UNDERGROUND BLASTING

TUNNELING

There are two reasons to go underground and excavate:

i. to use the excavated space, e.g. for storage, transport etc.
ii. to use the excavated material, e.g. mining and quarrying operations.

In both cases tunneling forms an integral part of the entire operation.

The main difference between tunnel blasting and bench blasting is that tunnel blasting is done towards one free surface while bench blasting is done towards two or more free surface.

Various drilling patterns have been developed for blasting solid rock faces, such as:

i. wedge cut or V cut
ii. pyramid or diamond cut
iii. drag cut
iv. fan cut
v. burn cut

Wedge cut

Blasthole are drilled at an angle to the face in a uniform wedge formation so that the axis of symmetry is at the centre line of the face.

The cut displaces a wedge of rock out of the face in the initial blast and this wedge is widened to the full width of the drift in subsequent blasts, each blast being fired with detonators of suitable delay time.

The apex angle is as near as possible to 60^0 (Figure 1)

This type of cut is particularly suited to large size drifts, which have well laminated or fissured rocks. Hole placement should be carefully preplanned and the alignment of each hole should be accurately drilled.

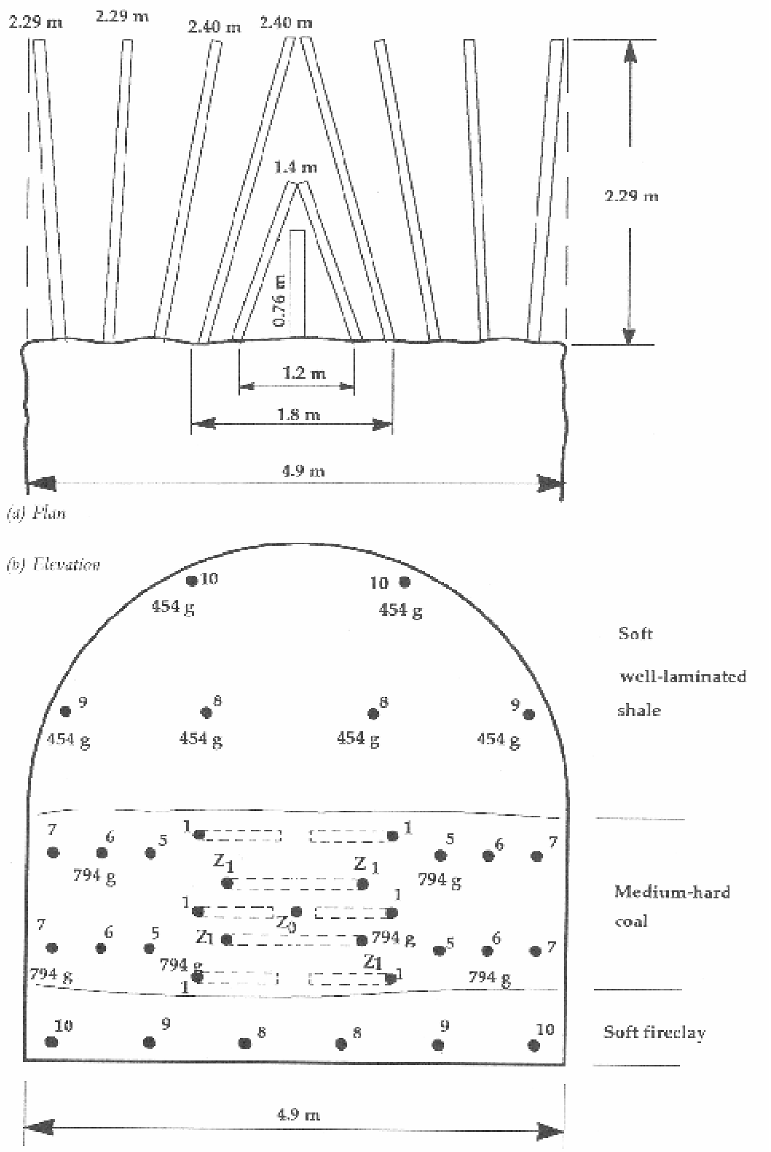

Figure 1: Wedge cut (after ICI)

Pyramid or diamond cut

The pyramid or diamond cut is a variation of the wedge cut where the blastholes for the initial cavity may have a line of symmetry along horizontal axis as well as the vertical axis (Figure 2).

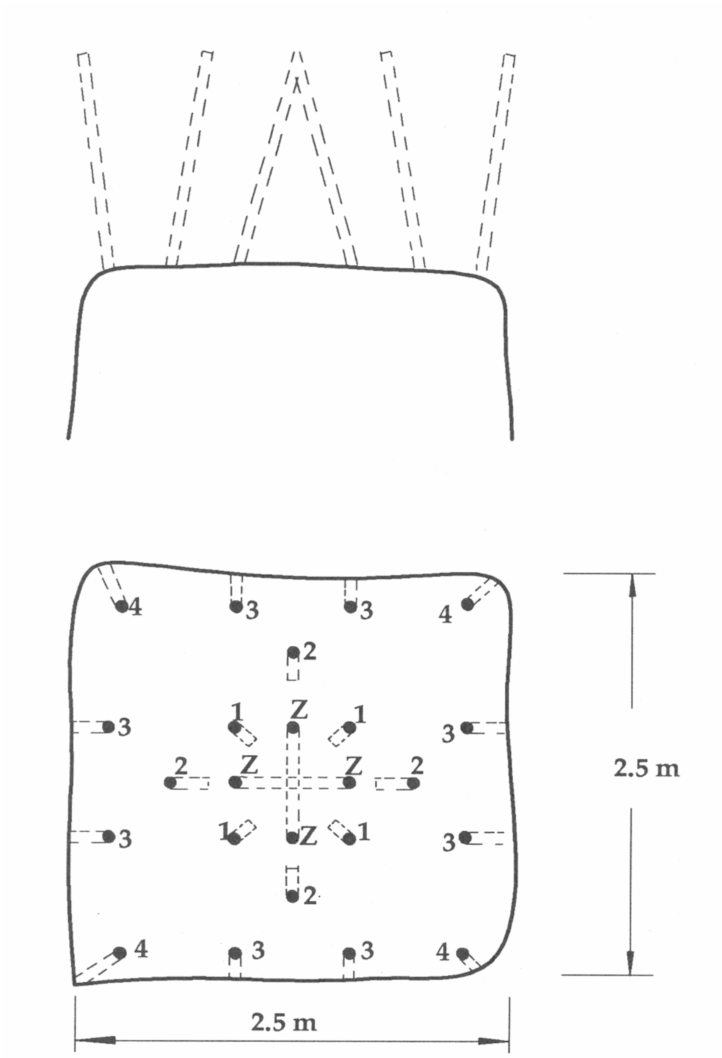

Figure 2: Pyramid or diamond cut (after ICI)

Drag cut

The drag cut is particularly suitable in small sectional drifts where a pull of up to 1 m is very useful (Figure 3).

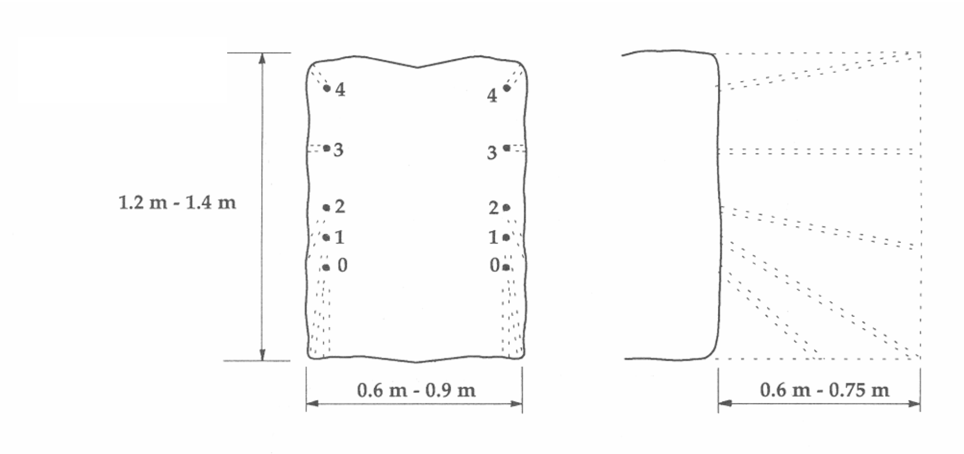

Figure 3: Drag cut

Fan cut

The fan cut is one-half of a wedge cut and is applicable mainly where only one machine is employed in a narrow drive. Generally the depth of pull obtainable is limited to 1.5 m (Figure 4).

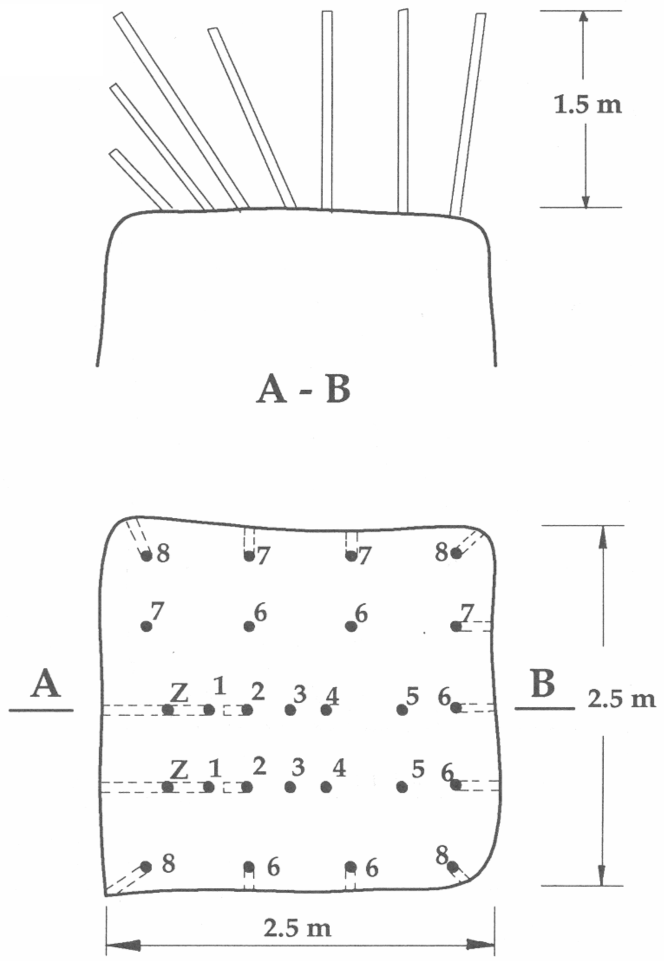

Figure 4: Fan cut

Burn cut

A series of parallel holes are drilled closely spaced at right angles to the face. One hole or more at the centre of the face are uncharged. This is called the burn cut (Figure 5).

The uncharged holes are often of larger diameter than the charged holes and form zones of weakness that assist the adjacent charged holes in breaking out the ground.

Since all holes are at right angles to the face, hole placement and alignment are easier than in other types of cuts. The burn cut is particularly suitable for use in massive rock such as granite, basalt etc.

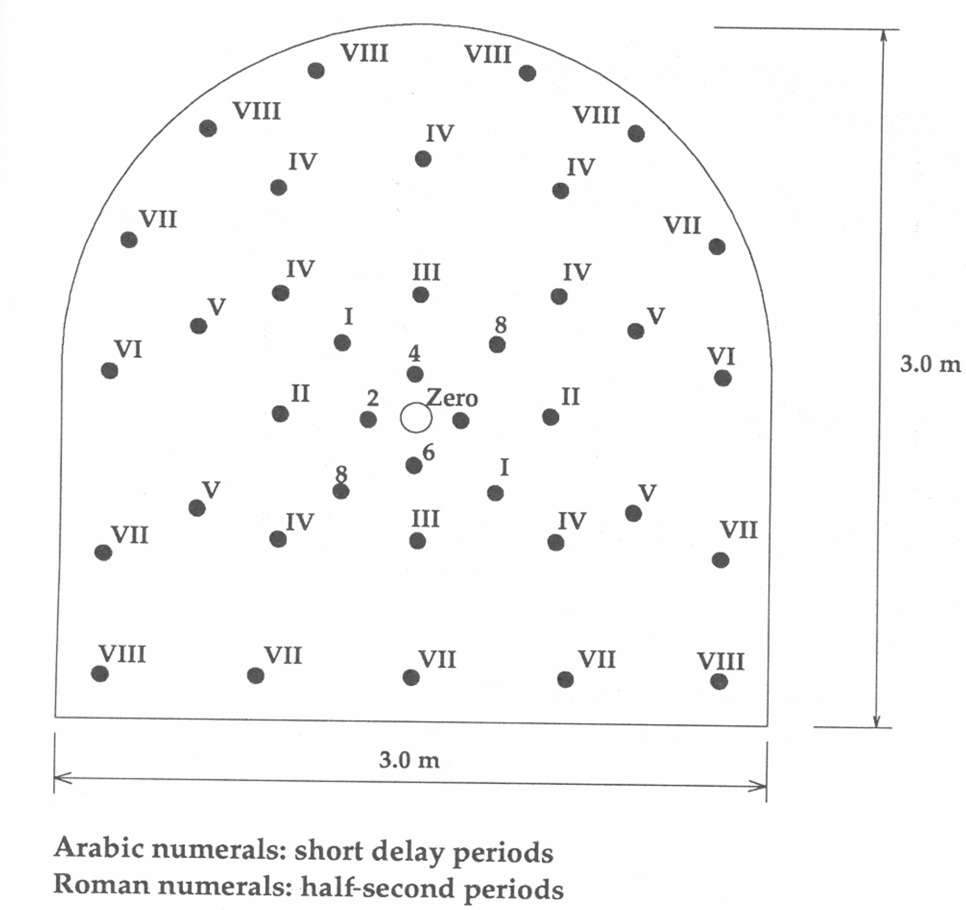

Figure 5: Burn cut (after ICI)

Sequence of detonation

For both fragmentation and throw, blasting efficiency depends on the delay sequence of blasthole detonation. Delayed detonation improves loadability of the entire cut, contributes to a better strata control and reduction of blast-induced vibrations.

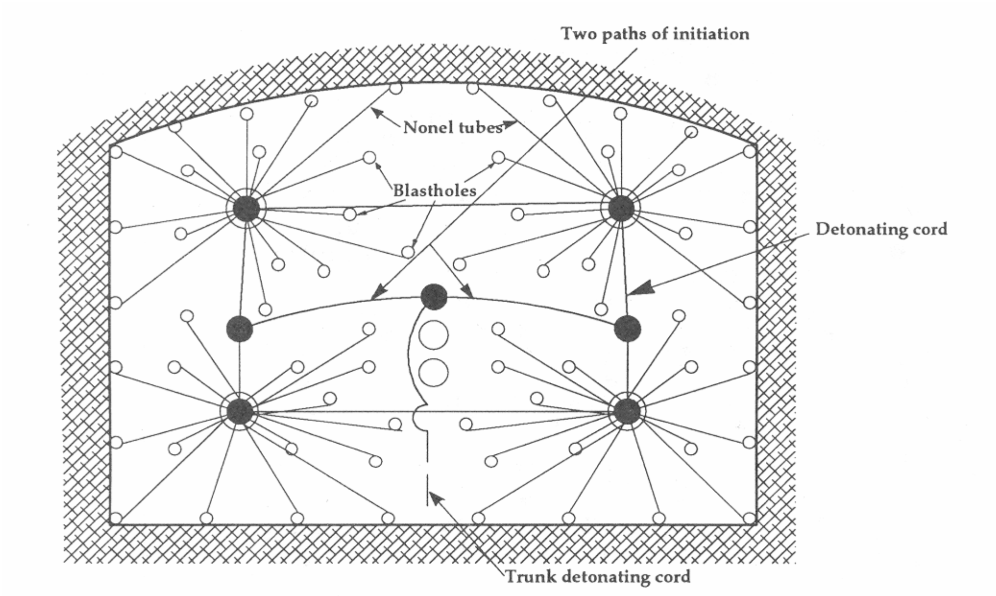

Figure 6: Bunch blasting with Nonel tubes and detonating cord.

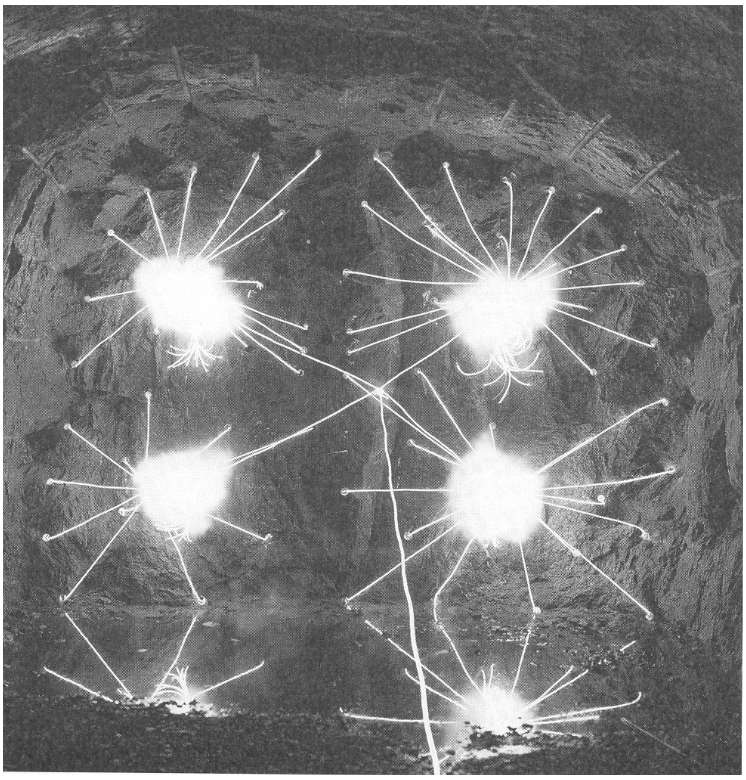

Figure 7: Firing of tunnel round with Nonel (after Olofsson)

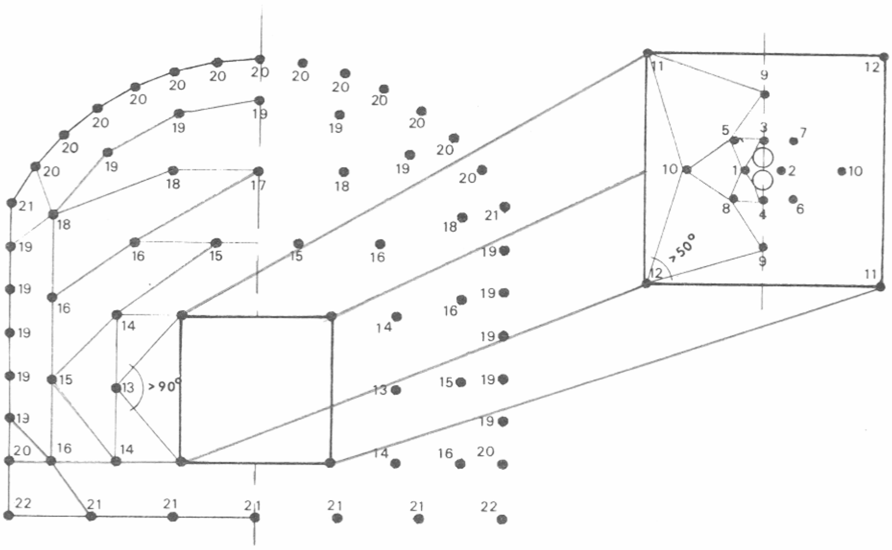

Figure 8: Firing sequence for tunnel numerical order.

SHAFT SINKING

In mining, shafts form a system of vertically or inclined passageways, which are used for transportation of ore, refill, personnel, equipment, air, electricity, ventilation etc. In quarrying, glory holes for transportation of materials such as at Perak Hanjoong.

An important requirement in shaft sinking is to provide optimum fragmentation of the rock so that it can be cleared quickly from the congested shaft-face area.

Blasting operation is carried out against gravity, and the scatter of the broken rock is confined in the shaft. It is common to use generous distribution of explosives throughout the rock using a large number of small diameter (35 – 42 mm) shotholes.

The number of holes N required for sinking a shaft of cross sectional area A in m^2 is given by:

$$N = 2.5A + 22$$

The drilling patterns for shaft sinking are basically the same as those used in tunneling but generally the cone cut is favoured (Figure 9 and 10).

Another commonly used pattern, unique to shaft sinking, is the bench cut (Figure 11 and 12)

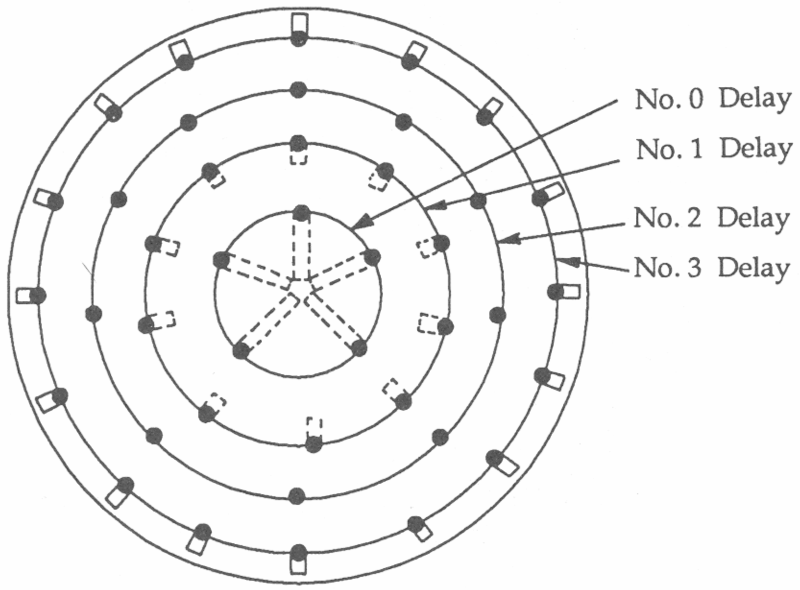

Figure 9: Full-face blasthole pattern for shaft sinking.

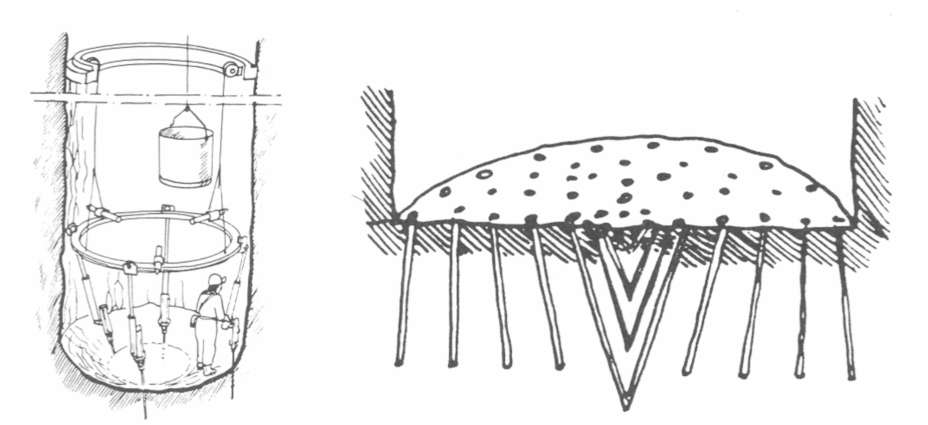

Figure 10: Shaft sinking with cone or pyramid cut.

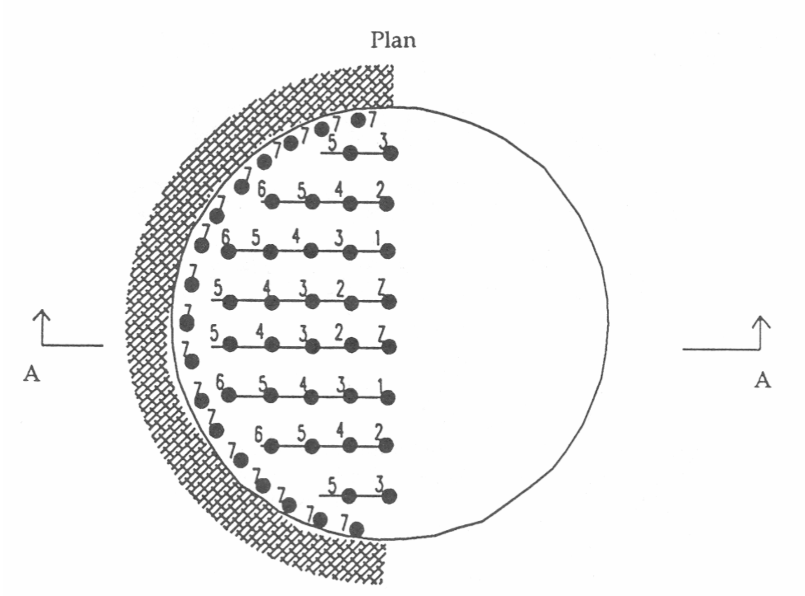

Figure 11: A bench-cut blasthole for shaft sinking.

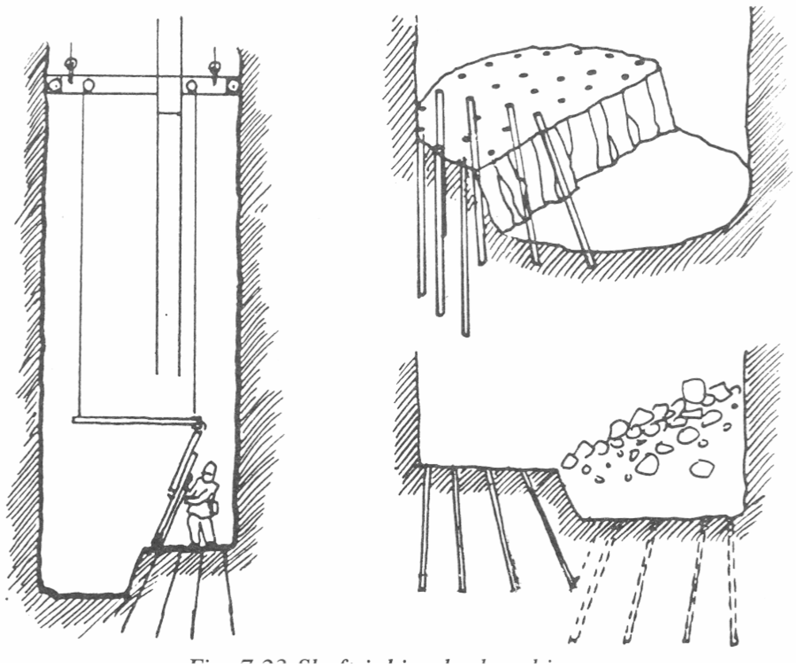

Figure 12: Shaft sinking by benching.

The explosives used in shaft sinking must always be water resistant. Even if the ground is dry, the flushing water from the drilling machines will always stay in the blastholes.

Suitable explosives such as Emulex 150 or any suitable NG based explosives are easily tamped to utilize the hole volume well.

The powder factor in shaft sinking is rather high, ranging from 2.0 kg/m^3 to 4.0 kg/m^3 (Olofsson).

If charges are fired electrically, great care must be taken in wiring the circuit. Since more than 100 detonators can be involved in each blast, they are connected either in parallel or in series-parallel.

It is therefore, important to ensure that the resistance of the circuit is properly balanced and that no charged hole is omitted from the circuit.

Due to higher risk of such errors in the generally unfavourable shaft sinking environment, Nonel type detonators are increasingly preferred for initiation.

BLASTING IN UNDERGROUND MINES

Underground mines are to extract underground metal-bearing orebodies. The excavation work for underground mines is usually divided into two broad categories. These are the development and production.

Development involves tunneling, shaft sinking, cross cutting, raising, etc so that the ore bodies are easily accessible and transportable after excavation. The blasting procedure is the same as discussed previously.

The production work can be subdivided into two categories: short-hole and long-hole blasting.

Short-hole blasting

The diameter and length of shotholes are usually limited to 43 mm and 4 m respectively.

Short-hole blasting is usually used in breast stoping for narrow, tubular orebodies such as gold or platinum reefs.

Figure 13 is an example of blasting arrangement in breast stoping in a gold mine in South Africa. Capped safety fuse and igniter cord (burning speed of 18 s/m) make the carrier of the initiating system.

The igniter cord is usually fired by an electric starter for igniter cord.

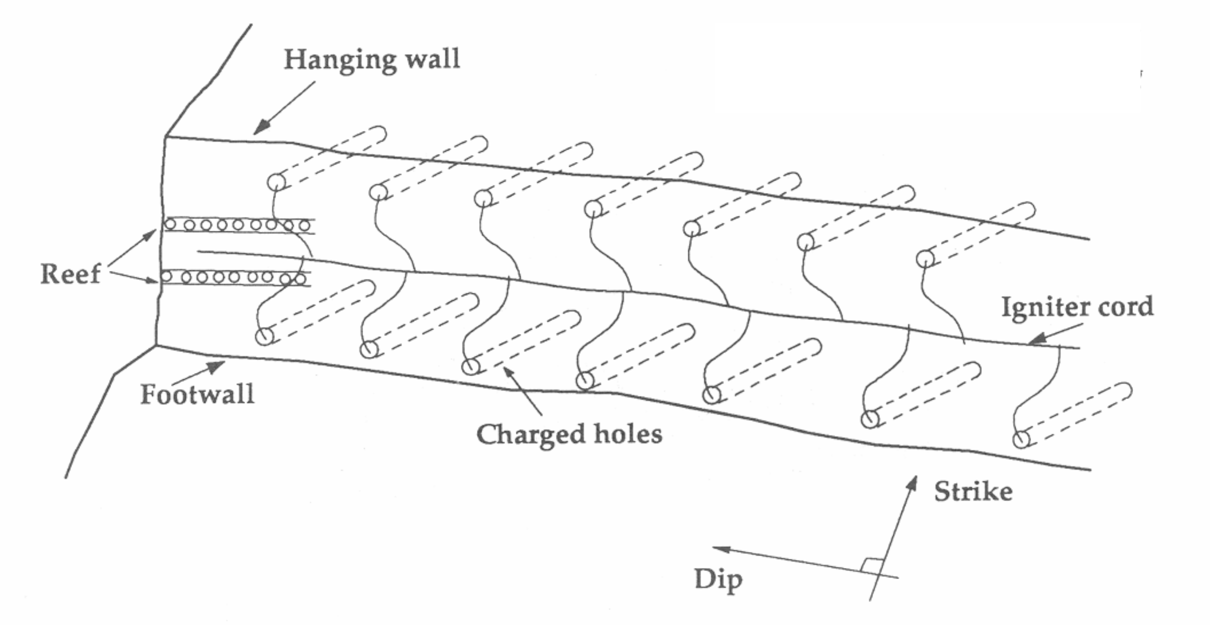

Figure 13: Blasting arrangement in breast stoping.

Long-hole blasting

Basically there are three long hole blasting systems: ring blasting, bench blasting and vertical crater retreat (VCR).

i. Ring blasting

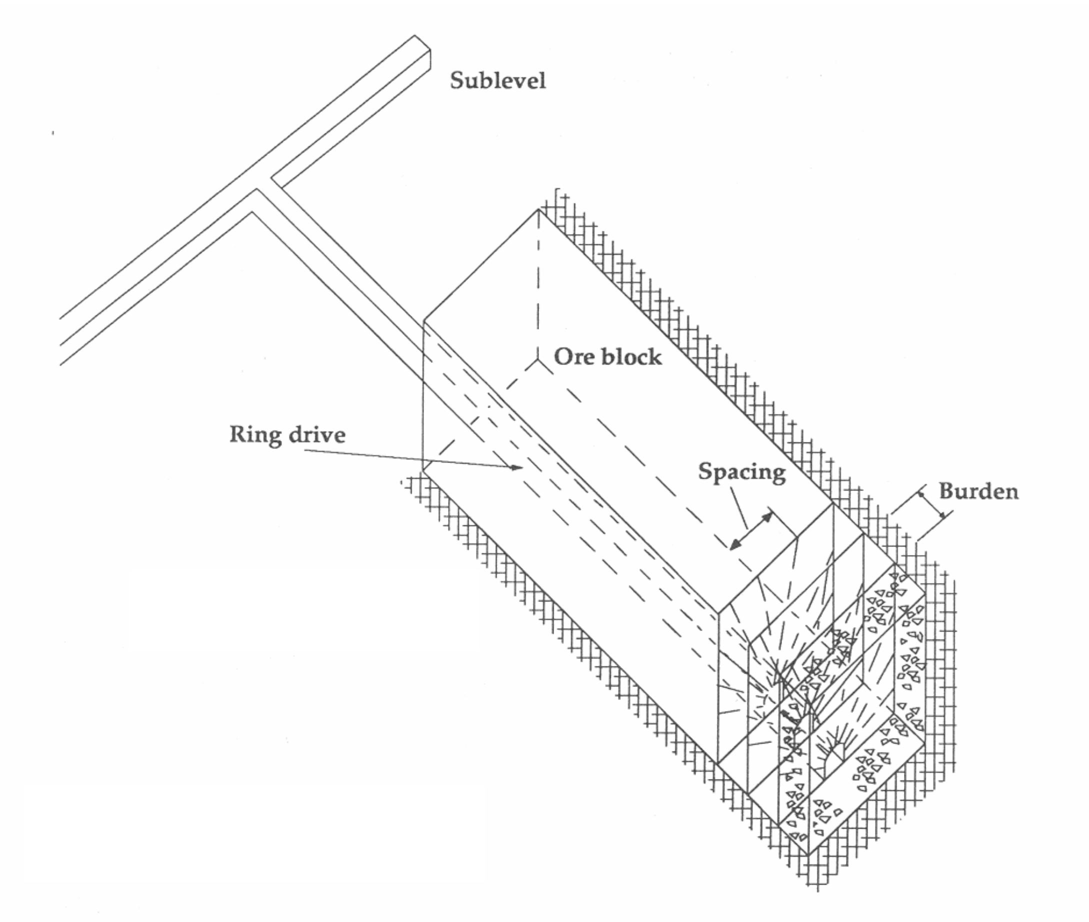

Figure 14: Operations in ring blasting (after AECI).

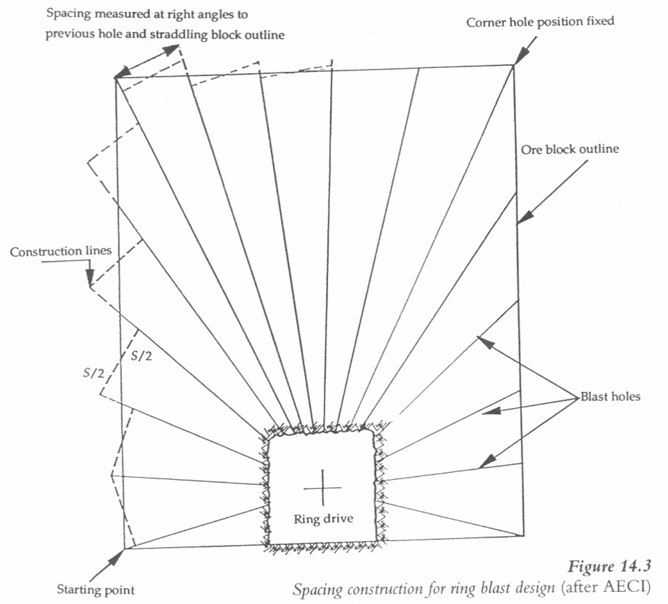

Figure 15: Spacing constructions for ring blast design (after AECI)

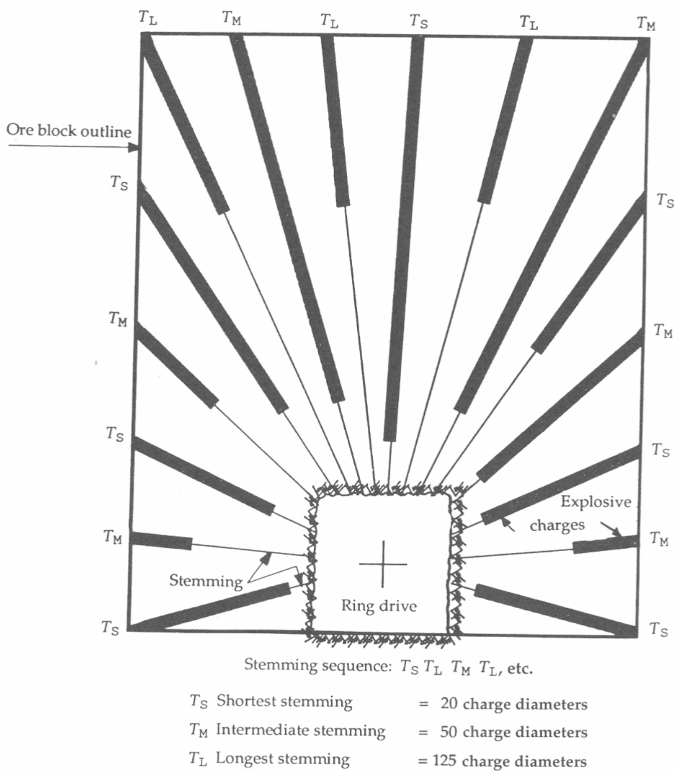

Figure 16: Stemming length for ring blasting.

ii. Bench blasting

Bench blasting is essentially to surface excavation. A development heading is first excavated at the top sublevel to provide drilling space. Then depending on thickness of orebody and/or availability of drilling machinery, either vertical or horizontal blastholes are drilled to increase the height of the excavation

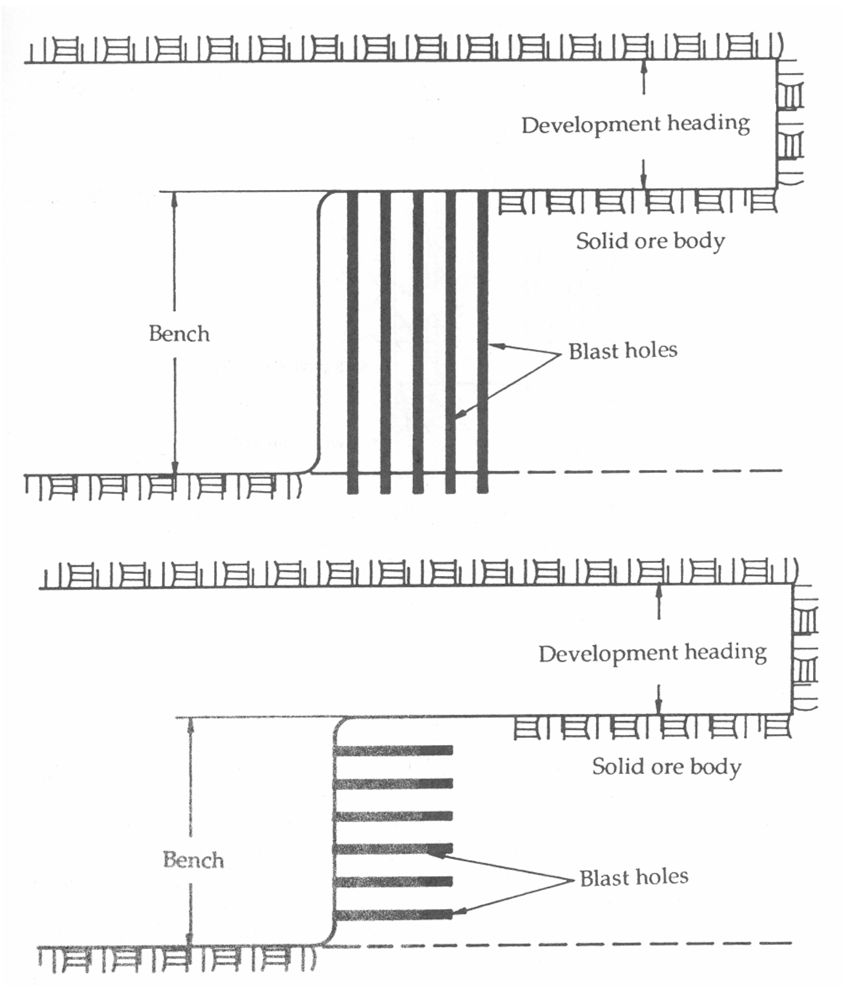

Figure 17: Bench blasting methods.

iii. Vertical Crater Retreat (VCR)

Vertical or subvertical blastholes are drilled downward from the top level to the bottom level. A cuboid of orebody can be excavated from the lower level upward by a number of horizontal slices using the same blastholes (Figure 18).

Spherical charges should be placed to obtain the maximum cratering effect. Gravity enlarges the crater dimensions.

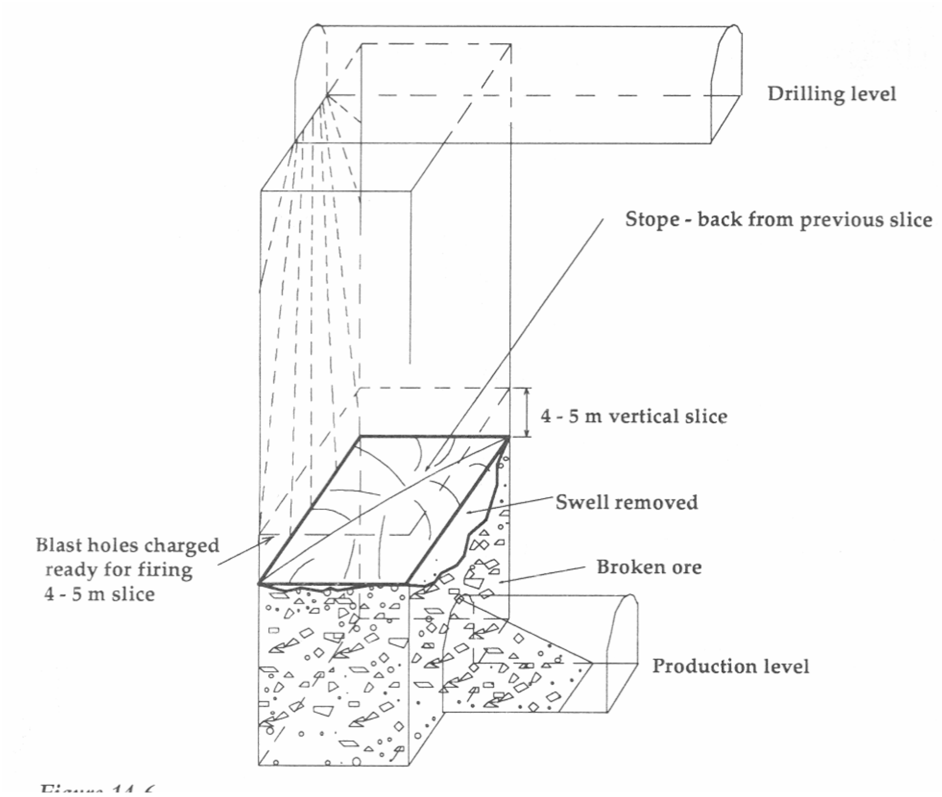

Figure 18: Vertical crater retreat method (after Agnew Nickel).

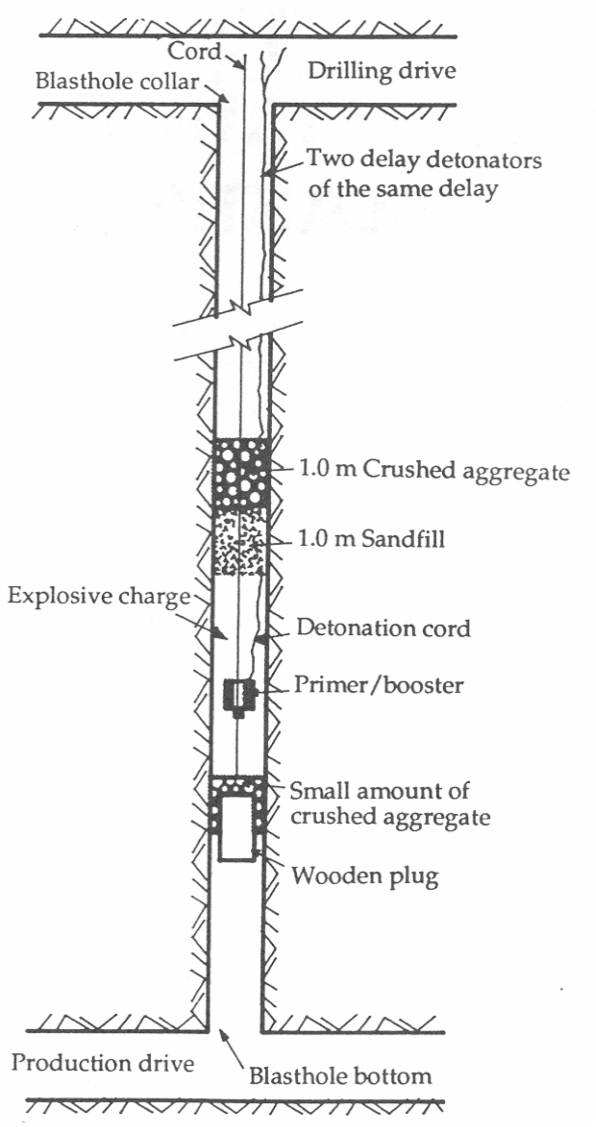

Figure 19: Arrangement of VCR blasting (after Edwards).