timber shaft has two hoisting compartments that measure six feet by six feet inside the timbers. The third compartment, used for a manway and utilities, is sometimes slightly shortened from the six-foot width.

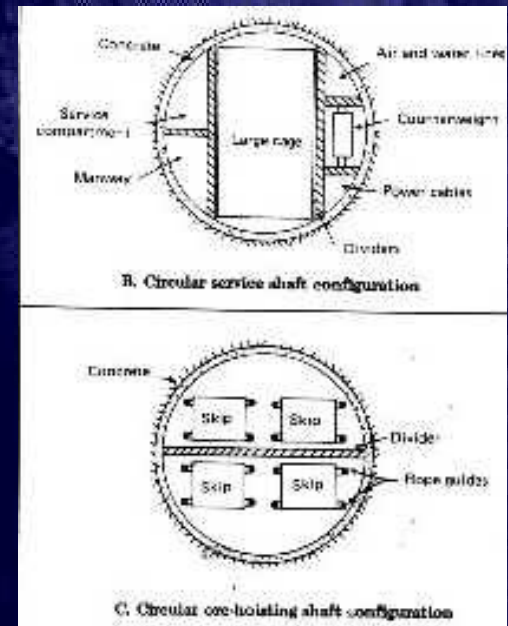


These timber shafts are still used for exploration entries in general and production shafts for small hard rock mines.

For remote sites, the shaft timber may be replaced with **steel sets** to save on weight and the cost of transportation. It is now widely believed that any savings thus realized are later lost in the shaft sinking costs and schedule, mainly due to the increased difficulty in installing blocking, catch pits, and water rings.

In addition, omission of hanging rods makes the sets more difficult to hang and align. Although a number of ingenious methods have been developed for timber shafts to successfully traverse bad ground conditions, timber shafts are no longer considered when bad ground or highly stressed ground is anticipated.

In North America, **suitable timber has become scarce and expensive**. For this and other reasons, shaft sinking by this method is now mainly confined to deepening existing timber shafts.



Shaft Sinking

If the nature of the ground above the bedrock is not known, it is advisable to drill test holes. Sandy or running ground, especially if wet, offers difficulties in shaft sinking.

A shaft-sinking plant consists of a headframe, hoisting equipment, an air-compressor for drills, concrete mixing equipment and suitable pumps.

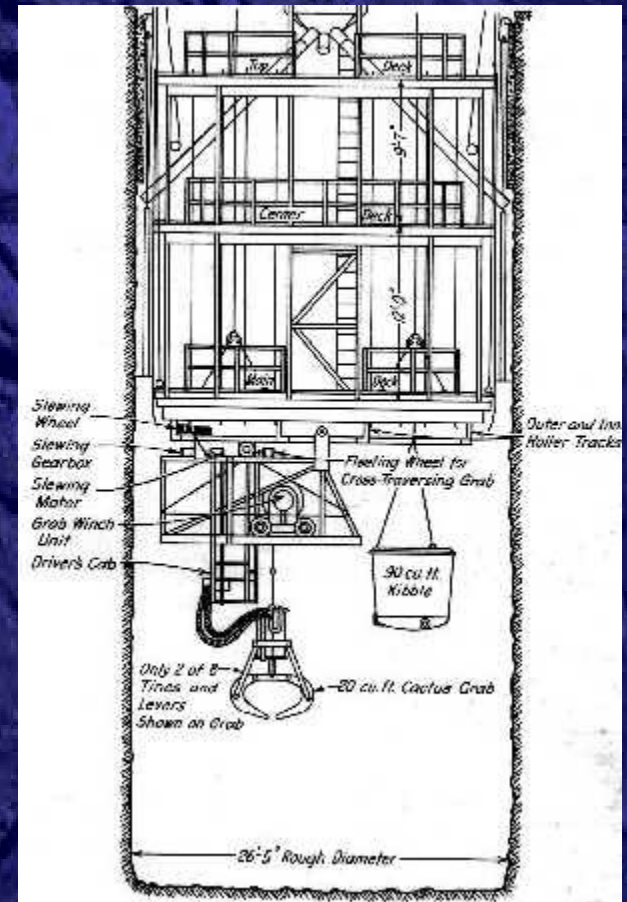


Sinking a shaft in solid rock usually consists of the following cycle:

- Drilling a round of holes
- Blasting
- Removing the broken rock
- Trimming the shaft to form
- Placing the sets in position
- Preparing to drill the next round.

An eight-hour cycle from blast to blast is common.

Concrete is mixed on the surface and conveyed down the shaft in a pipe. The shaft bottom is cleaned after mucking, the center line fixed by plumb bob, and the next round drilled. The stage is lowered if necessary. During mucking, the forms for concrete are placed in position.



Shaft Sinking (Soft Ground)

Method:

a) Wood/Steel Piling

The first set of piles, forming a circle around the shaft site is started at the surface. As the piles are driven down, the ground is excavated, and a circular crib is put in every few feet. In this way the shaft is sunk in a series of short wooden cylinders.

b) Open Caisson

In this method the shaft is started by digging a shallow excavation and placing a cutting shoe on the bottom of the pit. The ground inside and just under the shoe is excavated and the lining is built up as the shoe sinks.



c) Pneumatic Caisson

In this method, a bulkhead is built in the caisson above the bottom, forming an airtight compartment at the bottom. Compressed air is forced into this compartment through airlocks. All material passes through the airlocks.

d) Freezing Process

This method was first used in 1883. The wet ground is artificially frozen and then blasted and excavated as though it were solid rock. From 20 to 50 holes are drilled on the circumference of a circle. Circulating pipes are placed in the holes and a calcium or magnesium chloride solution is pumped through the pipes to freeze the ground.



e) Cementation Process

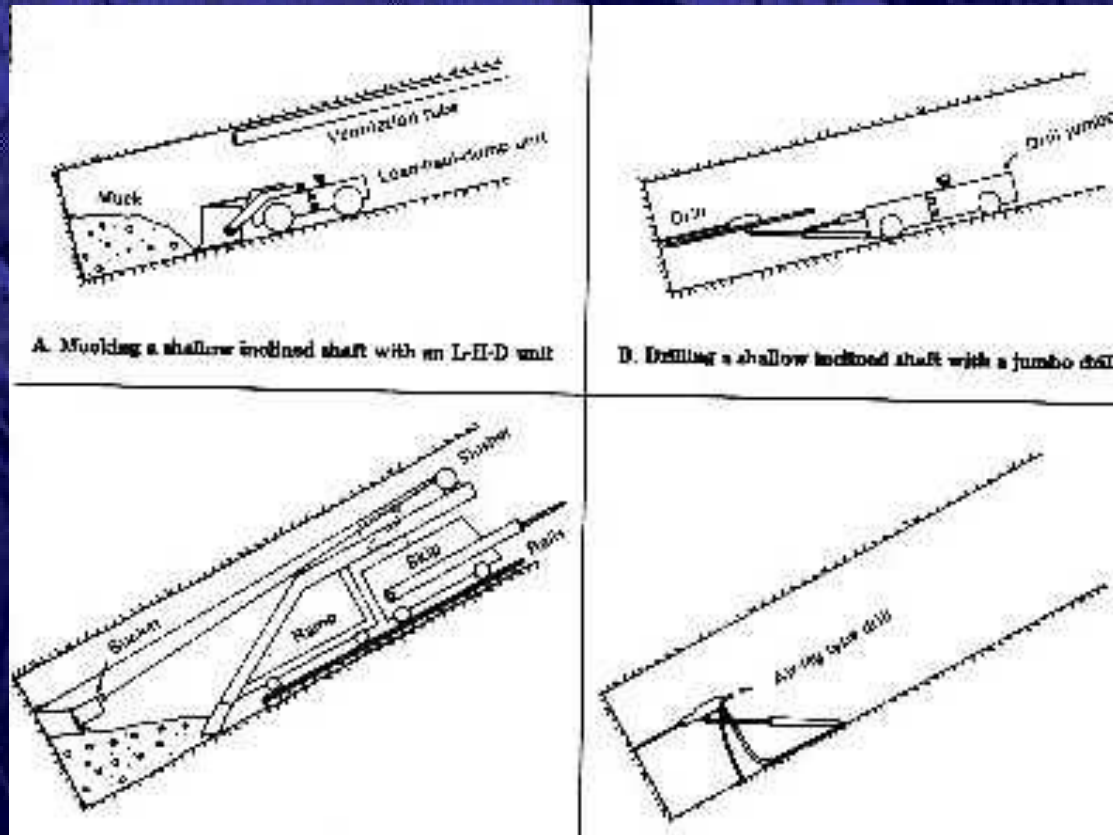
Cavities and fissures are filled with quick-setting cement under high pressure then allowed to set. Cement pumps are designed for pressure as high as 5000 lb/sq.in.

f) Boring

Large shot drills have been used to sink shafts. Holes 30 to 60 in. in diameter have been drilled underground between levels as winzes for pipes, ventilating air or for waste passes.



Driving an Inclined Ramp



Shaft Location

For a permanent shaft there are 2 main requirements, which may be in conflict with each other.

- First, the shaft should be located to provide the most economical length of haulage, considering the entire mine plan.
- Second, to ensure long life and a minimum of repairs, the shaft should be sunk in firm, stable rock.

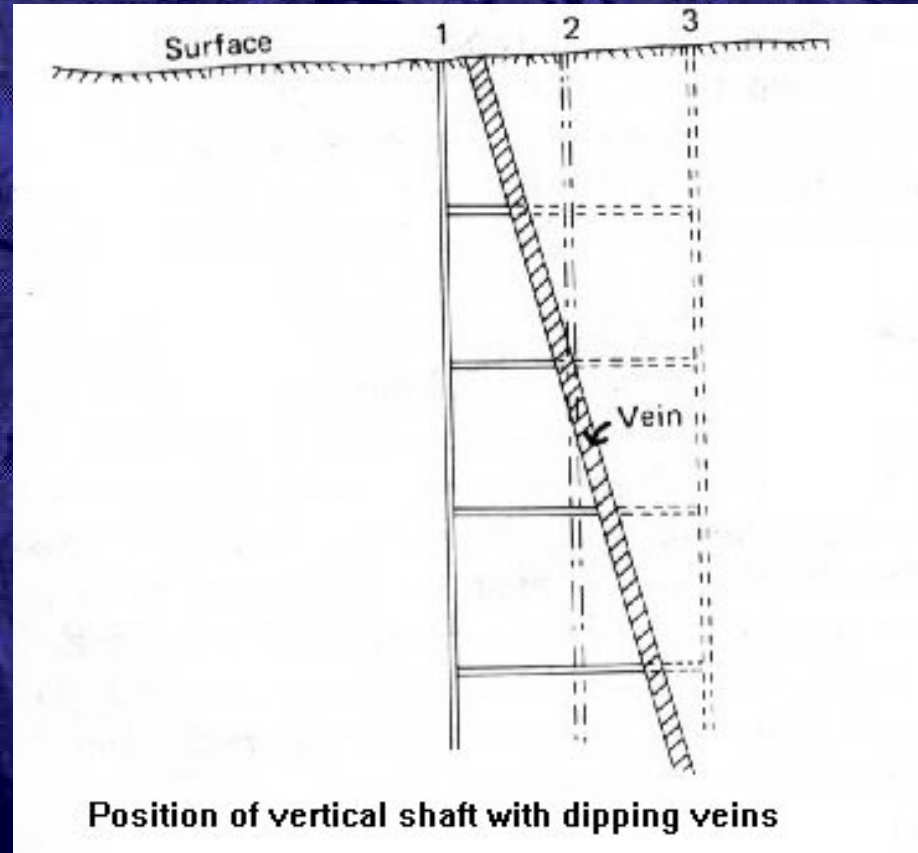


Shaft Location

a) Dipping Veins

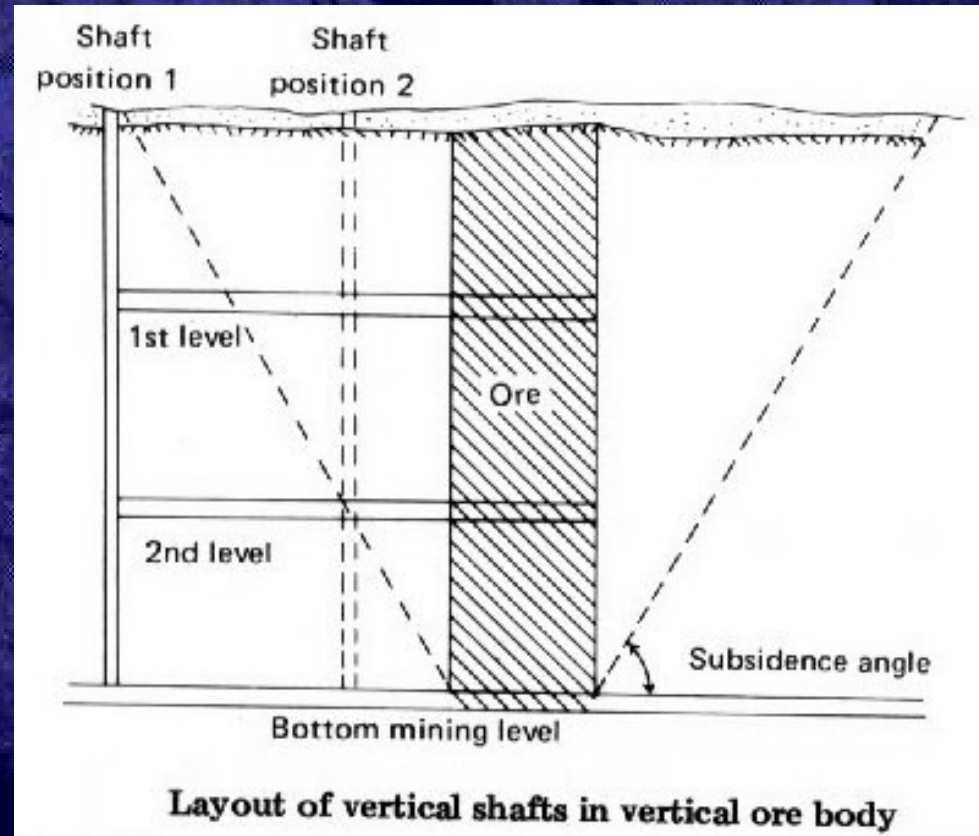
Most mines favour **vertical shafts** because there are now more sophisticated systems to dig them and hoisting speeds are greater. The choice of location of a vertical shaft in a narrow vein is shown above.

Position 1 is favoured because in a dipping vein, the hanging wall is more apt to move into any mining operations than the footwall. The disadvantage to this position is the **increase in length of crosscuts** as the shaft gets deeper



b) Vertical veins

In a vertical deposit, both walls may become weakened and move into the mined out area. If the shaft is too close to the deposit it will become unstable because of the walls moving into the mined out area. Either the shaft should be located beyond the area influenced by the **subsidence angle**, or to keep the wall rock stable, the area will have to be filled in as the ore is mined.



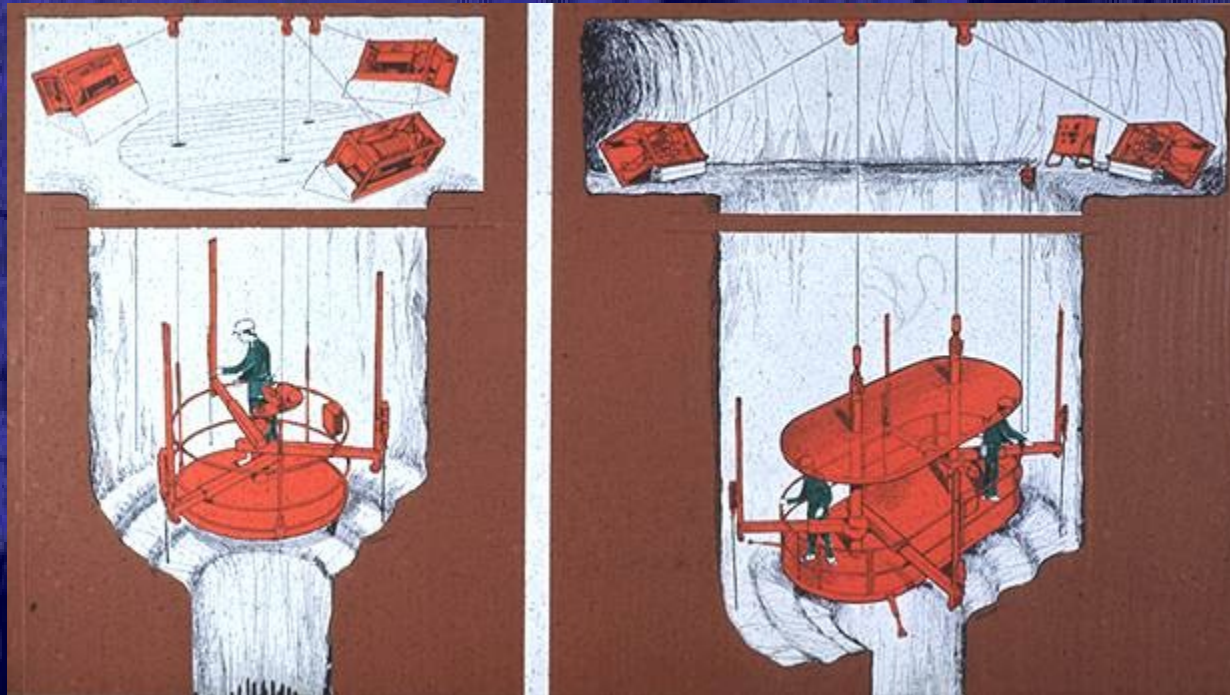
C) Ramps

With the increased use of LHD equipment, ramps or declines are popular ways of developing a dipping deposit. The ramp is normally driven in the footwall at a grade of 10 to 15%.



- Ramp : a heading containing horizontal curves used to as a transport corridor for rubber-tired mobile equipment.
- Decline : a straight heading suitable for installation of belt conveyors or mobile equipment

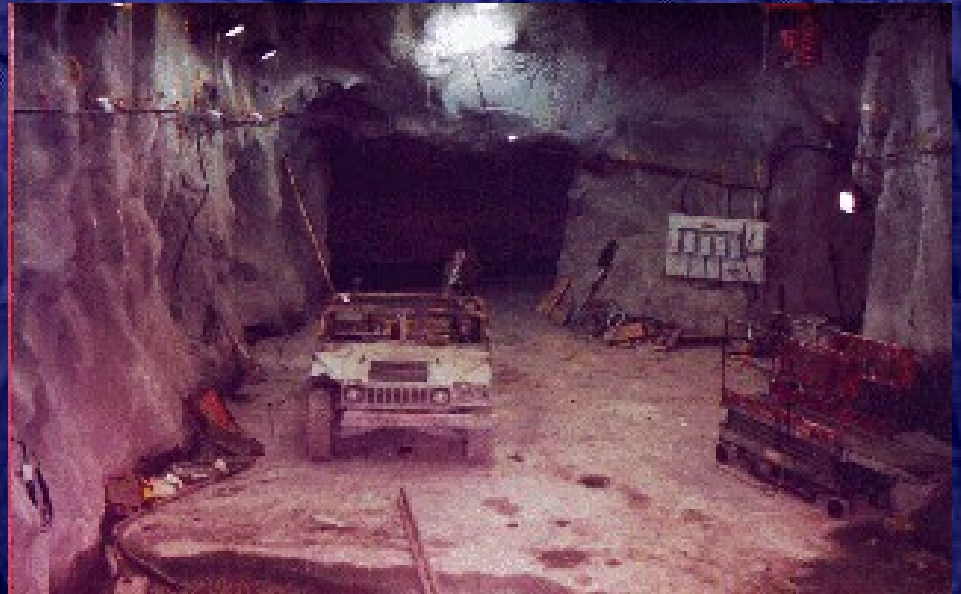
Bored Shafts



Lateral Development

For underground hard rock mines, the term "lateral development" means the horizontal headings in a mine, such as drifts and cross-cuts on a mine level. Lateral development includes the inclined headings (ramps and declines) between levels.

The traditional drill and blast method remains the least expensive and most practical means of advancing lateral headings.



Track versus Trackless

A **"track"** mine refers to one that has rail installed in its lateral headings to provide travel for trains drawn by battery-operated, trolley, or diesel locomotives. A **"trackless"** or "mechanized mine" refers to the use of rubber tired mobile equipment to advance the later development and haul the ore.

The trend has been away from track development. Trackless methods provide better flexibility. Both the productivity (ie. feet per man-shift) and rate of advance (ie. feet per month) are normally significantly higher for trackless headings



Design and Function

Design starts with determining the cross-section of the drift, cross-cut , ramp or decline. **Headings** are contoured to the minimum dimensions required to safely permit passage of the largest vehicle while providing space for roadway dressing, ditches, utility lines and ventilation duct. Safe clearances and the spacings of safety bays are specified in the Mines Act.



In the recent past, the size of mine headings has increased to accommodate larger vehicles. But if the heading becomes too large, it is not advanced as quickly and slows down mine development.

Employing remote operation and guidance systems that enable one operator to run two or three units of equipment simultaneously allow greater productivity improvement than further increasing opening sizes.



Design and Function

For trackless headings are normally **arched**, it is common practice to hang the vent duct and utility lines on the ditch side to save space and help protect them from wayward vehicles.

The back of these headings may be gently arched or driven flat backed, depending on the ground conditions.



Laser Control

Historically, both conventional and trackless development headings were driven using standard line and grade plugs as a means of controlling the azimuth and gradient of the heading. As the distance between control points and the face increases, the quality of control diminishes. Typically, line and grade plugs are useful for about 280 feet and then new controls must be installed



Laser Control

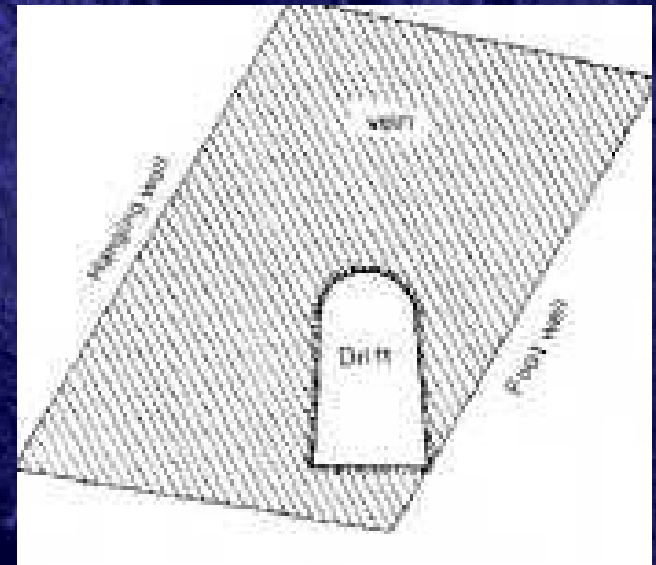
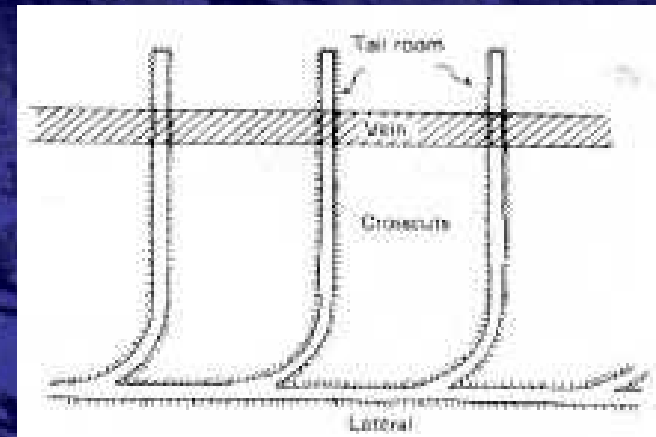
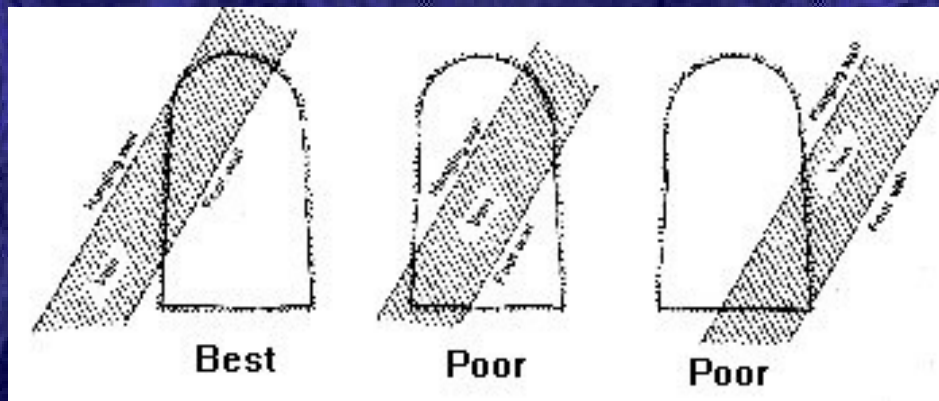
Grade plugs are installed in the walls of the heading. Line plugs are installed in the back, and may or not include a survey control point. Both types of controls are frequently damaged during regular mining practice.

For straight development headings that exceed 800 feet in length, the solution to these problems is the use of **laser beams**.



Drift Location

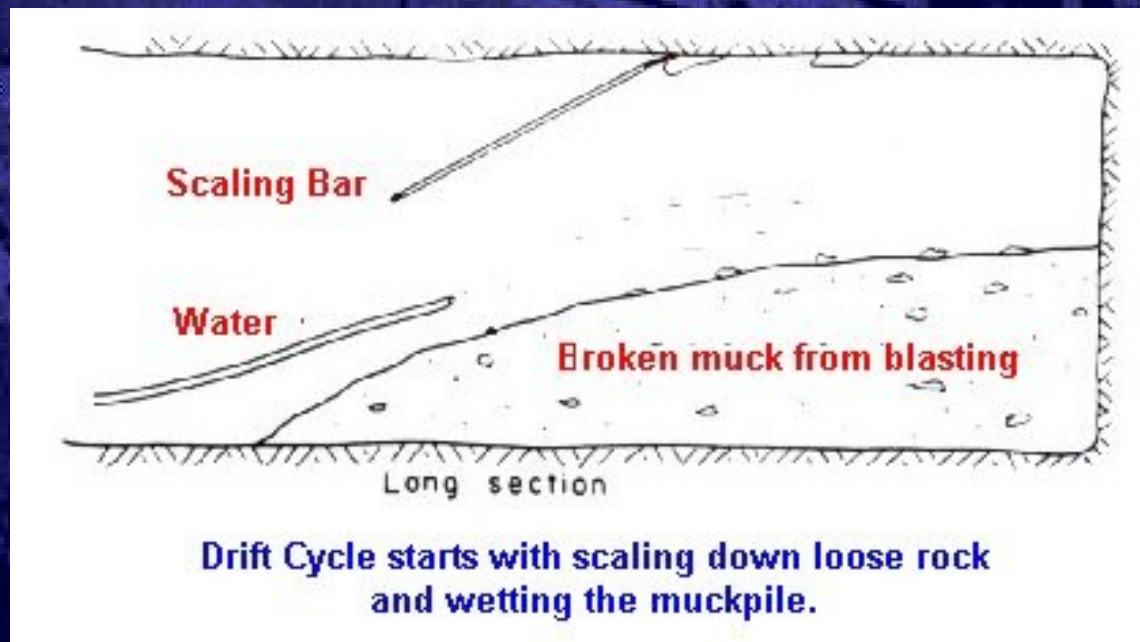
Most drifts are permanent and used throughout the life of the mine. It is important that drifts be located in positions where they can be preserved.



Drift Cycle

Phase 1

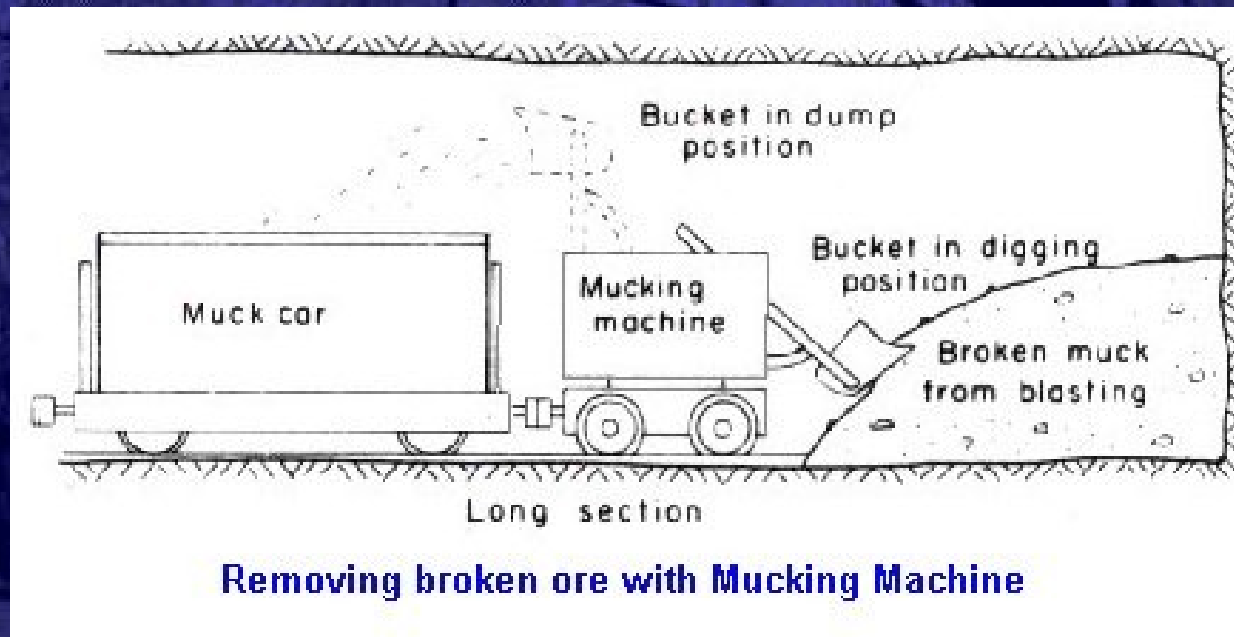
In a freshly blasted heading, the first thing that is done is to scale or bar down loose rocks, then water the walls and muck pile to control dust.



Drift Cycle

Phase 2

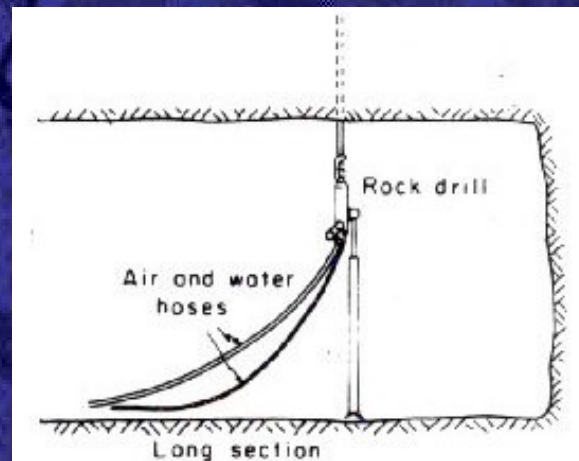
Once the ore is broken, it is mucked out and removed by mucking machine or LHD.



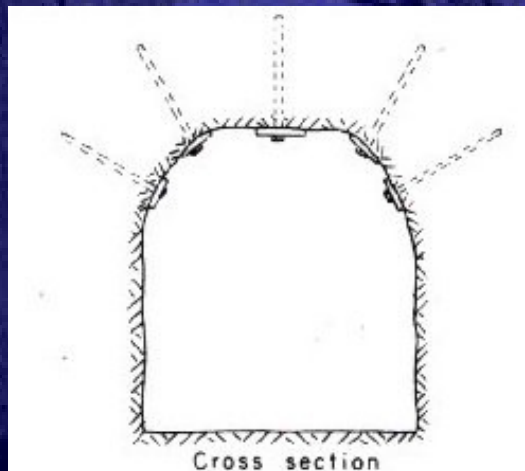
Drift Cycle

Phase 3

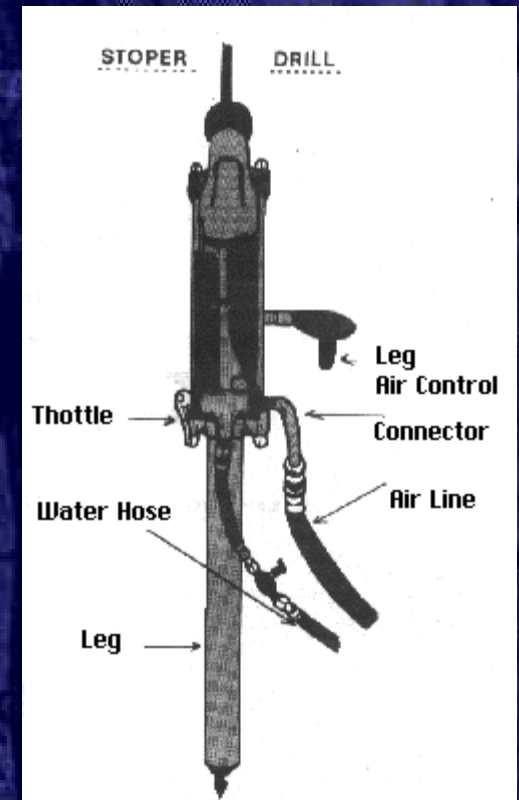
After all of the muck is removed, the heading is rock bolted or timbered.



Using a Stoper Drill to drill holes for installation of screen & rock bolts..



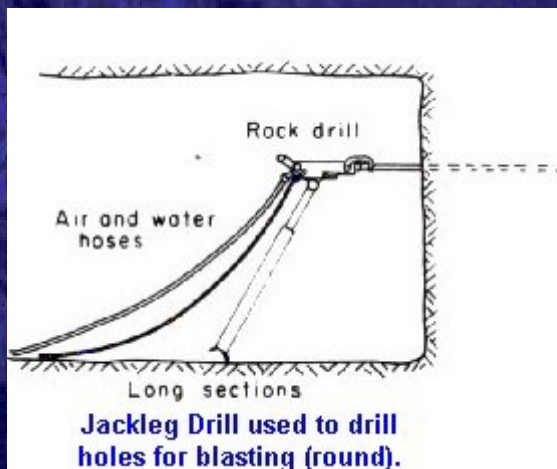
Installation of Rock Bolts.



Drift Cycle

Phase 4

If no ground support is needed, then drilling of the next round is started. A jackleg drill is usually used but jumbo drills are becoming popular.



Jackleg



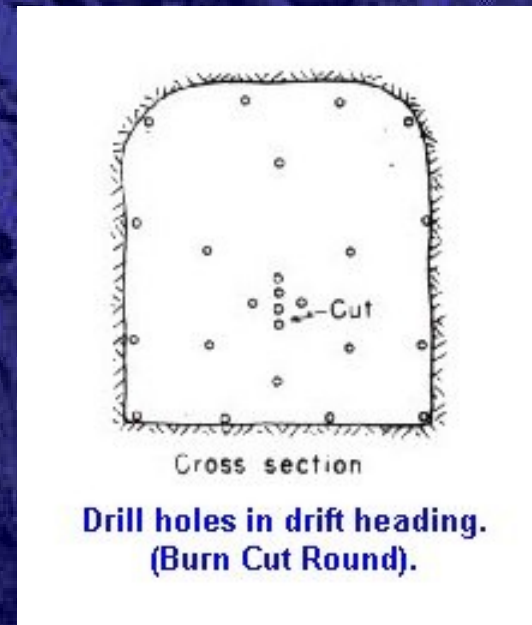
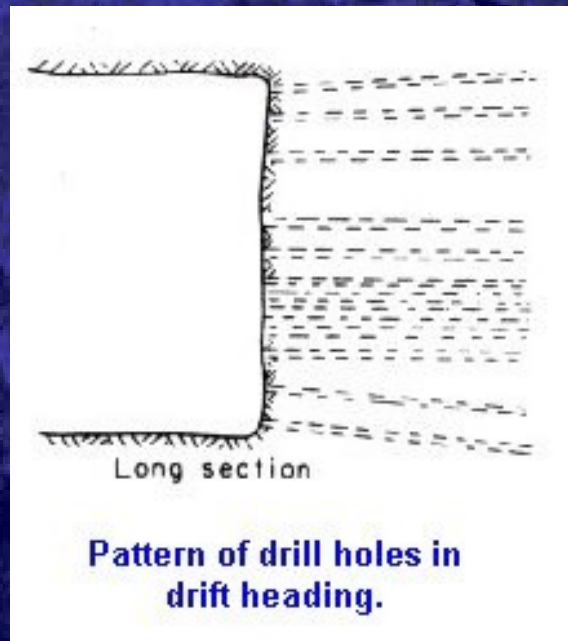
Jumbo



Drift Cycle

Phase 4

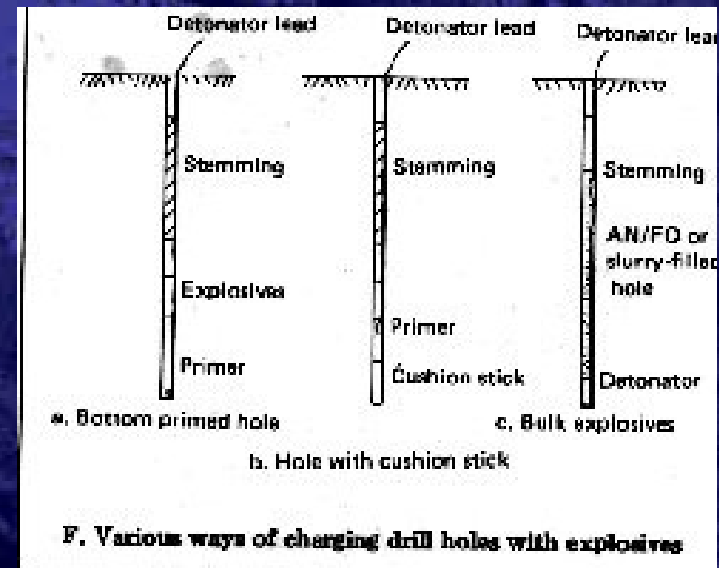
A burn-cut round is used to break the advancing heading.

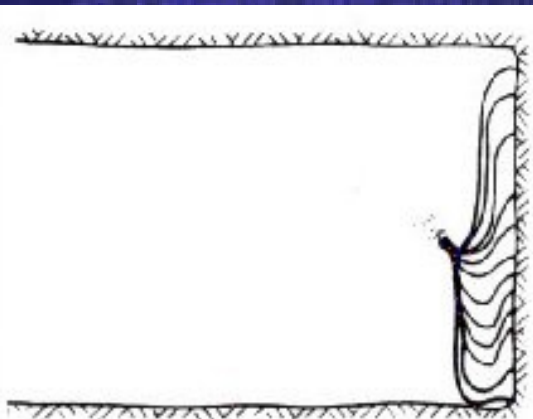


Drift Cycle

Phase 5

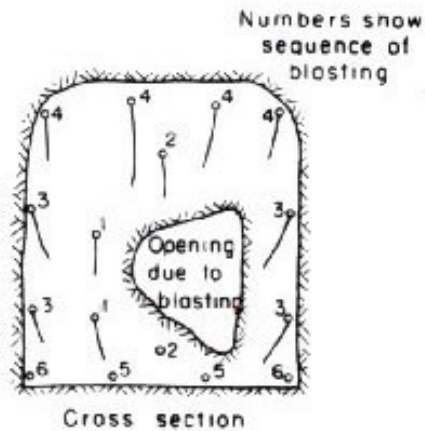
Loading the round comes next. The first stick of explosive that goes into the hole is called the detonator stick, which contains the cap and fuse. The rest of the hole is then filled with explosive.





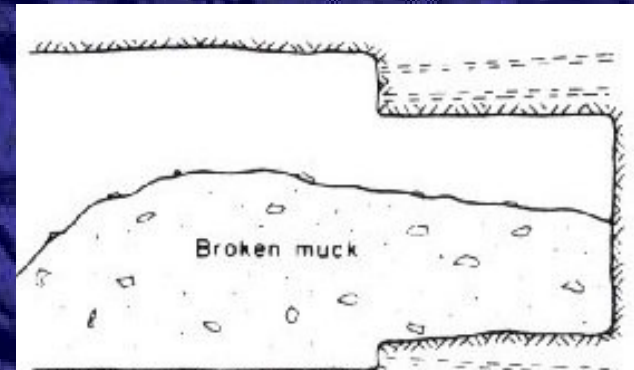
Long section

Lighting the fuses.



Cross section

Heading after cut and 2 relievers have been detonated.



Long section

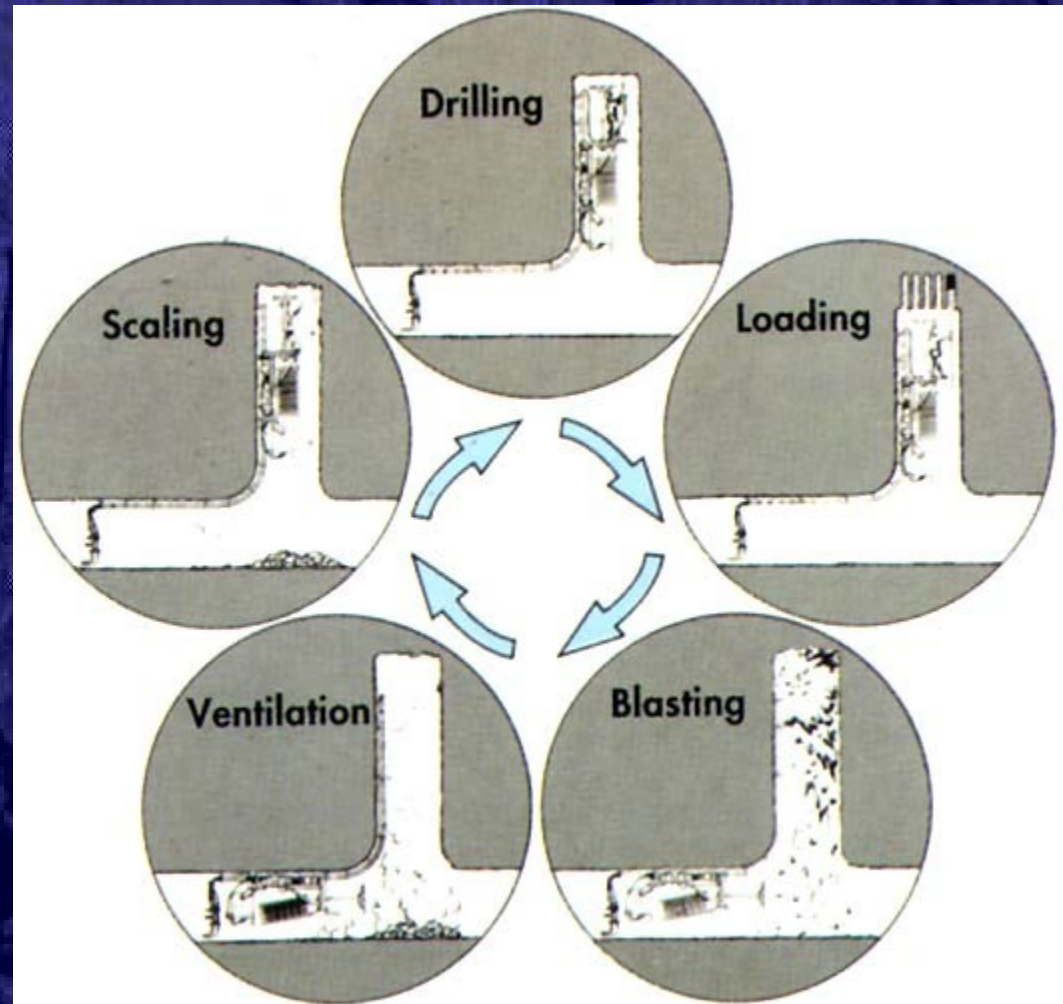
Round after all holes except back and lifters have been detonated.

Once the opening has been blasted the cycle starts again.

Vertical Development

a) Raise Machines (Alimak)

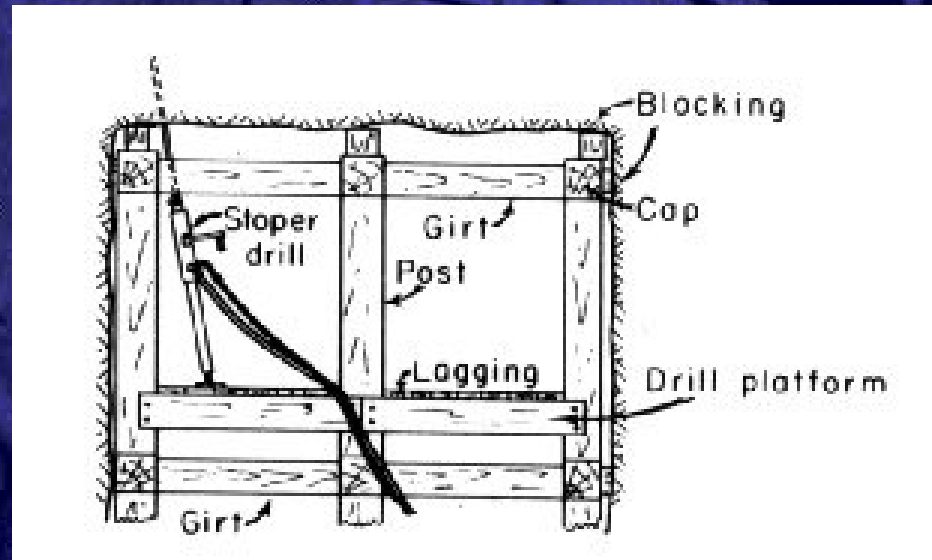
A recent development in driving raises is the **mechanical raise-climbing machine**, which runs on a track fastened to the sides of the raise. It includes a drilling platform and a means of hauling supplies up the raise.



Vertical Development

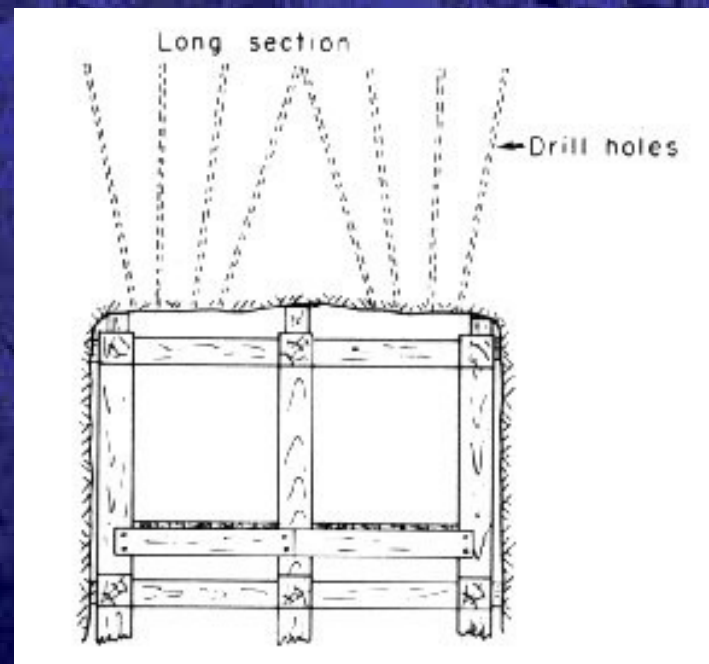
b) Timbered Raise Cycle

A stoper drill is commonly used for drilling in a raise.



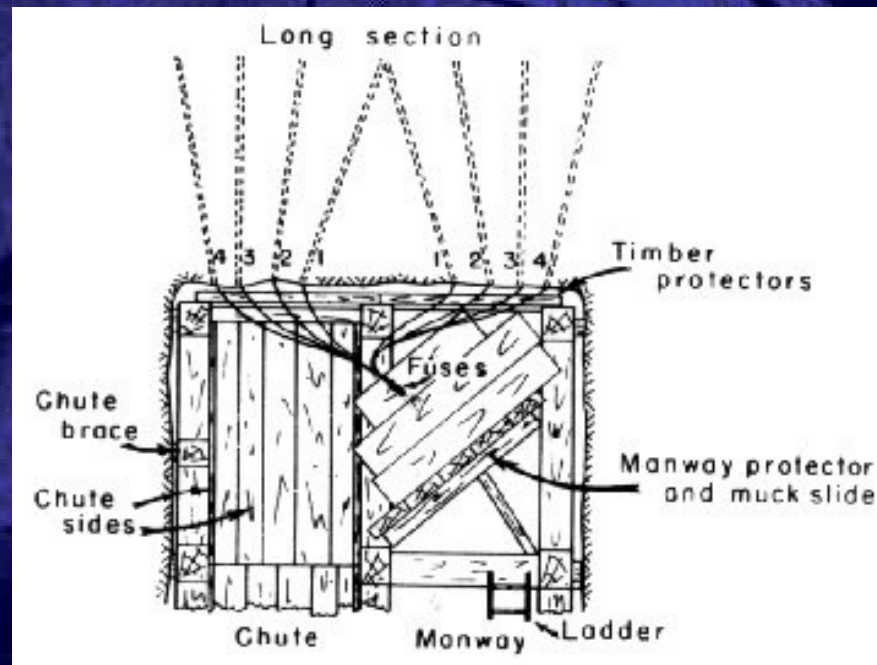
Vertical Development

The V-cut type of round or drill pattern is popular.

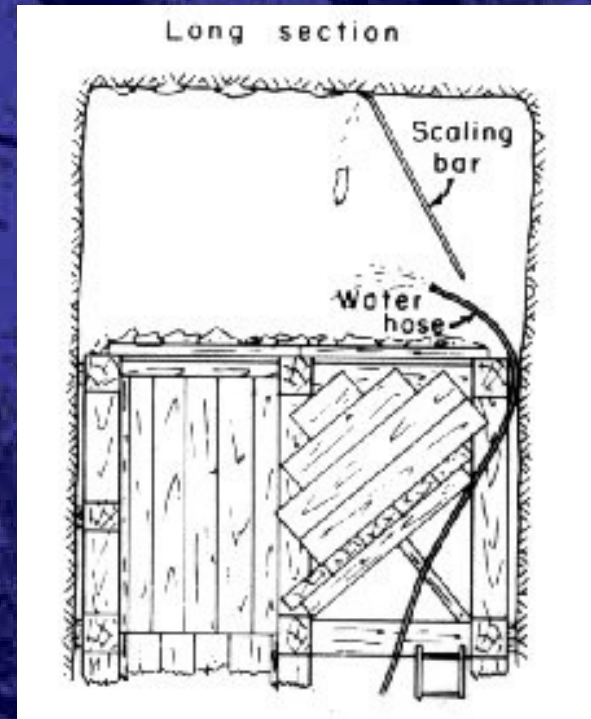
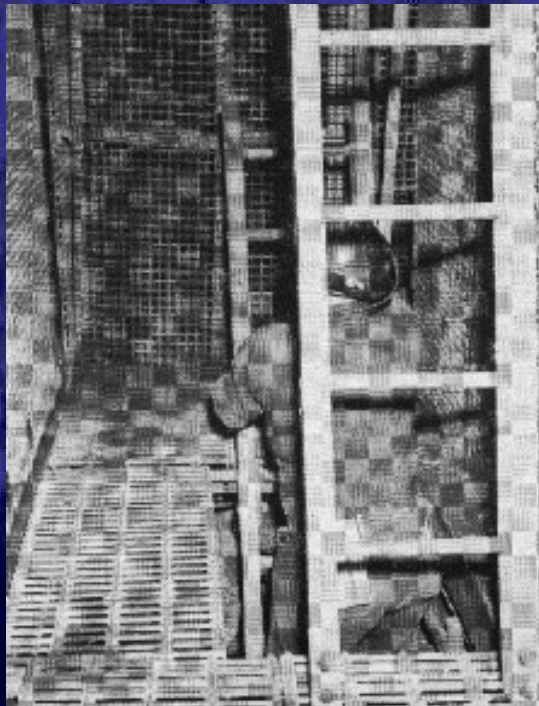


Before blasting down the round, the timber below must be protected and the blasted rock must be directed into an orepass or chute.

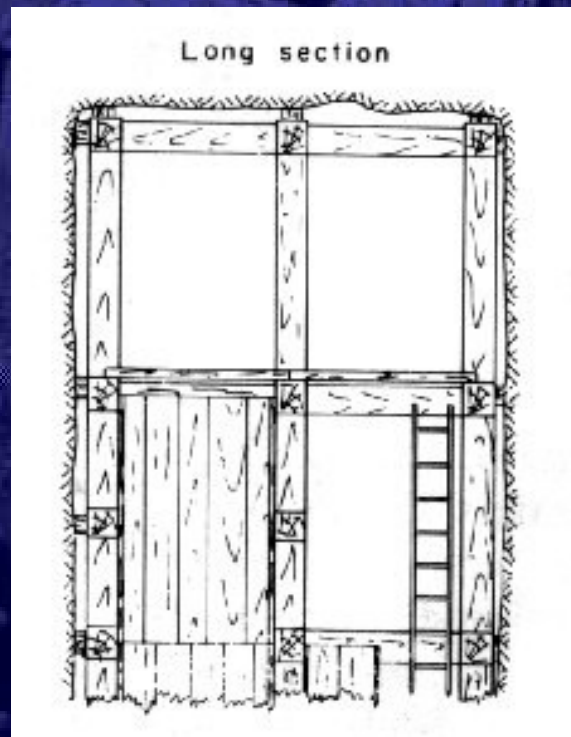
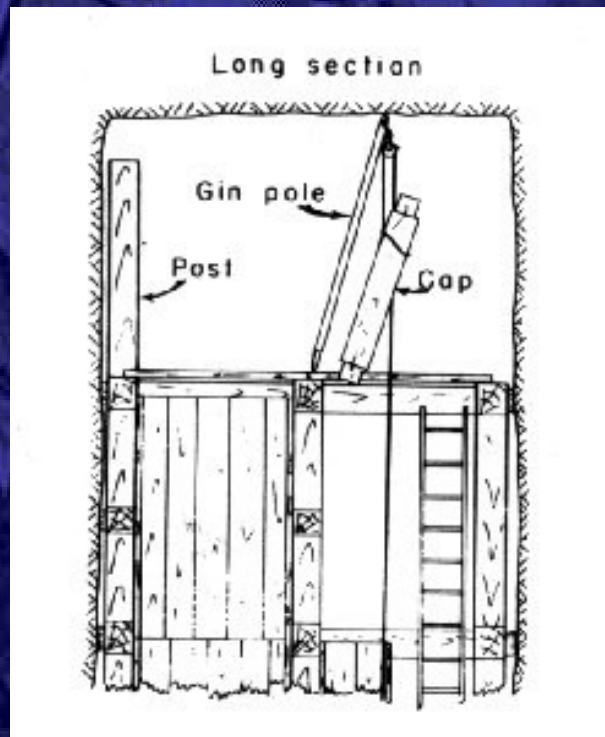
A common procedure is to direct the ore into a slide, which keeps the broken ore from dropping down the manway. The timbers that are directly exposed to the blast are covered with lagging. The round is then loaded and blasted.



After the blast, the loose rock needs to be cleaned away and water is used to control the dust. The loose rock on the back and sides must be scaled down.



After the raise has been made safe, the manway slide is removed, a floor is built on top of the timber set, and the timber for the next set is hoisted and set in place where it is aligned and blocked tightly into position.

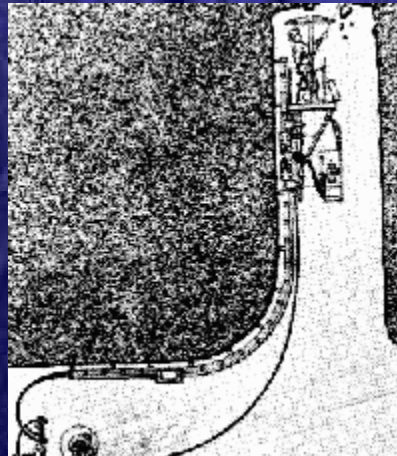


The cycle is then ready to start again

Raise Machines

A recent development in driving raises is the mechanical raise-climbing machine, which runs on a track fastened to the sides of the raise. It includes a drilling platform and a means of hauling supplies up the raise.

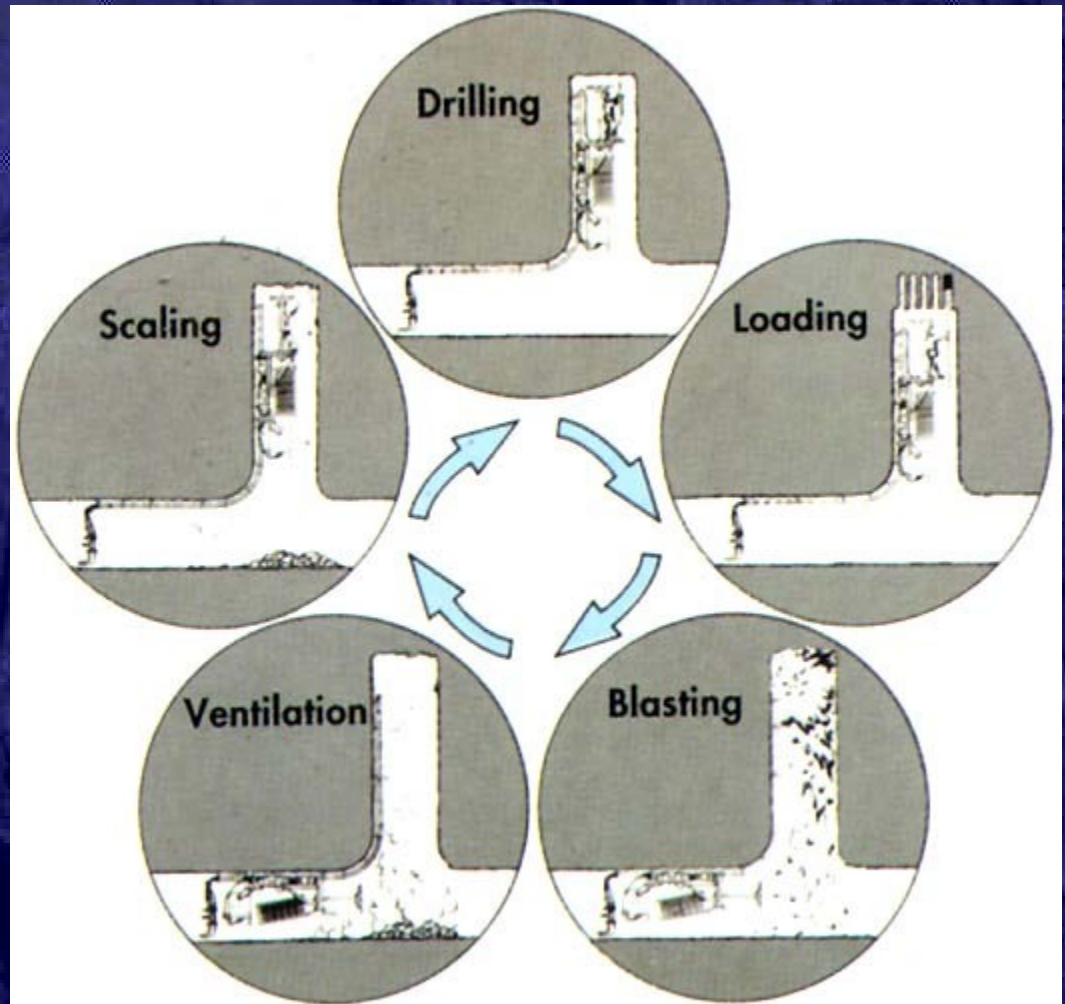
When the climber gets to the top of the raise, the miners climb onto the deck, scale down the loose rock, and are ready to drill. When drilling is complete, another section of track is added and the climber is moved down to a protected position.



On this track is a row of teeth, which meshes with the gear on the raise climber. Turning the gear directs the climber up or down the raise. The climber is driven by compressed air.

Alimak Raise Cycle

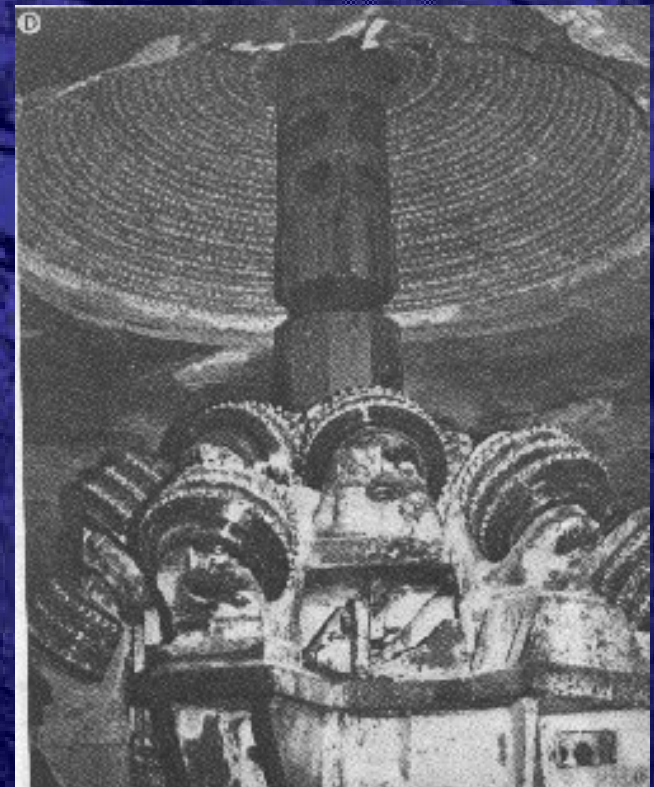
- Scaling
- Drilling
- Loading
- Blasting
- Ventilation



Raise Bore Machines

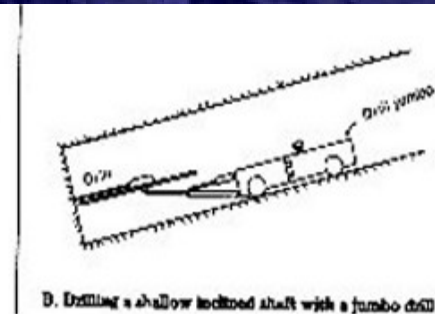
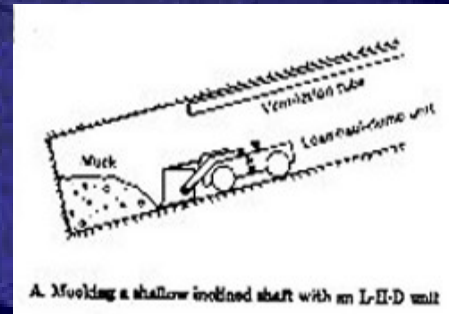
Hard rock can now be cut with various types of rotary bits so drilling or boring large diameter openings has become practical. A raise boring machine drills a pilot hole to the level below. A drill rod or shaft is extended through the hole to the level below where a large diameter bit is fastened on.

The raise bore machine lifts the bit and creates a high force or thrust of the bit against the face while rotating the bit. The finished section is smooth and often support is not required.

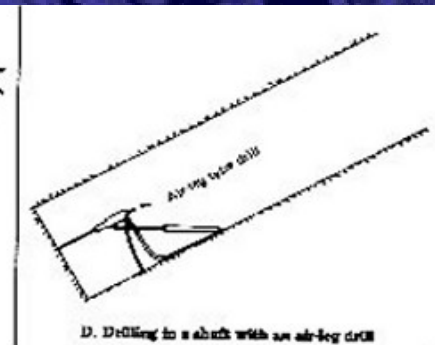
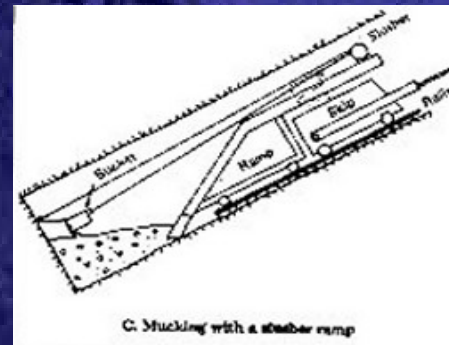


Ramp Development

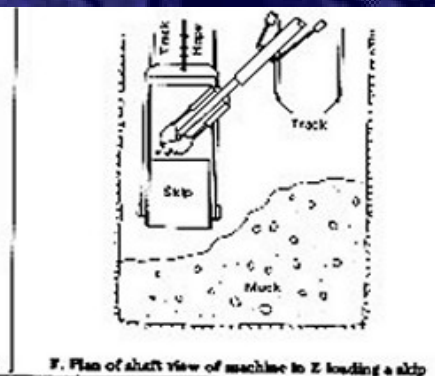
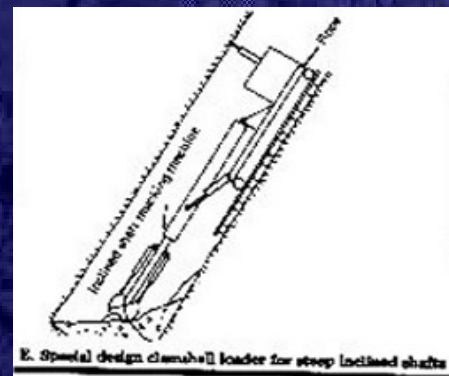
A. Using a LHD



B. Mucking Machine



C. Clamshell Loader



Development Costs

DEVELOPMENT	UNIT	OP LABOUR	OP SUPPLIES	MAINT LABOUR	MAINT SUPPLIES	CONTRACTS	TOTAL
Ore Drives	metre	272	540	153	106	0	1,071
Crosscuts	metre	320	635	180	125	0	1,260
Ladder Raises	metre	220	150	0	0	0	370
Alimak Raises	metre	0	0	0	0	1,100	1,100

You have reached the end of Unit 16