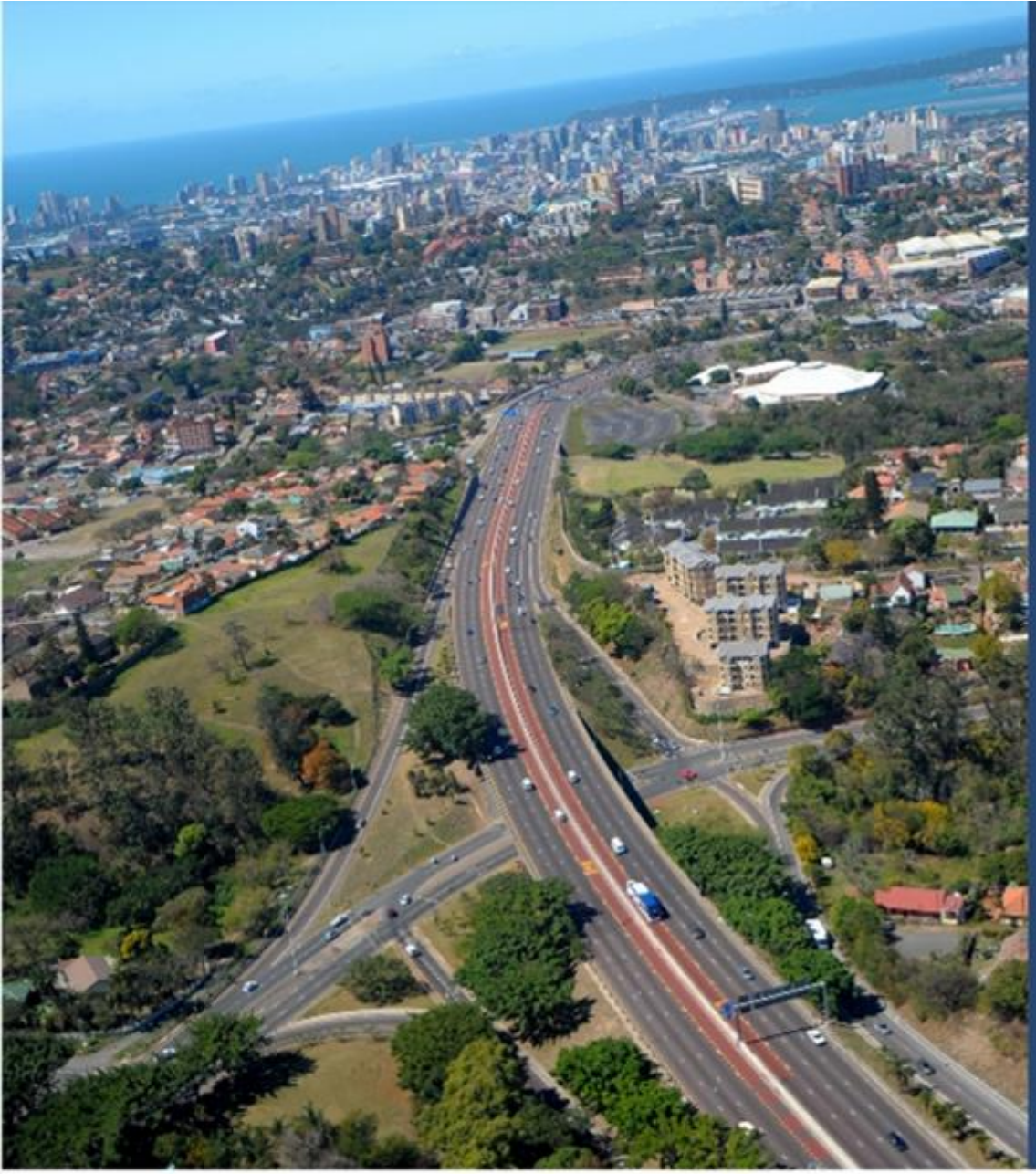
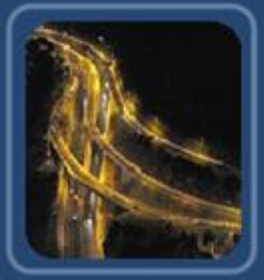


SARF

better roads



South African Road Federation

12.10
Hard Excavation by Blasting

Presented by Louis Melis

26 July 2021

Three factors affect the environment in blasting (**FIGURE** *3.10.-24.*):

- Air shock waves
- Ground vibration
- Flyrock

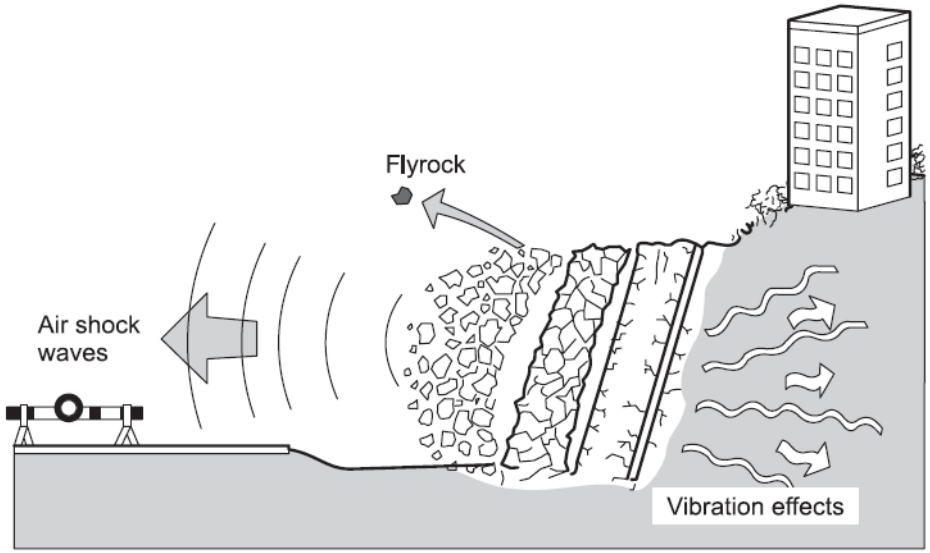
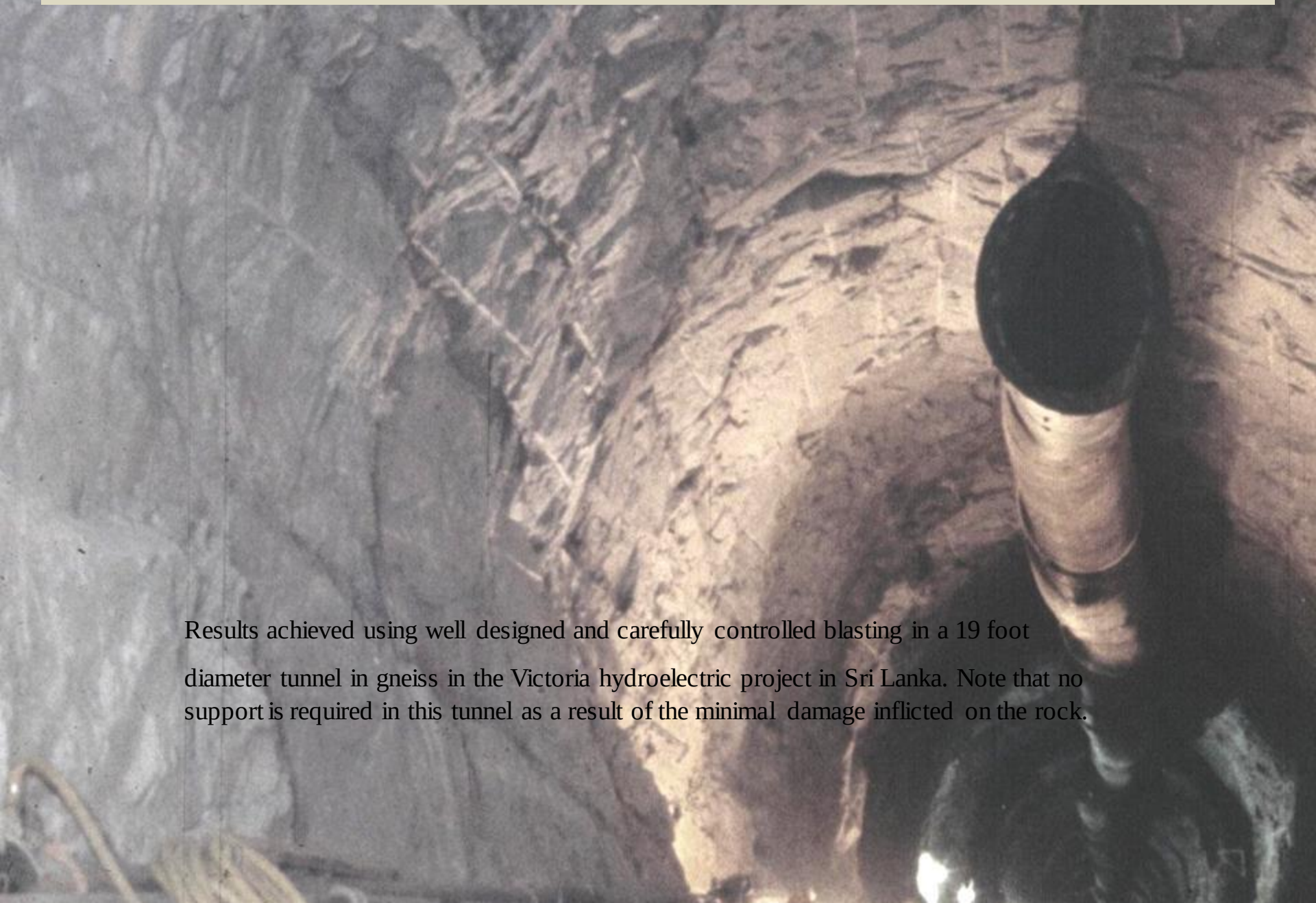


FIGURE *3.10.-24. Three factors that affect environment in blasting*

COTO 12.10 HARD EXCAVATION BY BLASTING

Comparison between the results achieved using controlled blasting (on the left) and normal bulk blasting for a surface excavation in gneiss.

COTO 12.10 HARD EXCAVATION BY BLASTING



Results achieved using well designed and carefully controlled blasting in a 19 foot diameter tunnel in gneiss in the Victoria hydroelectric project in Sri Lanka. Note that no support is required in this tunnel as a result of the minimal damage inflicted on the rock.

COTO 12.10 HARD EXCAVATION BY BLASTING

Blast Hole Drilling For Controlled Blasting:

- Equipment – Capable, Sturdy and Good working order.
- Accuracy – Drilling direction –deviation from alignment.
- Accuracy – Blast Hole Setting Out and Collaring/Positioning.
- Hole Diameter – Smaller and closer spacing results in more even distribution of Explosive Charge.

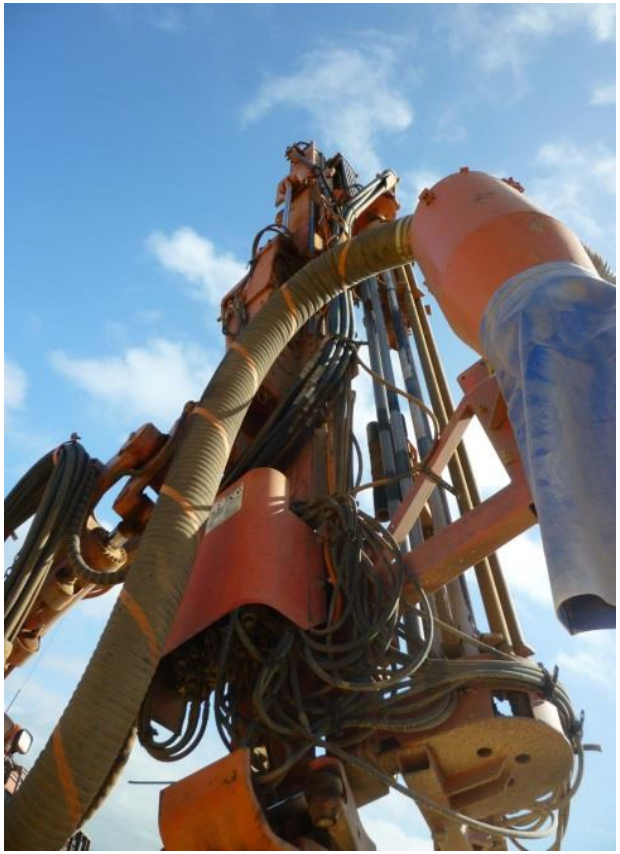


FIGURE *4.2.-42. Selection of bits.*

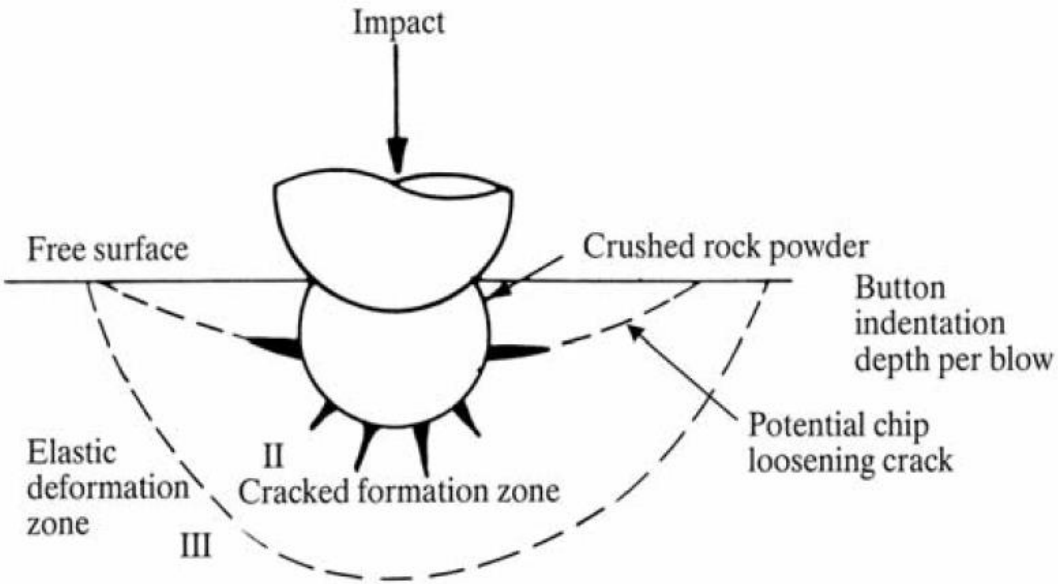
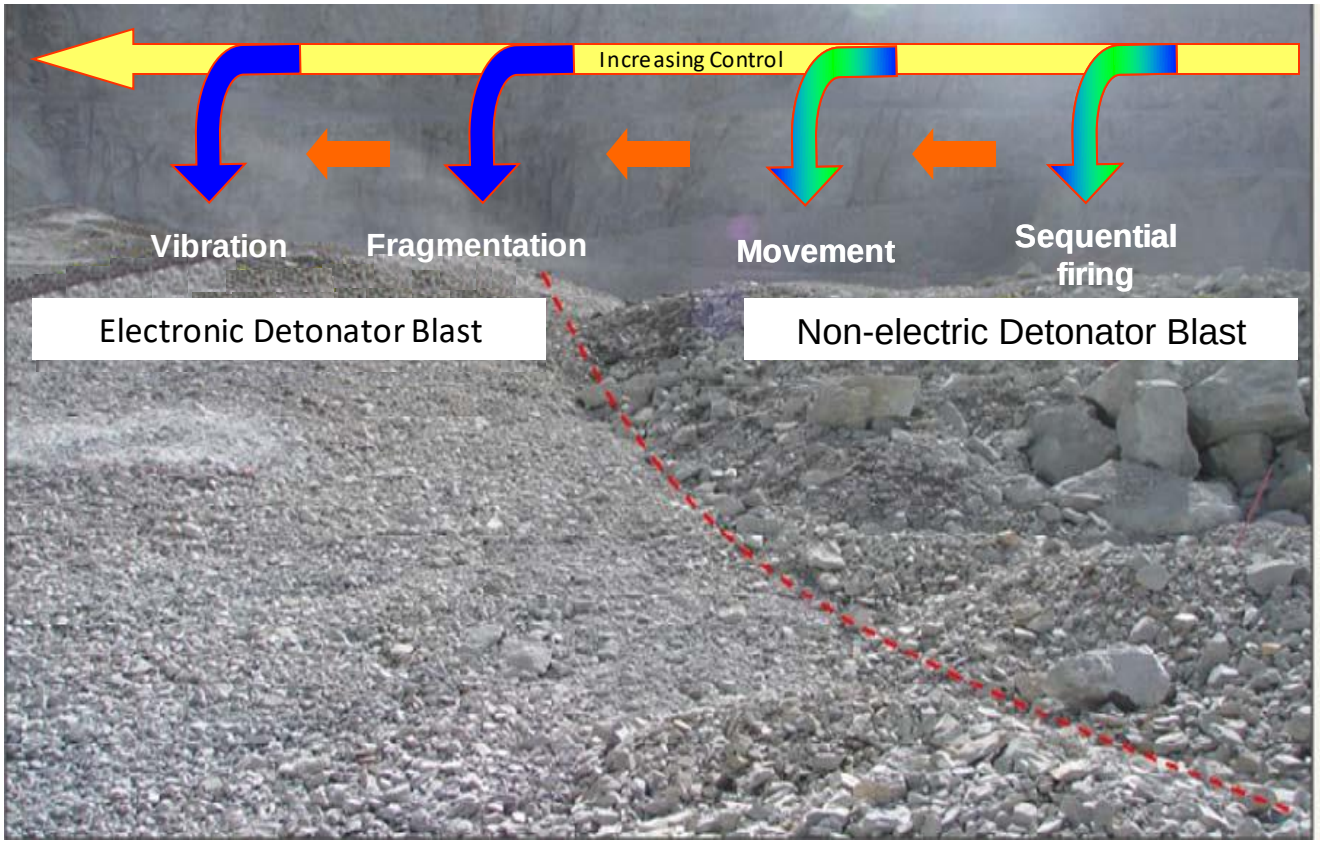


FIGURE *3.1.-1. Rock breakage in percussive drilling*

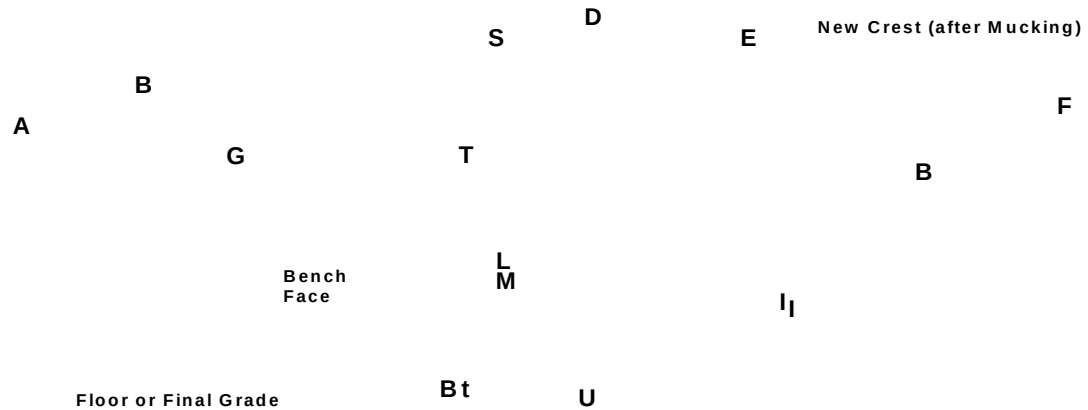
There is some confusion about the difference between a Heavy ANFO and a Doped Emulsion. The basic difference is that a Heavy ANFO can be augured whilst a Doped Emulsion is pumped. The difference is essentially the proportions of drill and base emulsion and whether the resulting mixture more closely resembles an emulsion or ANFO in terms of consistency and therefore the type of delivery equipment required. A general guide is that if the mixture contains 55% or more emulsion phase, then it is a doped emulsion.

Importance of accuracy

- Vibration
  - Accuracy
    - Sub-millisecond
  - Single hole firing

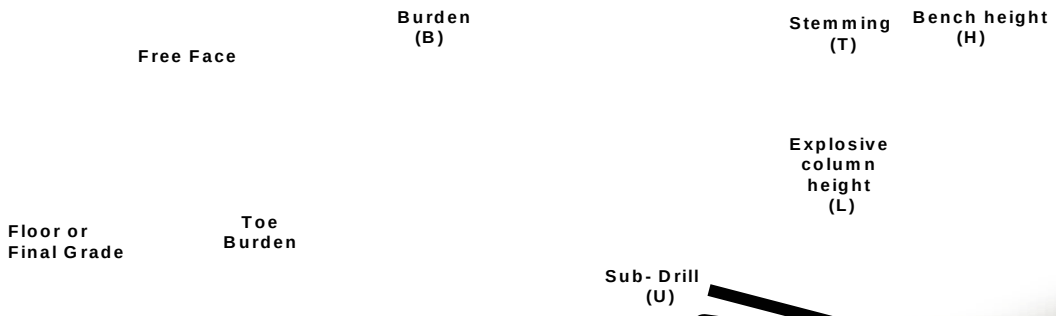


Blast Design - Bench Parameters



A	Hole to crest	**G**	Crest	**L**	Explosive column height
B	Burden	**H**	Bench height	**U**	Sub drill
C	Bench floor	**I**	Bank angle	**Bt**	Toe burden
D	Hole diameter			**T**	Stemming height
E	Back break			**S**	Spacing
F	Side break				

True burden and spacing may be different than the apparent burden and spacing due to delay pattern



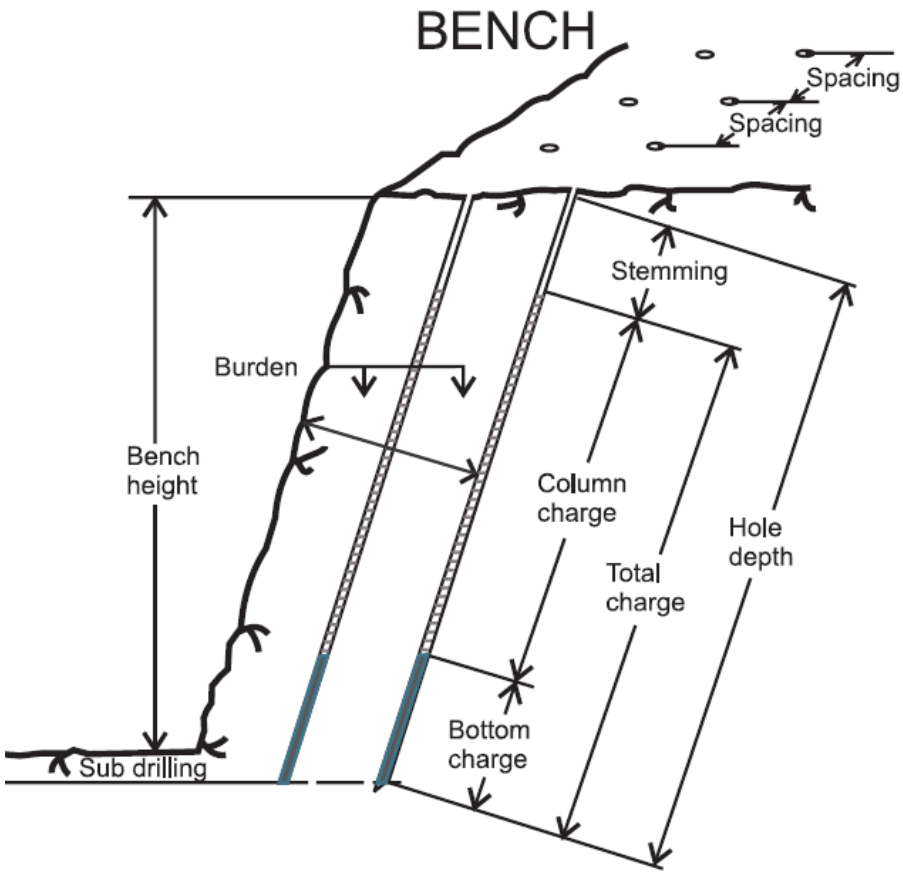
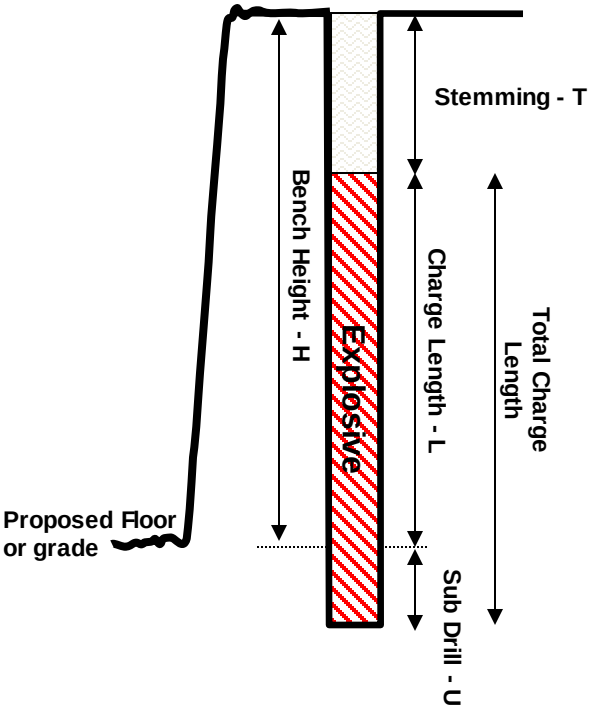
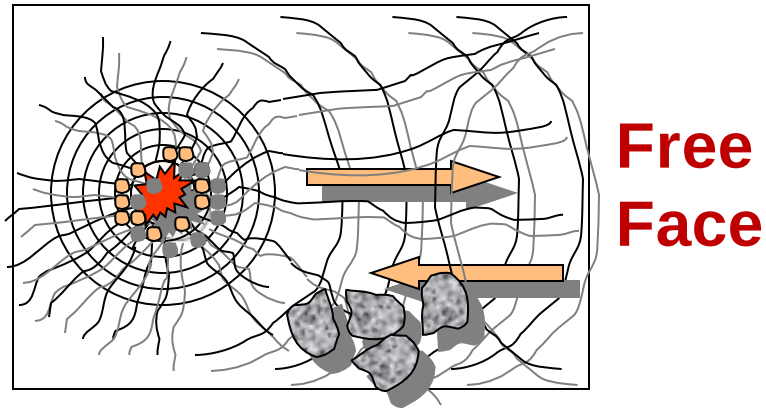


FIGURE *4.2.-5. Bench blasting*

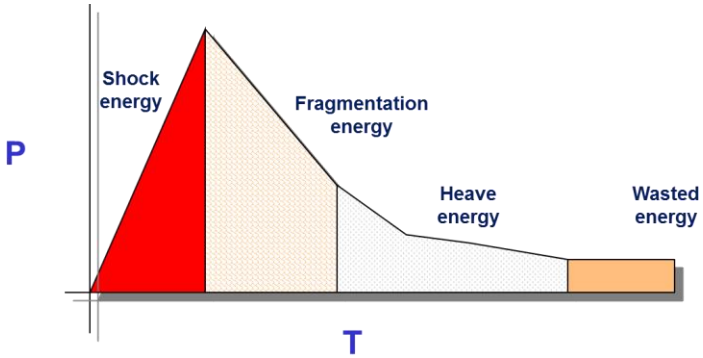
Bench height



Drilled Hole – Explosives events



- First Stage – Circular shockwave (crushing blast hole walls) – detonation shock front
- Second Stage – fragmentation stage – compressive stress wave – tensile stresses caused by reflection from free face – fissures / fractures from blast hole
- Third Stage – Gasses penetrate fissures / fractures and movement of rock occurs



Rock is affected by a detonation in three principal stages. First, a shock wave released by the detonation passes through the rock mass at a (detonation) velocity of 3000 m/s - 6000 m/s, depending mainly on the rock geology. This velocity corresponds to 0.15 - 0.3 milliseconds per meter of burden. The rock is stressed by compression (**FIGURE** *3.10.-20.*). The shock wave does not break the rock, but crushes the blasthole walls and produces microscopic joints, which help to break and cut the rock in the second stage.

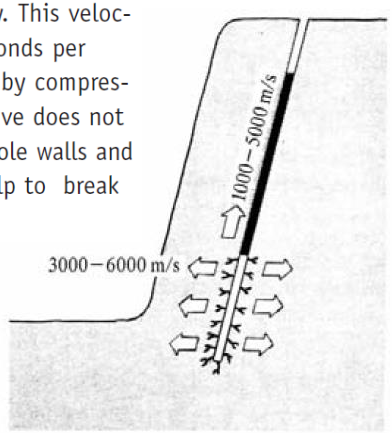


FIGURE *3.10.-20. Rock compression*

After reflecting from free faces, the shock waves expose the rock to tensile forces. Shock waves are reflected from bench faces or joints in the rock. Experiments have shown that the velocity of the shock wave after reflection is 500 m/s - 2000 m/s or 0.5 - 2.0 milliseconds per meter of burden. Tensile forces cause small primary, often radial, cracks that extend from the center of the hole (**FIGURE** *3.10.-21.*).

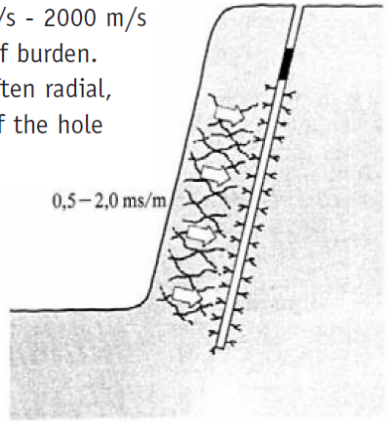


FIGURE *3.10.-21. Reflection of shock waves from free faces.*

Upon detonation, large quantities of high-pressure gases are formed. Through rapid heat release, the expanding gases spread into the primary cracks (**FIGURE** *3.10.-22.*). The cracks expand, the rock's free surface moves forward, pressure is unloaded and tension increases in the primary cracks. The primary cracks then expand to the surface which promotes the complete loosening of the rock. The burden is consequently torn off.

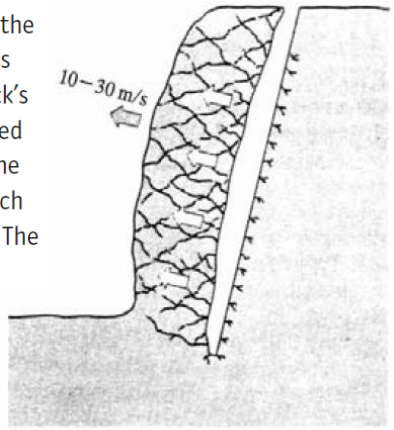
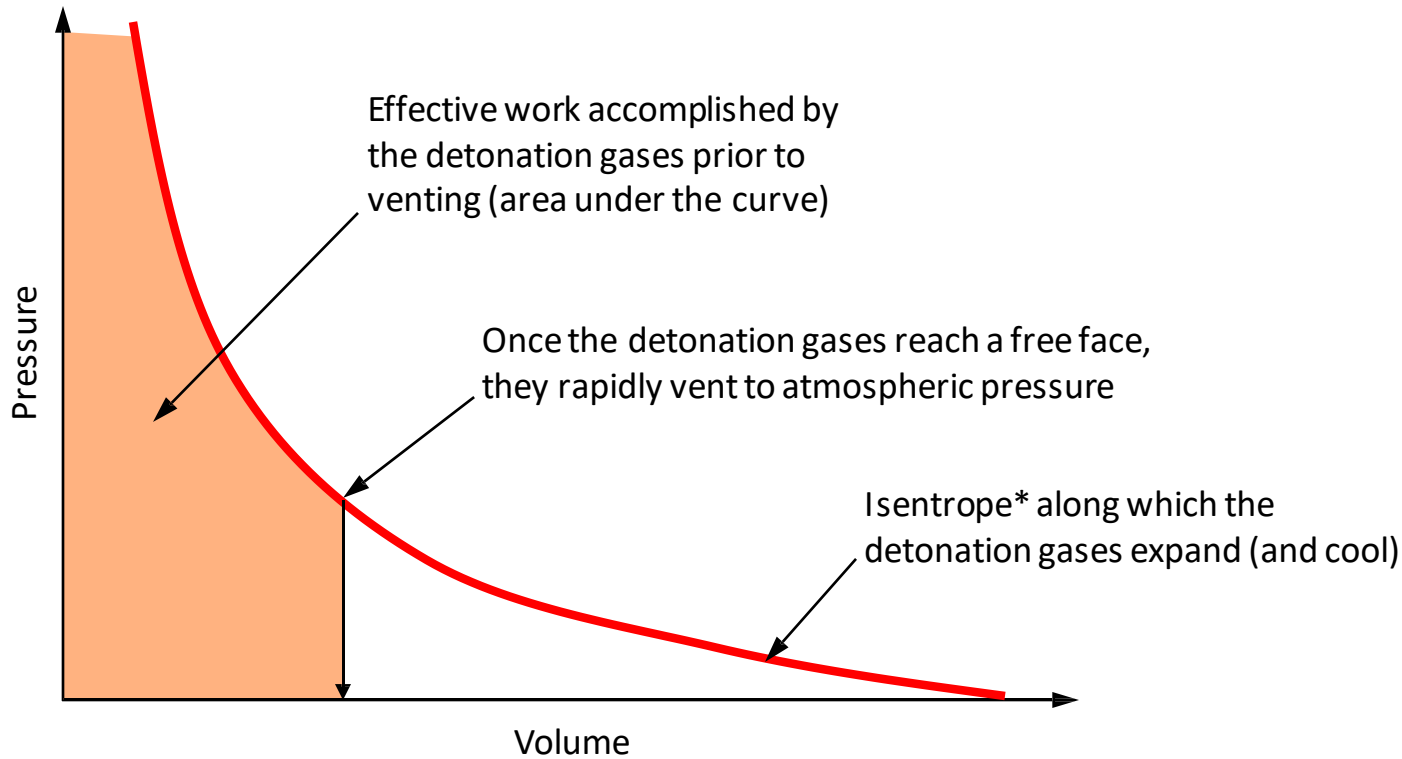


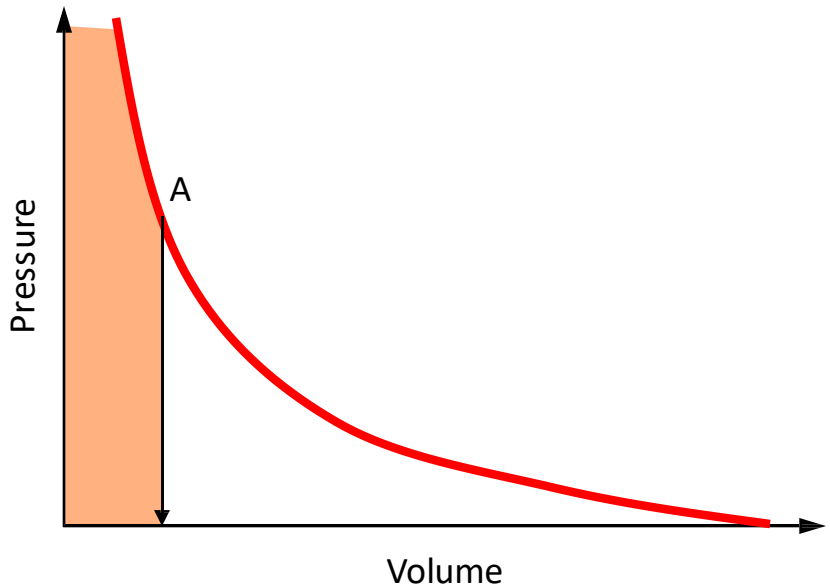
FIGURE *3.10.-22. Gas expansion.*

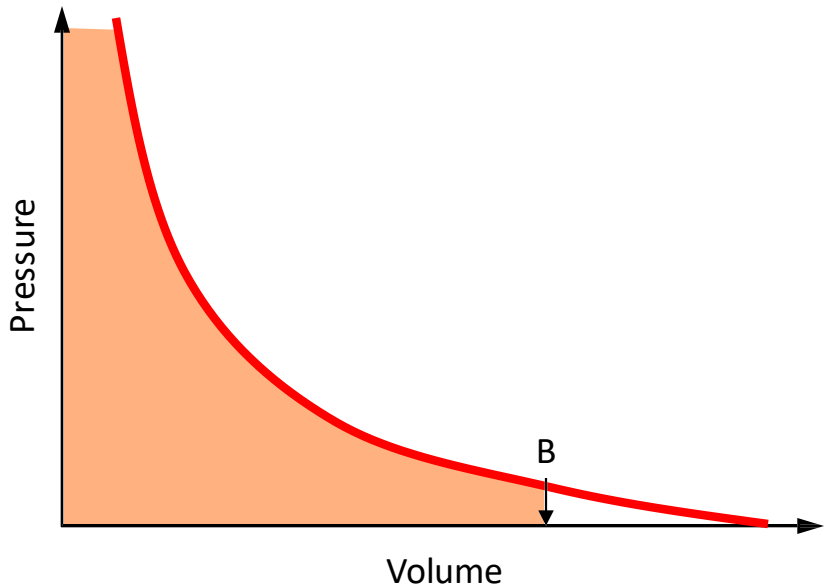
Pressure-Volume Relation (Equation of state)



* Curve of constant entropy (idealised adiabatic process whereby there is no heat transfer into or out of the system)

Pressure-Volume Relation





Early venting (powerful charge and/or little confinement). Little effective work within the rock mass, little vibrations, lots of noise.

Late venting (weak charge and/or high confinement). High effective work, high vibrations, little noise. ***To be avoided in wall control situations.***

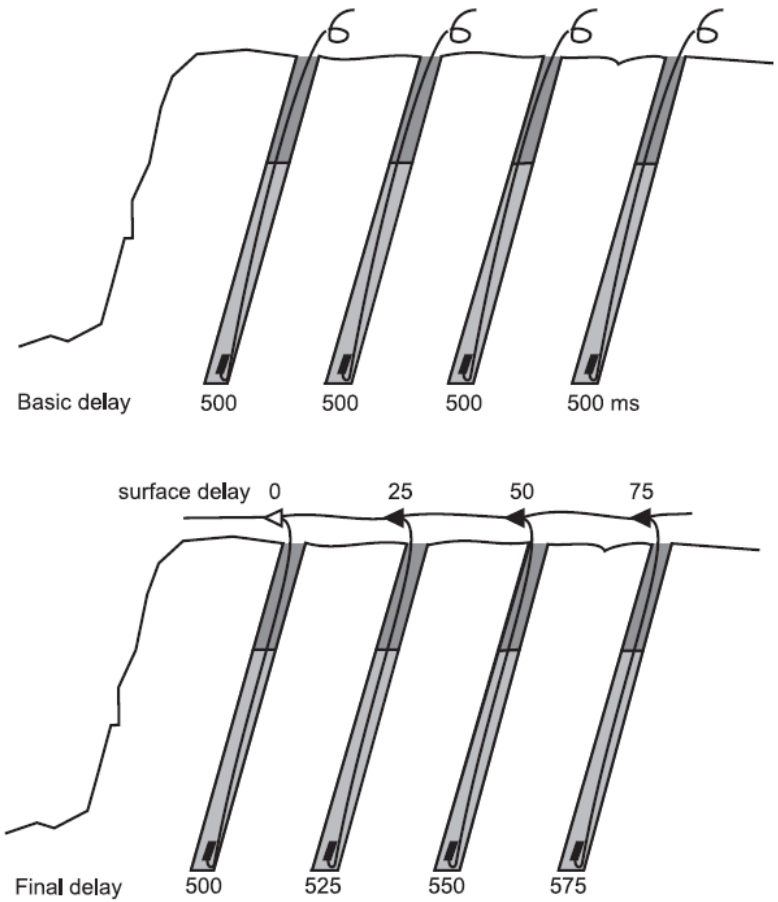


FIGURE *3.10.-12. Principle of function of non-electric system in open pits.*

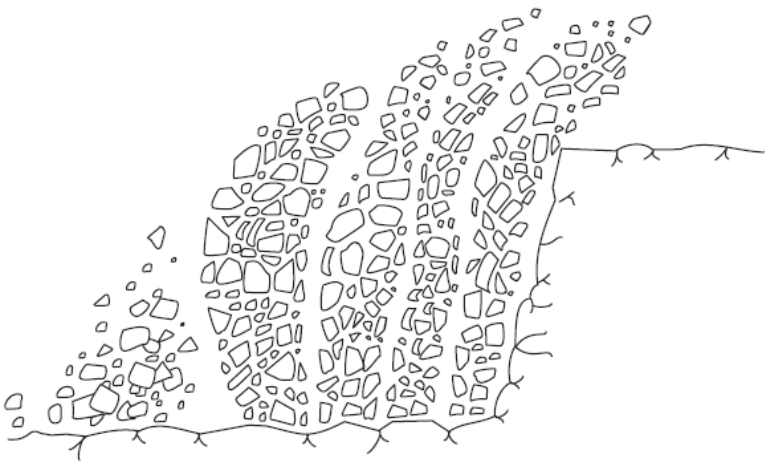


FIGURE *4.2.-17. Insufficient delay between rows.*

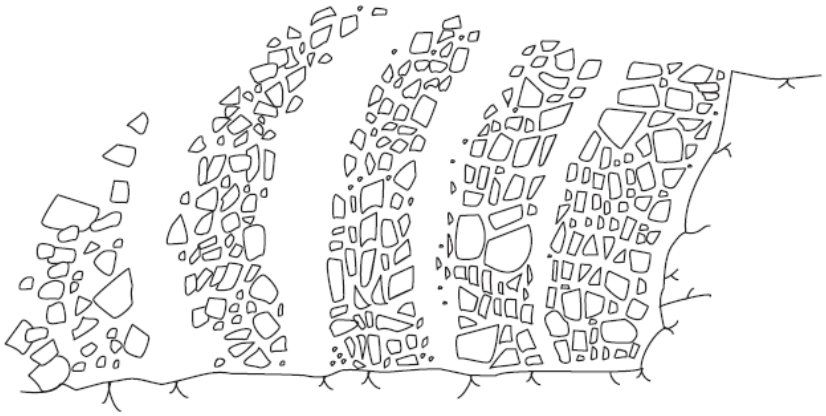
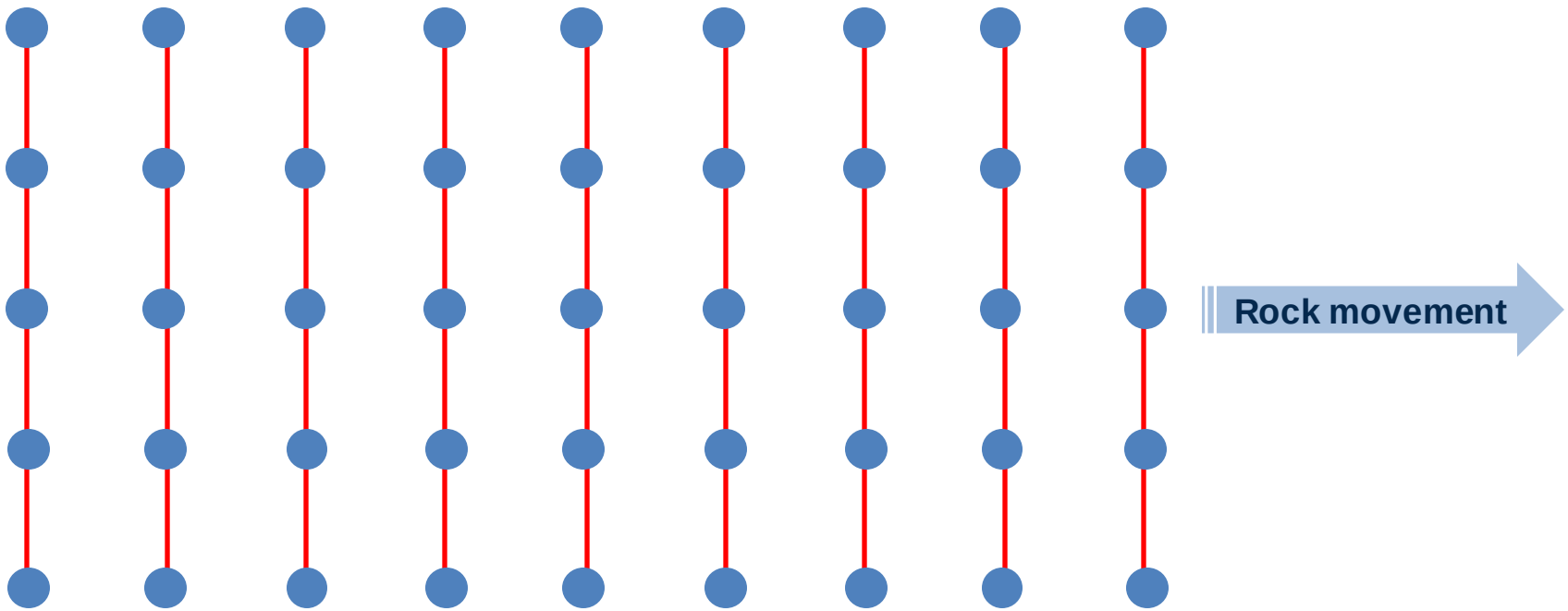


FIGURE *4.2.-18. Perfect delay between rows.*

How the initiation sequence affects fragmentation & muck-pile

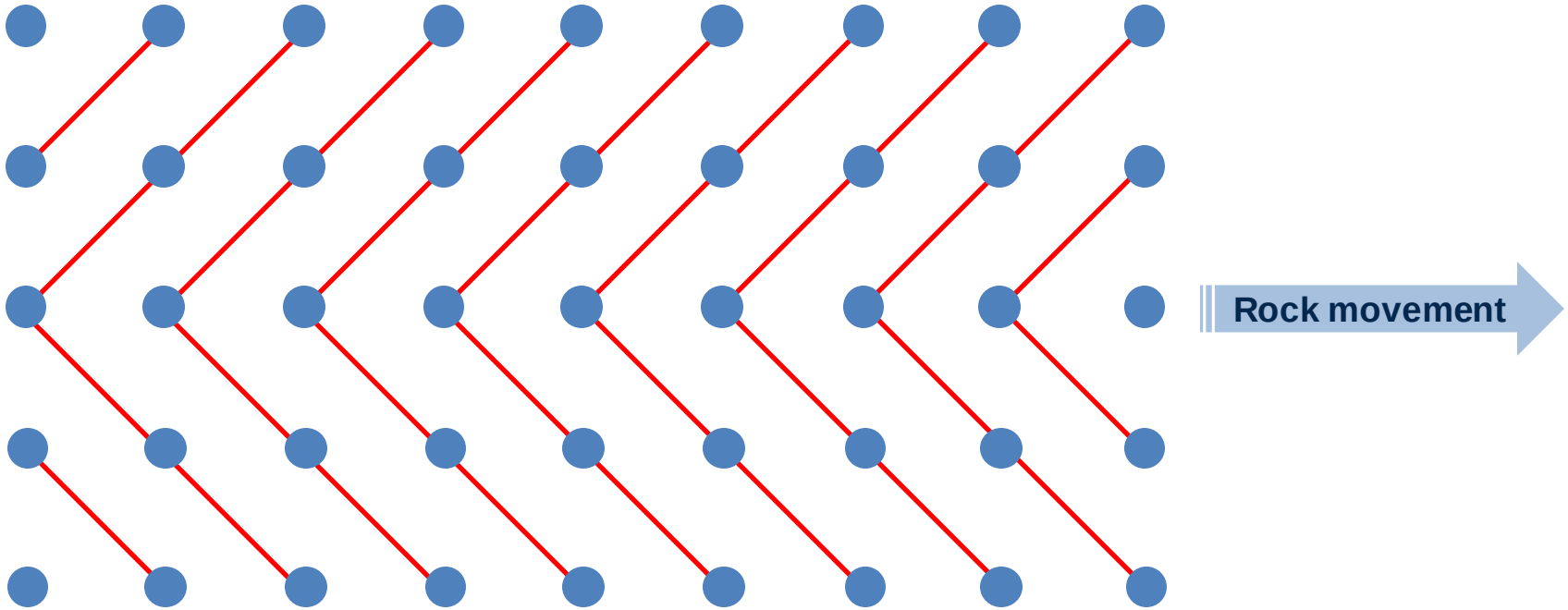


Line blasting / row-by-row

- Best cast
- Lowest muck-pile

NOTE: consistent powder factor

How the initiation sequence affects fragmentation & muck-pile



Full chevron / V-type

- Best fragmentation
- Highest muck-pile

NOTE: consistent powder factor

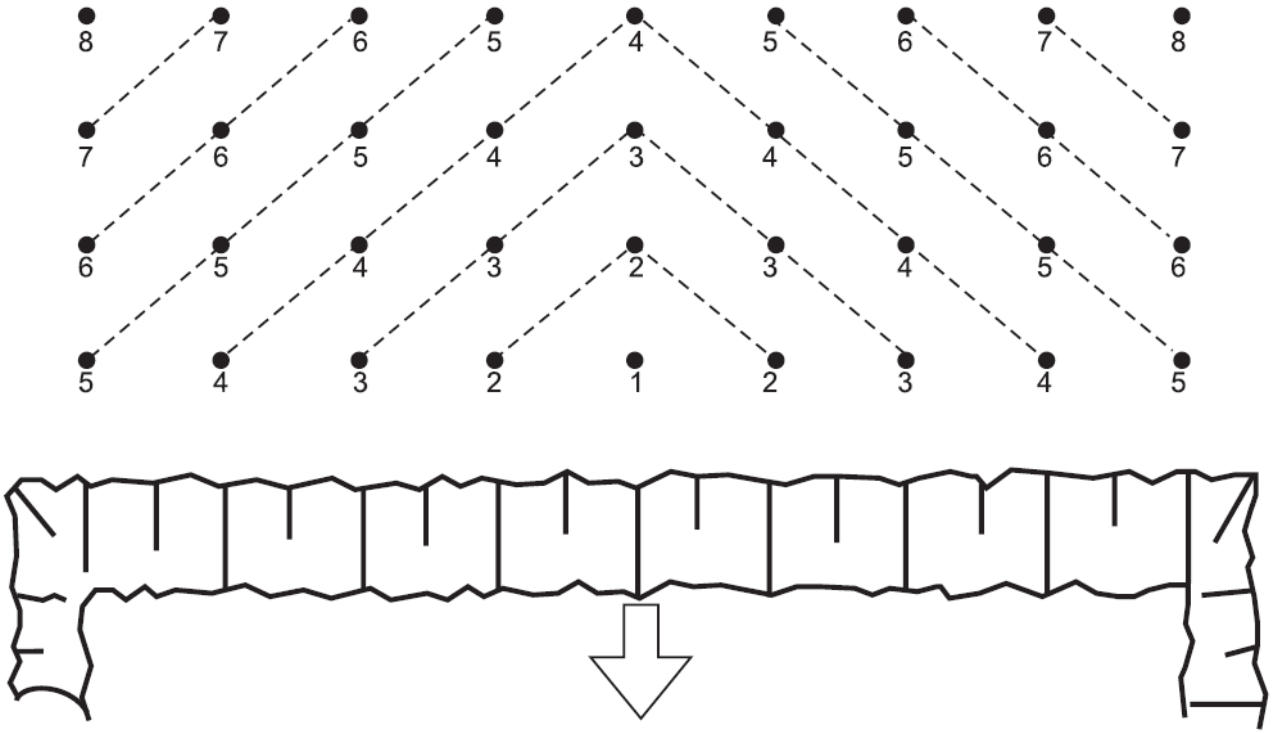


FIGURE ***4.2.-20.*** *Firing pattern/Better fragmentation.*

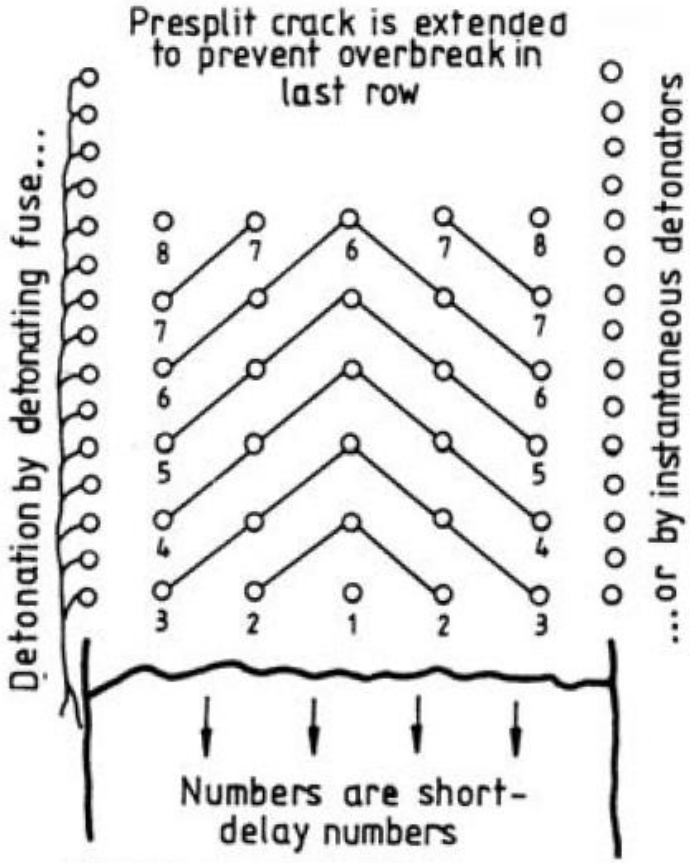
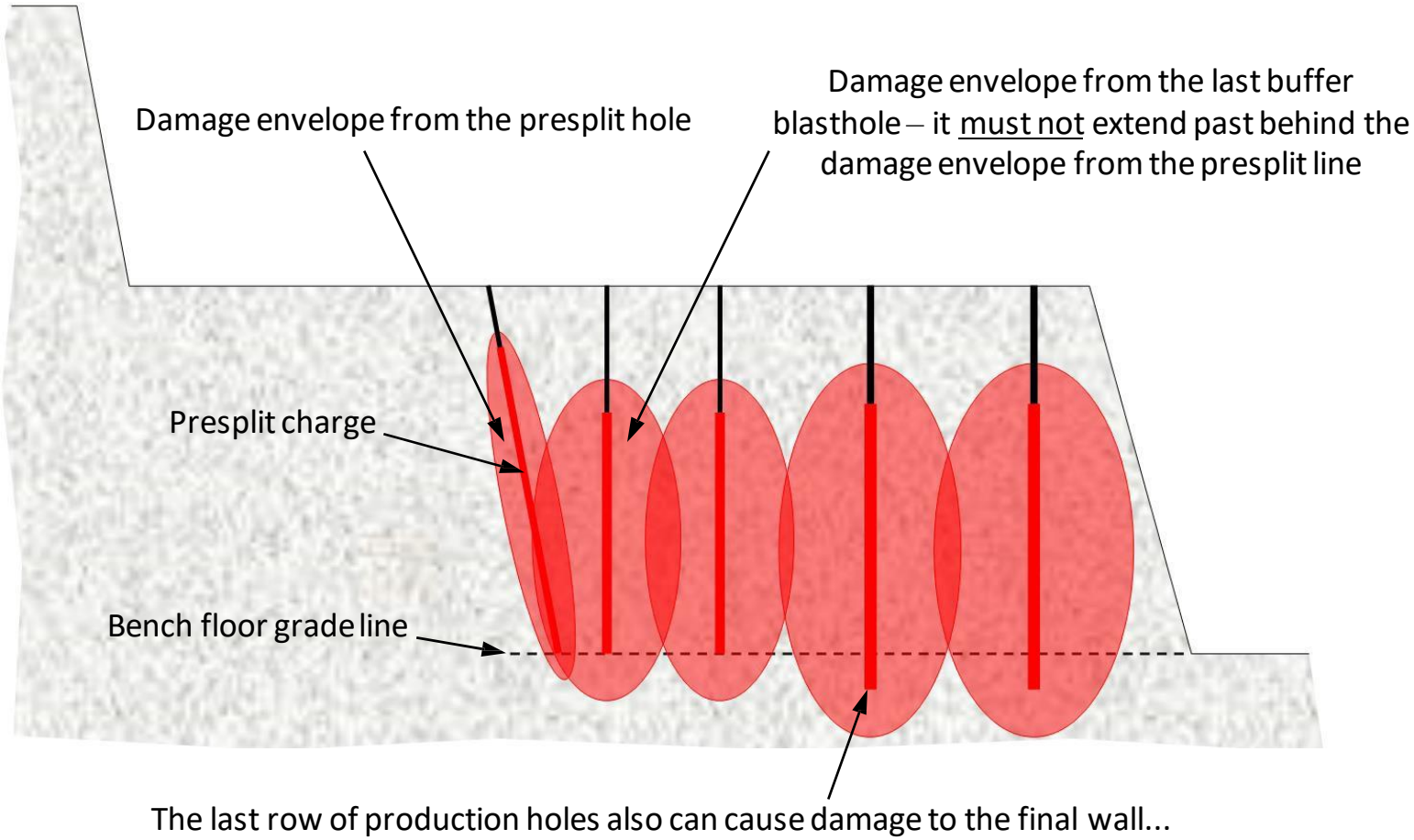


FIGURE *5.2.-3. Blasting presplit holes before bulk holes in a shot.*

Damage From Other Holes in the Trim Blast



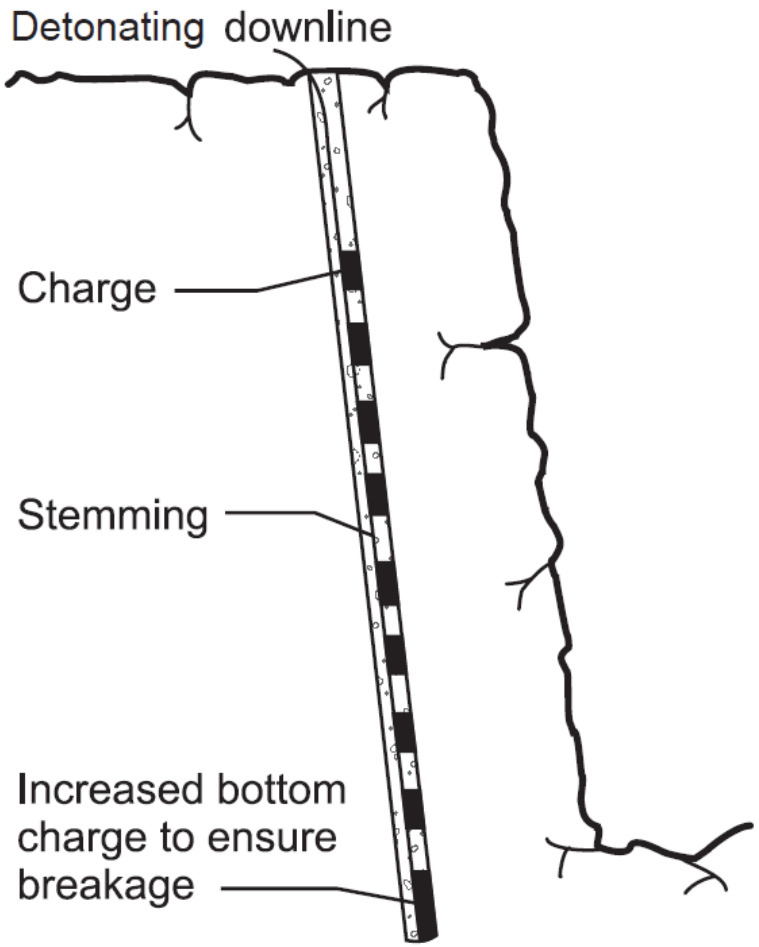
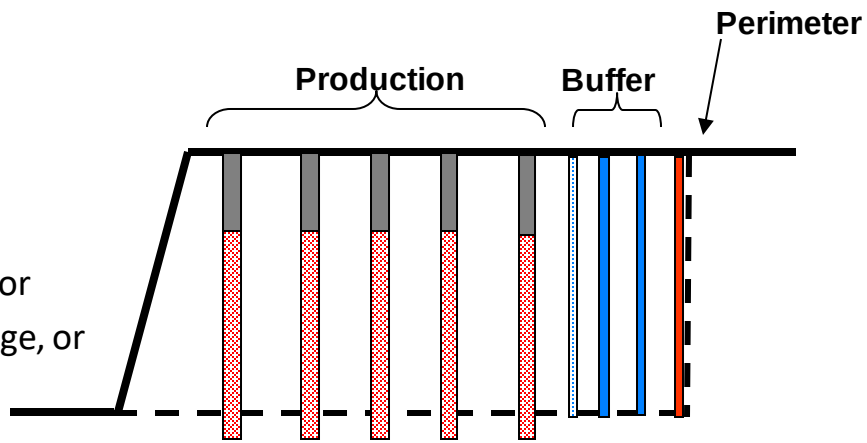


FIGURE *5.2.-8. Cushion blasting.*

Highwall Control

Controlled Bulk (Production) and Perimeter Blasting

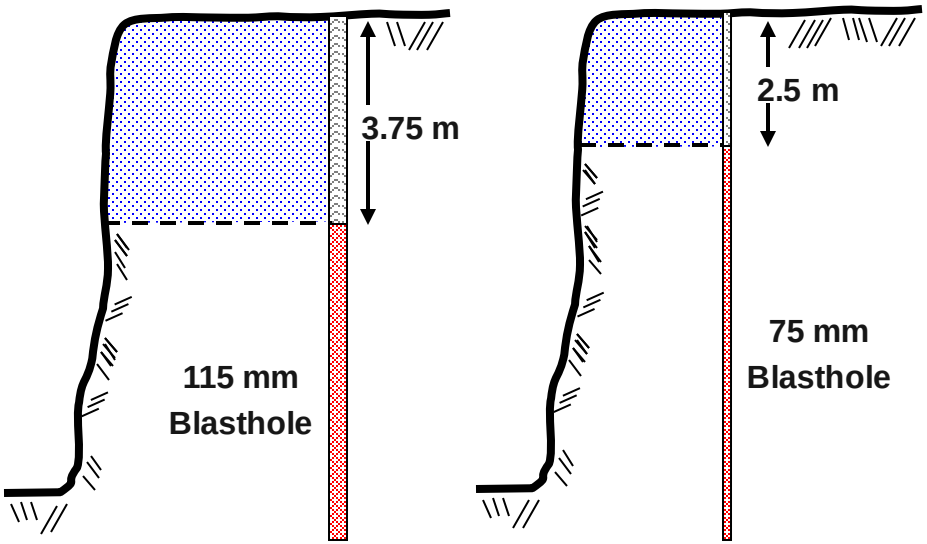
- **Production Portion of Blast:**
  - Reduced Powder Factor
  - Reduced Blast Hole Burden and Spacing
  - Reduced Blast Hole Diameter
  - No Anfo or Pumped Emulsion
  - Ensure Free Face and Relief
- **Buffer Portion of Blast**
  - Reduced Burden
  - Reduced Column Charge
  - Accuracy of Timing (Electronics)
- **Perimeter of Blast**
  - Pre-Split, - decupled and/or decked charge, or
  - Smooth Blast, decupled and/or decked charge, or
  - Line Drilling



Typical Layout of a Bench

STEMMING LENGTH

- **Rule of Thumb - Stemming Length**
  - **Drill Cuttings**
    - Material found on bench, primarily from drilling
    - Range of 30 to 40 hole diameters (d)
  - **Crushed Stone/Rock**
    - Range 20 to 30 hole diameters (d)



	Rock type	Normal	Controlled	Stemming
Rule of Thumb Hole diameters (d)	Hard	20	30	Crushed Stone[1]
	Hard	30	40	Drill Cuttings
	Medium	25	35	Drill Cuttings[2]
	Soft	15	25	Drill Cuttings[3]

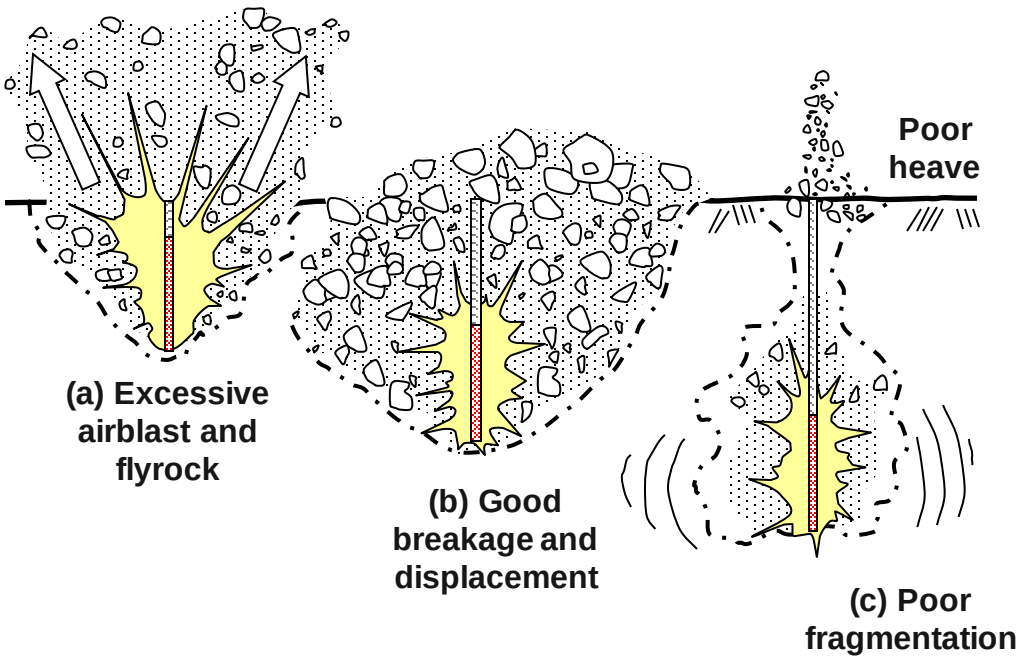
[1] Clean Crushed Stone, mean size, $^{1}/_{10}{}^{th}$ Hole diameter
[2] Crushed Stone, tests show not as effective in medium to soft rock in controlling potential flyrock
[3] Columns shorter than 20d generally cause noise, airblast, flyrock and overbreak
The optimum stemming length, depends very largely on rock properties and degree of confinement and can cary from about 20 to 60d

Stemming

Stemming Material Type

- The size of the stemming material, crushed stone/rock
  - > 1/10th of the hole diameter
    - e.g. For blasthole diameters in the range 50 to 130 mm, angular crushed rock in the approximate size range of 6 to 13 mm makes a very effective stemming material

Control of Flyrock



Safe Vibration

USBM curve that is generally used in South Africa. (After Chiappetta, March 2000)

(mm/s)(in/sec)

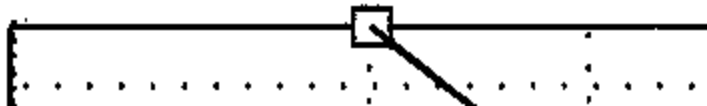
254 10

Safe Vibration L
Human Per

Human response curves compared with potential damaging limits.
(After Chiappetta, 2000)

(mm/s)(in/sec)

254 10



COTO 12.10 HARD EXCAVATION BY BLASTING

Location: Letseng Main Pit Block M160 — *Operator: A. Forbes*

Notes: Maloraneng Village

Record Duration: 10.0 sec
Sample Rate: 1024/sec

Distance: N | *Wgt. Per Delay: N* | *Scaled Distance: 0.0*

Seismic

Gain: 1 Trigger: .04 in/s Vector Sum: 1.64 in/s @ 12.80 Hz

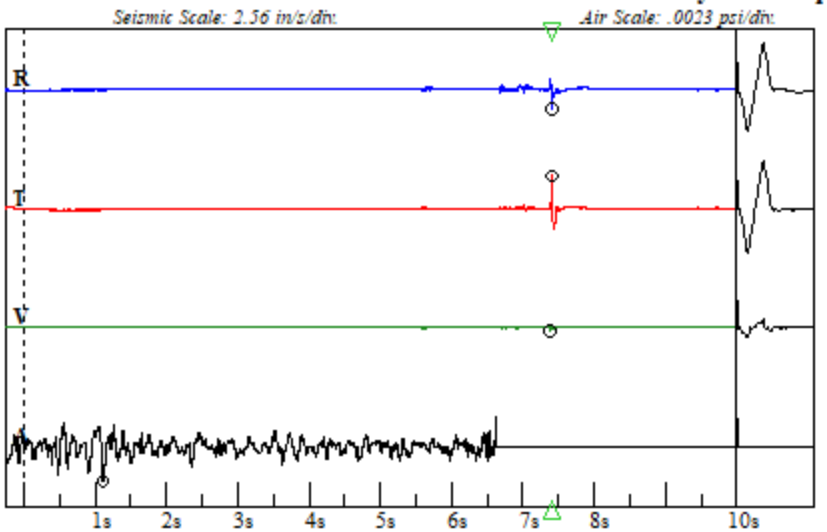
Channel	Radial	Transverse	Vertical
Velocity (in/s)	0.845	1.405	0.155
Frequency (Hz)	36.50	12.80	256.00
Trigger >>> Peak	7403.3	7403.3	7378.9

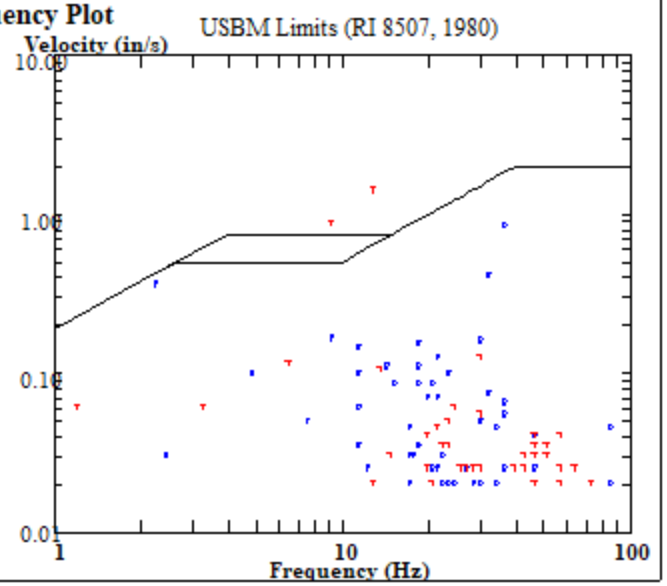
Air

Gain: 1 Air Trigger: 125 dBL

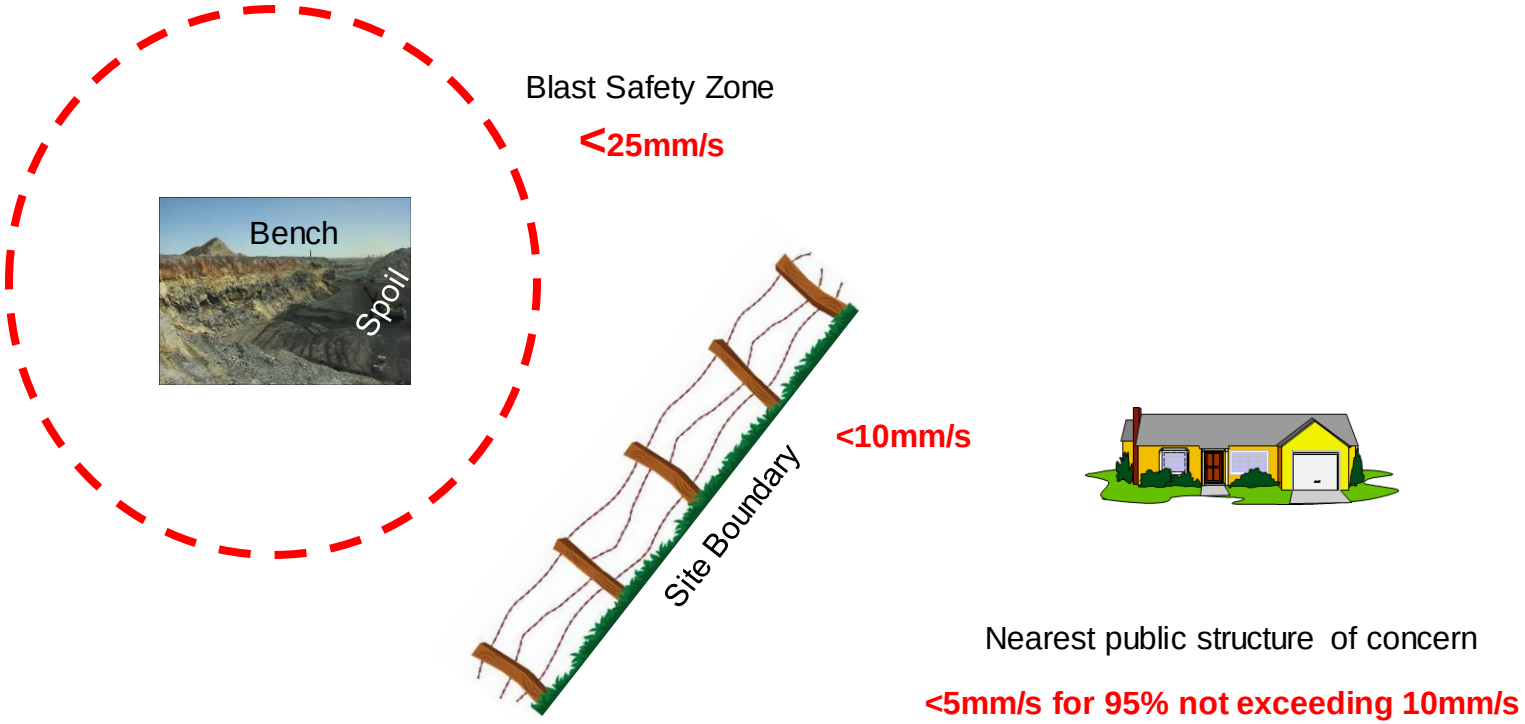
Measurement	Value	Trigger >>> Peak	
		1114.3	
psi	.001342		
dBL	113.3		
Hz	7.4		

Waveform Analysis / Frequency Plot

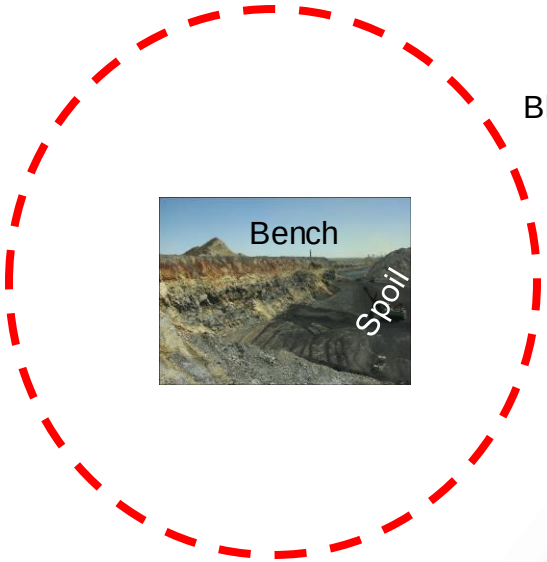




Ground Vibration

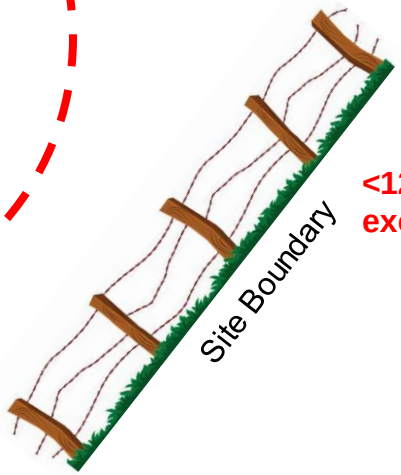


Airblast



Blast Safety Zone

<134 dB



<128 dB no more than 10% to exceed at a max 134 dB

Nearest public structure of concern

<115 dB for 95% of blasts, maximum of 120 dB

COTO 12.10 HARD EXCAVATION BY BLASTING

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