Rock Blasting – Lecture 3

Types of Explosives and Basic Blasting Theory

Classification of explosives

Low explosives (deflagrating)
VOD < 2000 m/s
E.g. gunpowder, fireworks, cordite

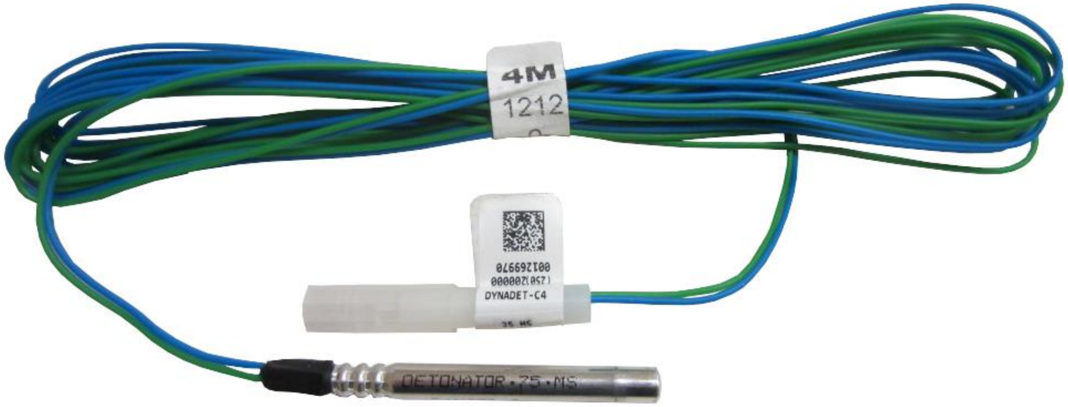
Industrial explosives (detonating)
VOD 2000 - 7000 m/s

Detonator sensitive or 'primary' explosives
Can be initiated by standard detonator
E.g. dynamite, blasting gelatin, Anzomex, packaged emulsion

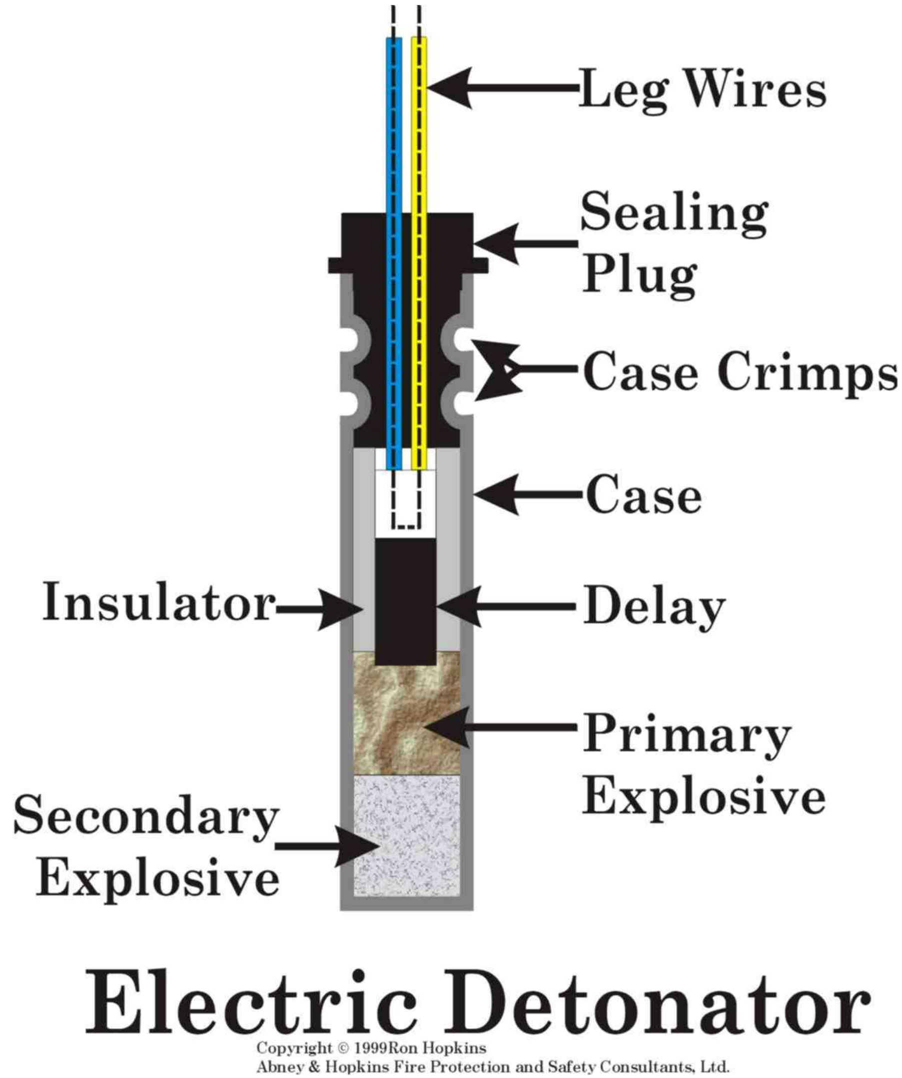
Blasting agents
Individual ingredients non-explosive.
Cannot be initiated by detonator – primary explosive charge required.
E.g. ANFO, emulsion, slurry.

High explosives (military)
TNT, PETN, HMX, Semtex

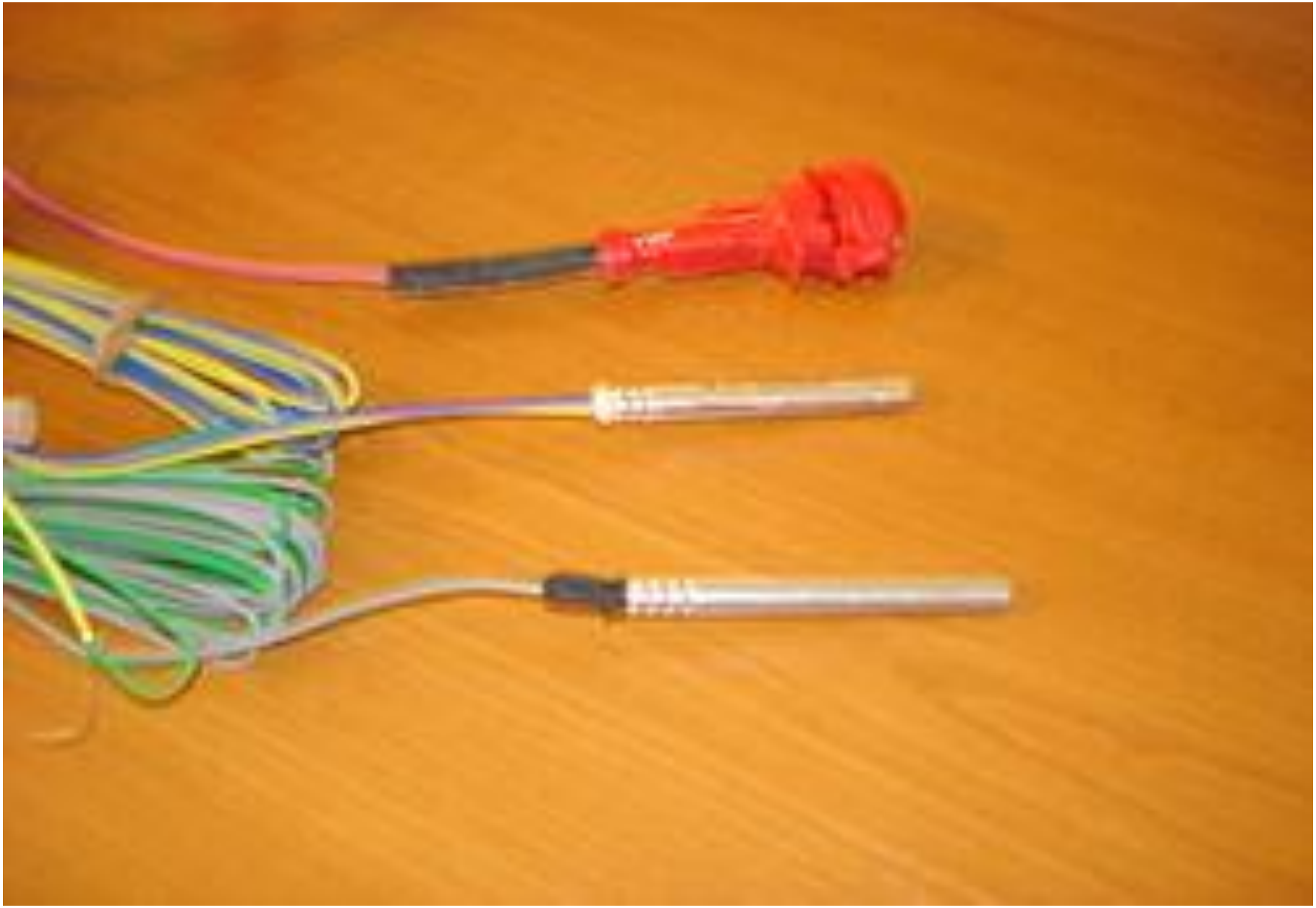
Initiating Explosives: These are used only as a charge in detonators and detonating cord



Example of Detonators



Nonel Detonator with 25ms Delay



High Explosives:

The reaction of these explosives is supersonic and generates a high pressure shock wave accompanied by rapid expansion of the reactive products.

Examples:

Trinitrotoluene (TNT);

Nitroglycerin, and

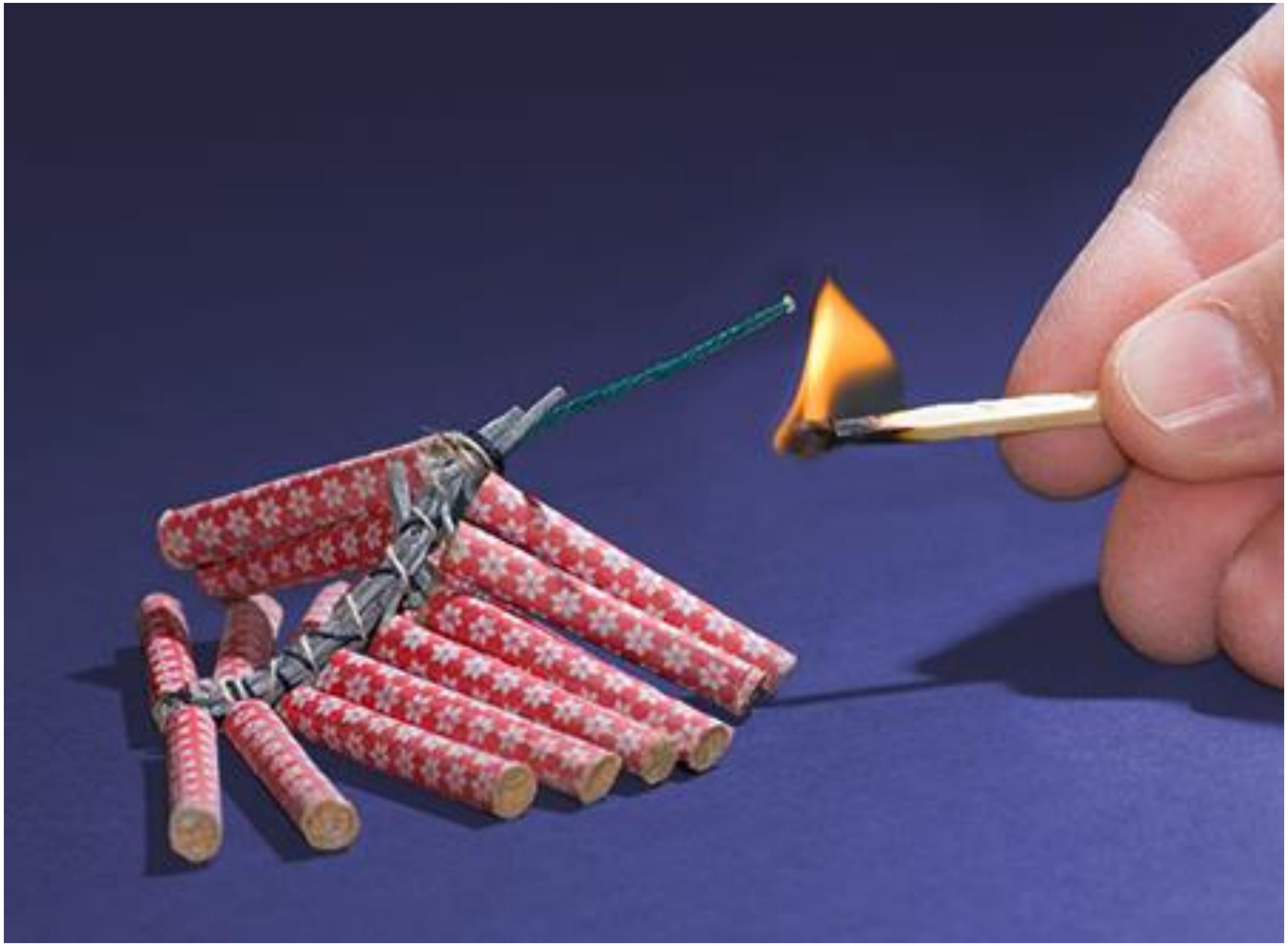
Dynamites.

Inserting detonators into Explosives - Priming

Charging Explosives – Placing Explosives in Blast-holes

Low explosives (deflagrating): - VOD < 2000 m/s

e.g. Gun powder and fireworks



Mining explosives

Fire point Cord Detonator Explosives cartridges

Blasting agents:

A blasting agent consists primarily of inorganic nitrates and carbonaceous fuels, and may contain additional non-explosive substances such as powdered aluminum.

Blasting agents include:

- Ammonium nitrate fuel oil (ANFO)
- Bulk emulsions
- Slurries
- Water gels

Emulsion

ANFO

Water gels

Slurries

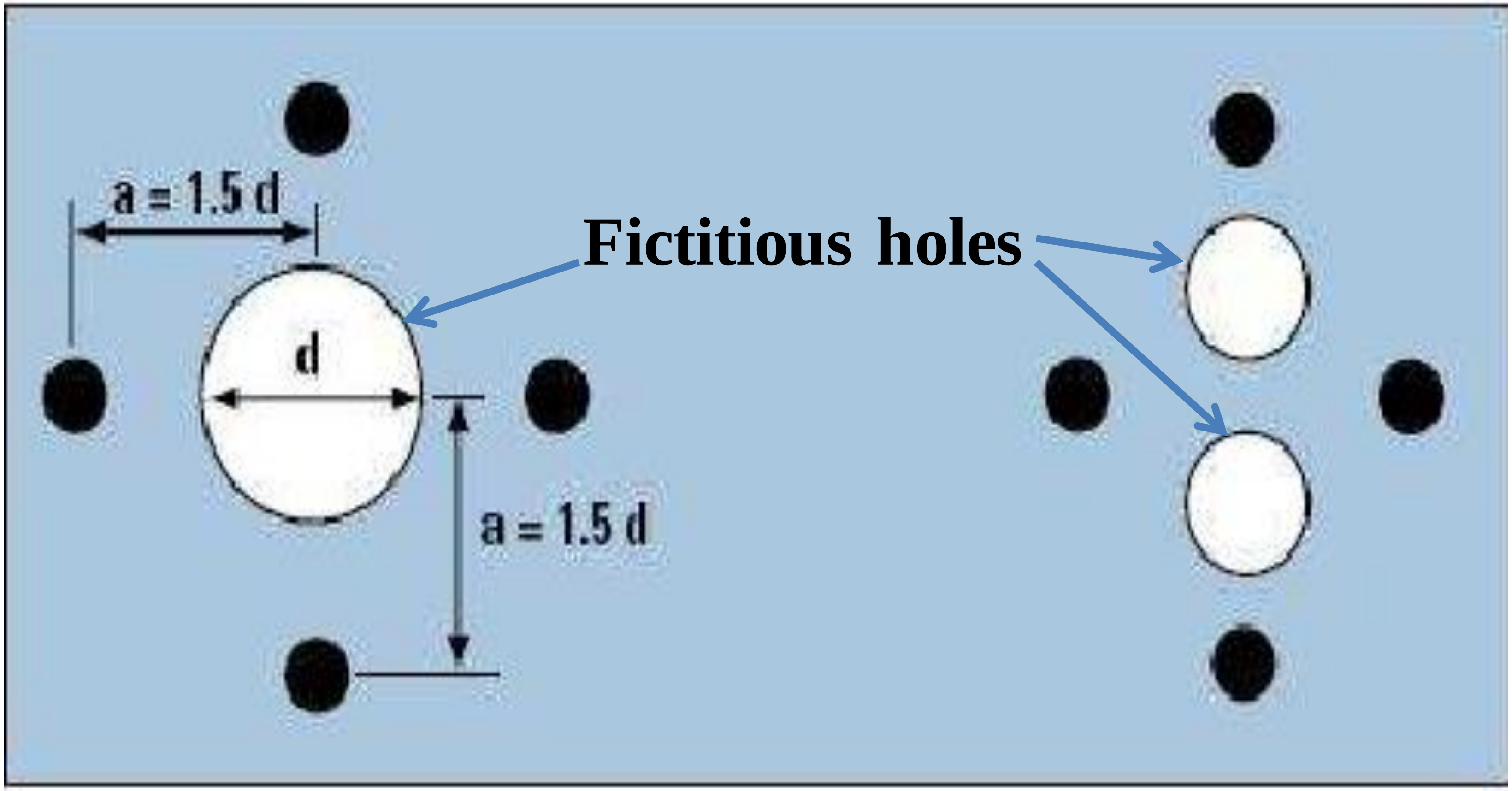
Blast Design

In underground excavations, there is need to create free rock face for successful blasting.

Various "cuts" are used in creation of free face including:

- Wedge cut or V cut
- Burn cut
- Pyramid or Diamond cut
- Drag cut
- Fan cut

Typical Design of Large Hole Burn Cuts



Fictitious Hole

Fictitious Hole: $D = d \times \sqrt{n}$

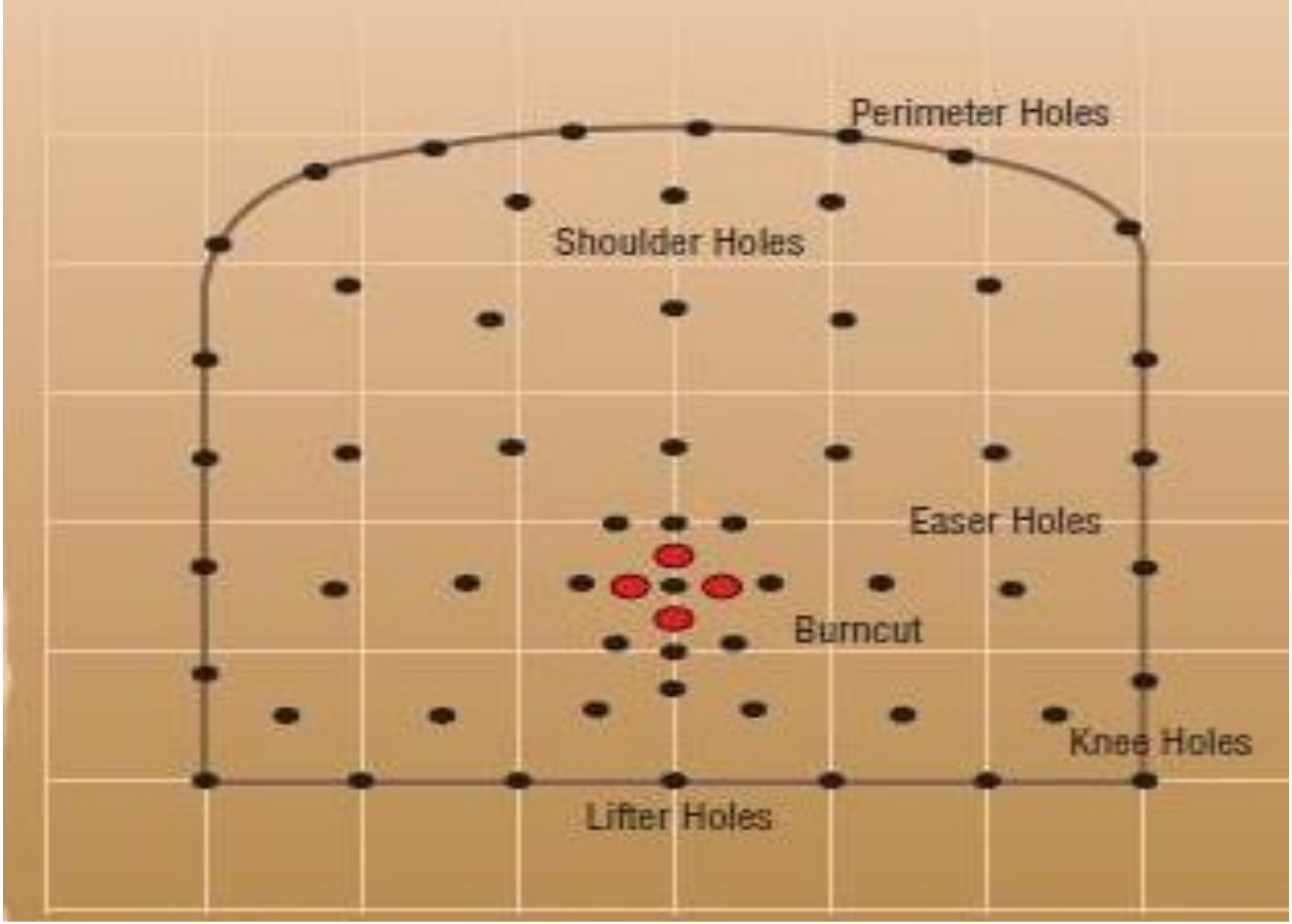
Where:

D = Fictitious empty large hole diameter

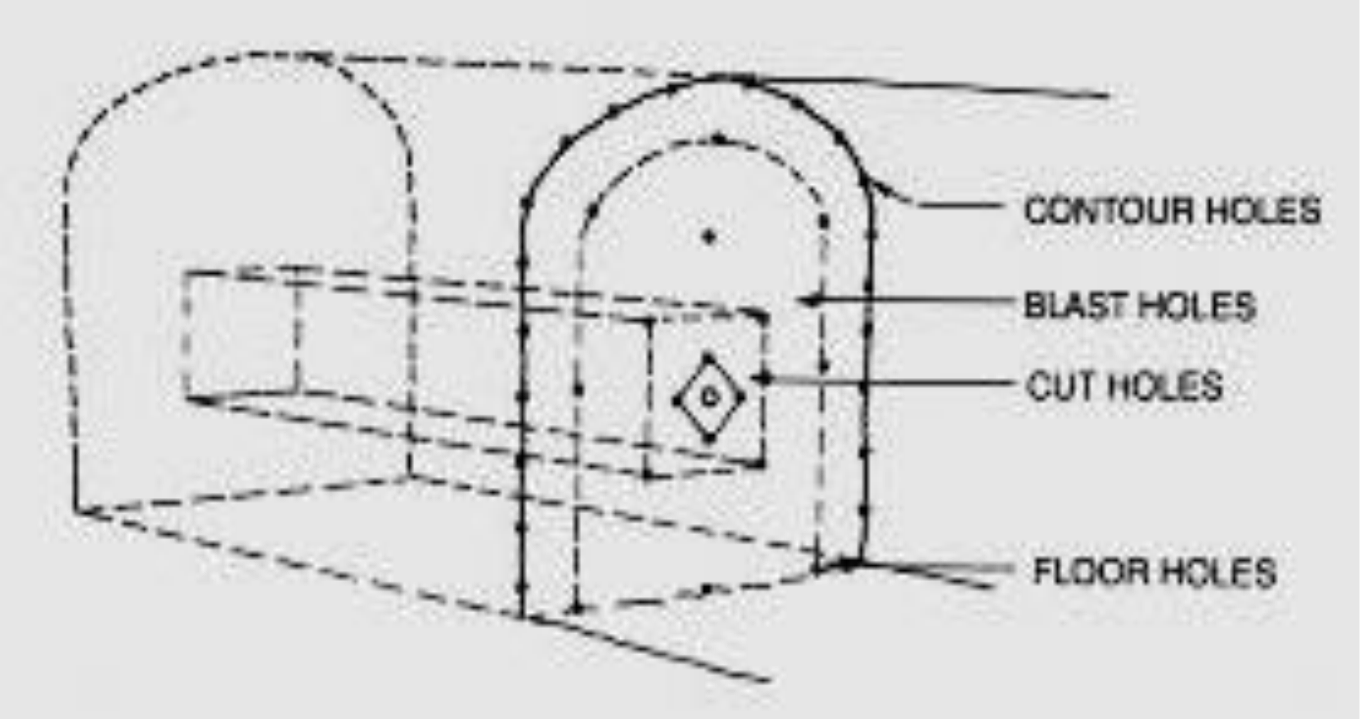
d = diameter of empty drilled large hole

n = number of drilled blast-holes

Blast design in a development end



Blast design in a development end



Basic Blasting Theory

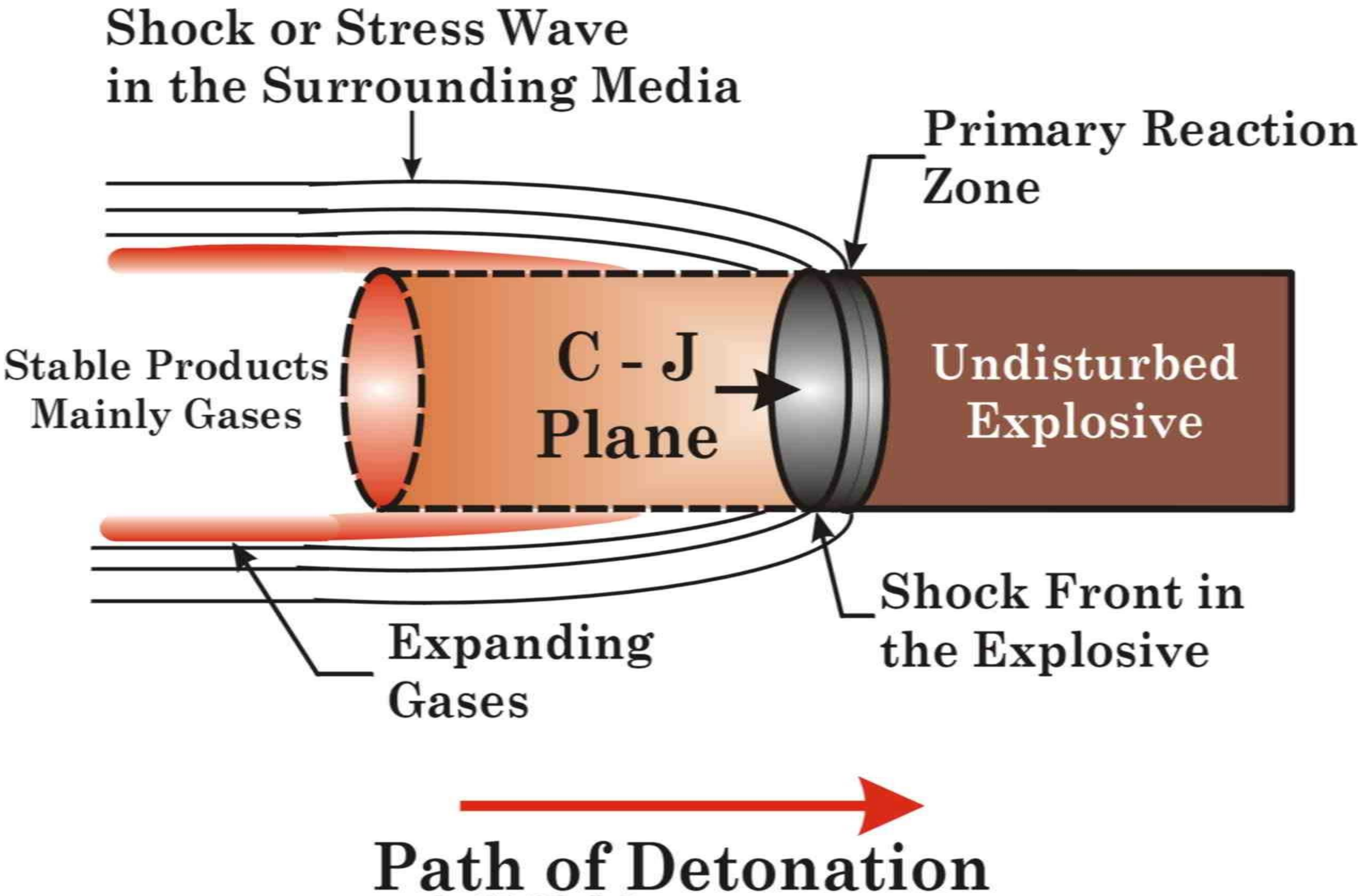
Detonation of an explosive

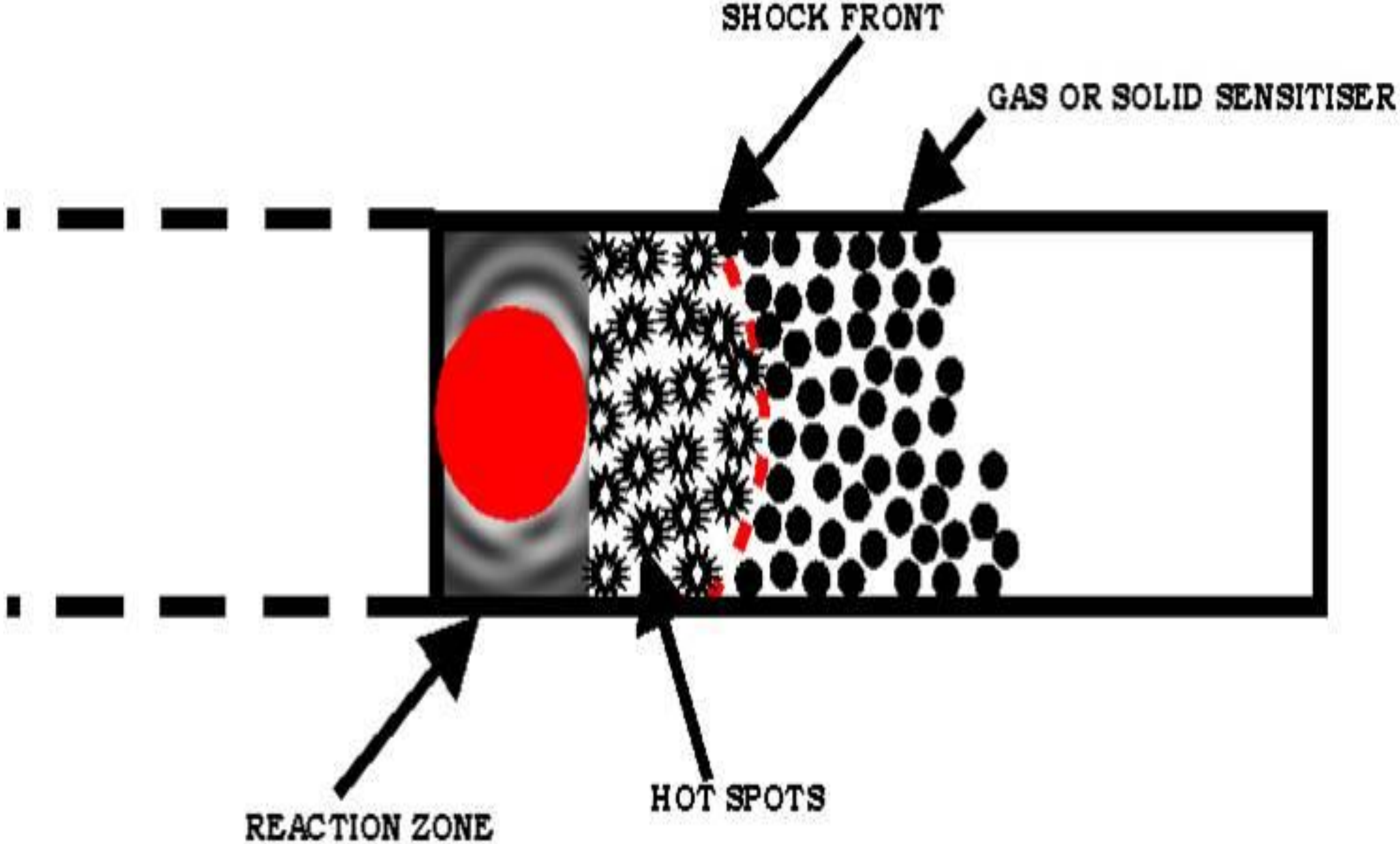
When an explosive detonates in a blast hole, it rapidly transforms into gases at very high temperature and pressure - exothermic reaction

The chemical reactions take place and travels along the explosive column faster than the acoustic velocity.

- Chapman-Jouget (C-J) process.

- Creates a shock condition
- Shock loading onto the blast hole wall
- Result in compressive stresses and crush the rock


Shock or Stress Wave
in the Surrounding Media
Primary Reaction
Zone
Stable Products
Mainly Gases
C - J
Plane
Undisturbed
Explosive
Shock Front in
the Explosive
Expanding
Gases
Path of Detonation



SHOCK FRONT
GAS OR SOLID SENSITISER
REACTION ZONE
HOT SPOTS

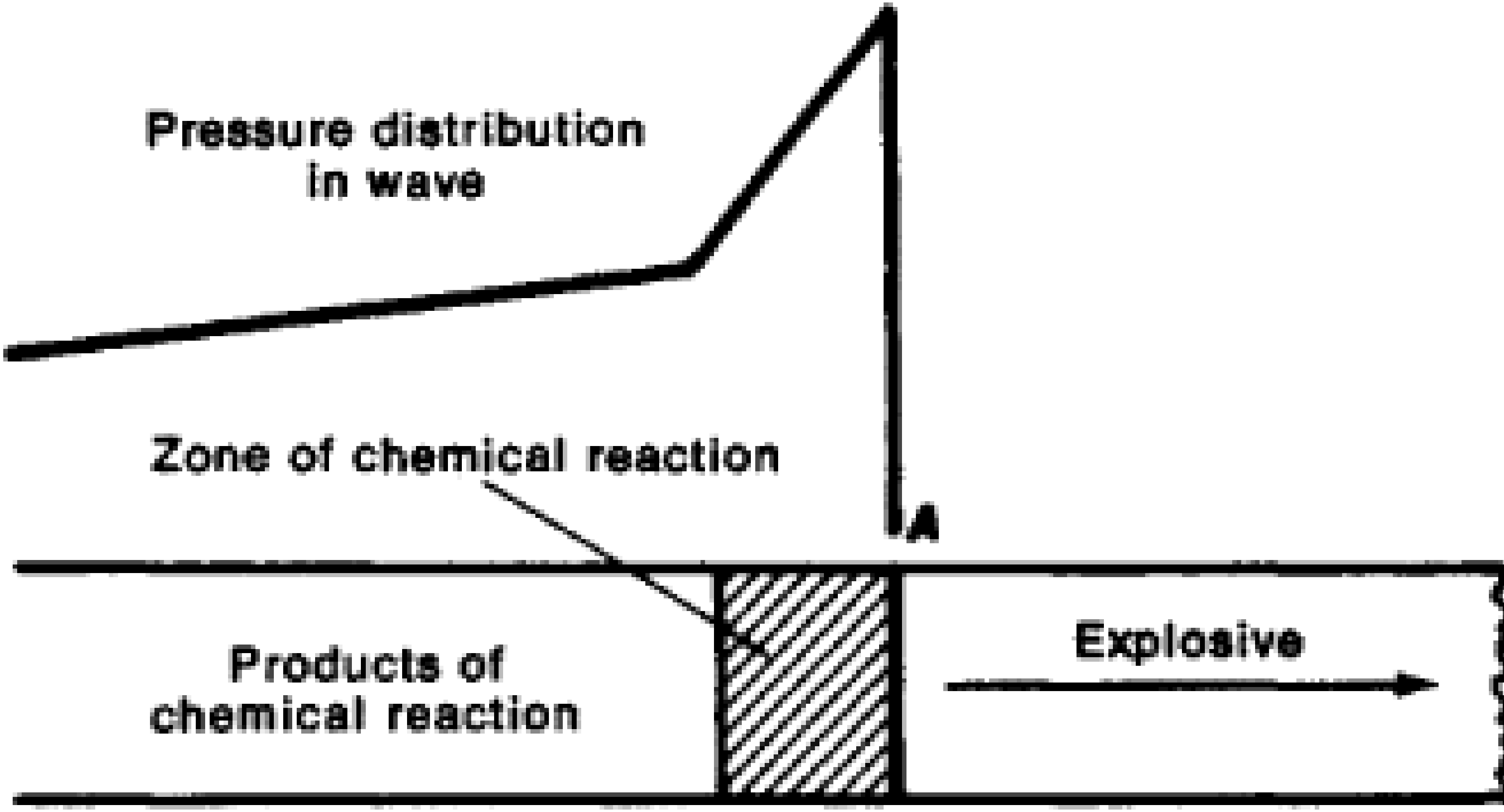
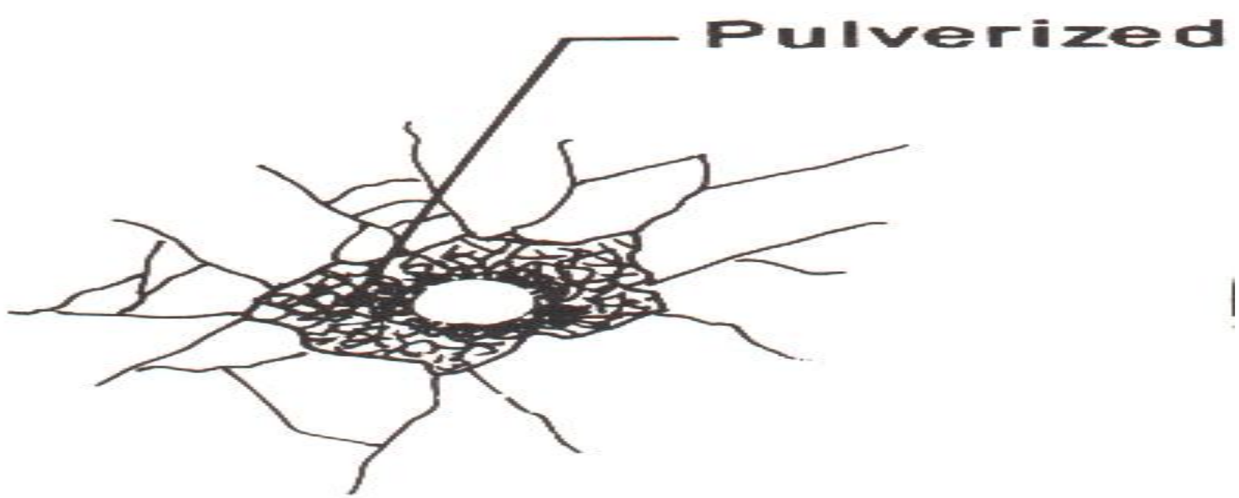


Diagram of a detonation wave: *(A)* shock wave front. The arrow shows the direction of propagation of the wave.

Blasting theory – 3 principal stages

1st stage:

After initiation, the blast-hole expands due to the high pressure upon detonation.

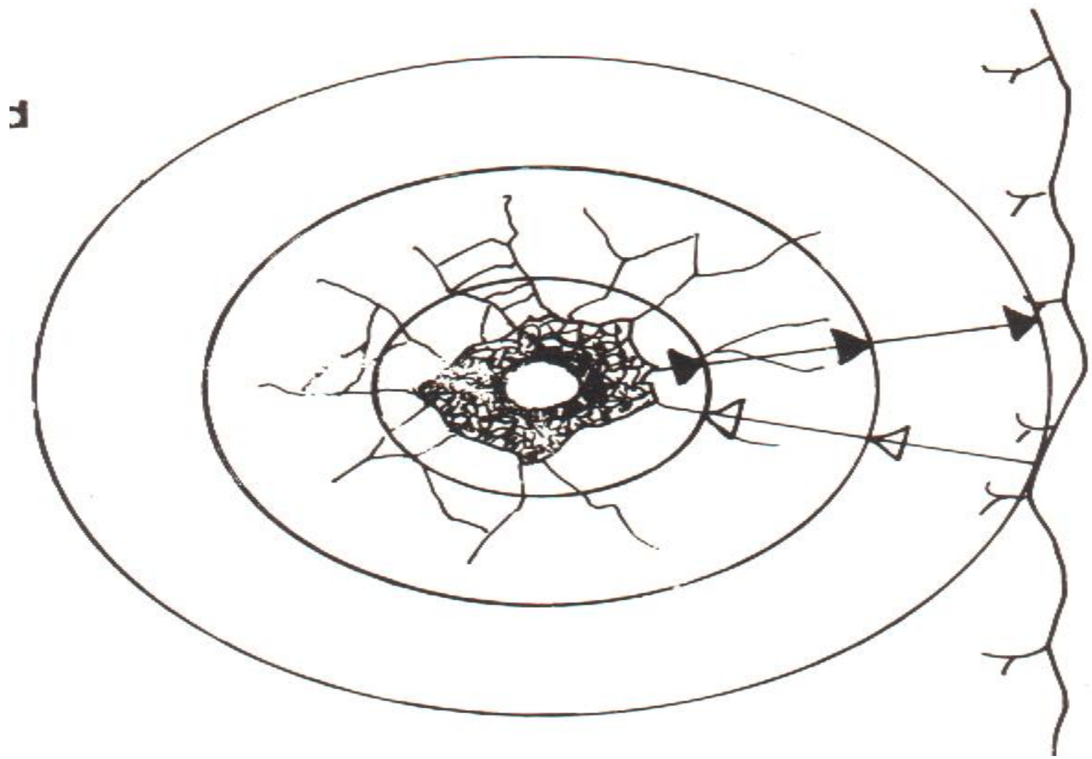


2nd stage:

- Compressive stress waves emanate in all directions from the blast-hole with a velocity equal to the sonic wave velocity in the rock.

- Upon reaching free face, compressive stress waves reflect causing tensile stresses in the rock mass between the blast-hole and the free face.

If the tensile strength of the rock is exceeded, the rock breaks in the burden area creating cracks.

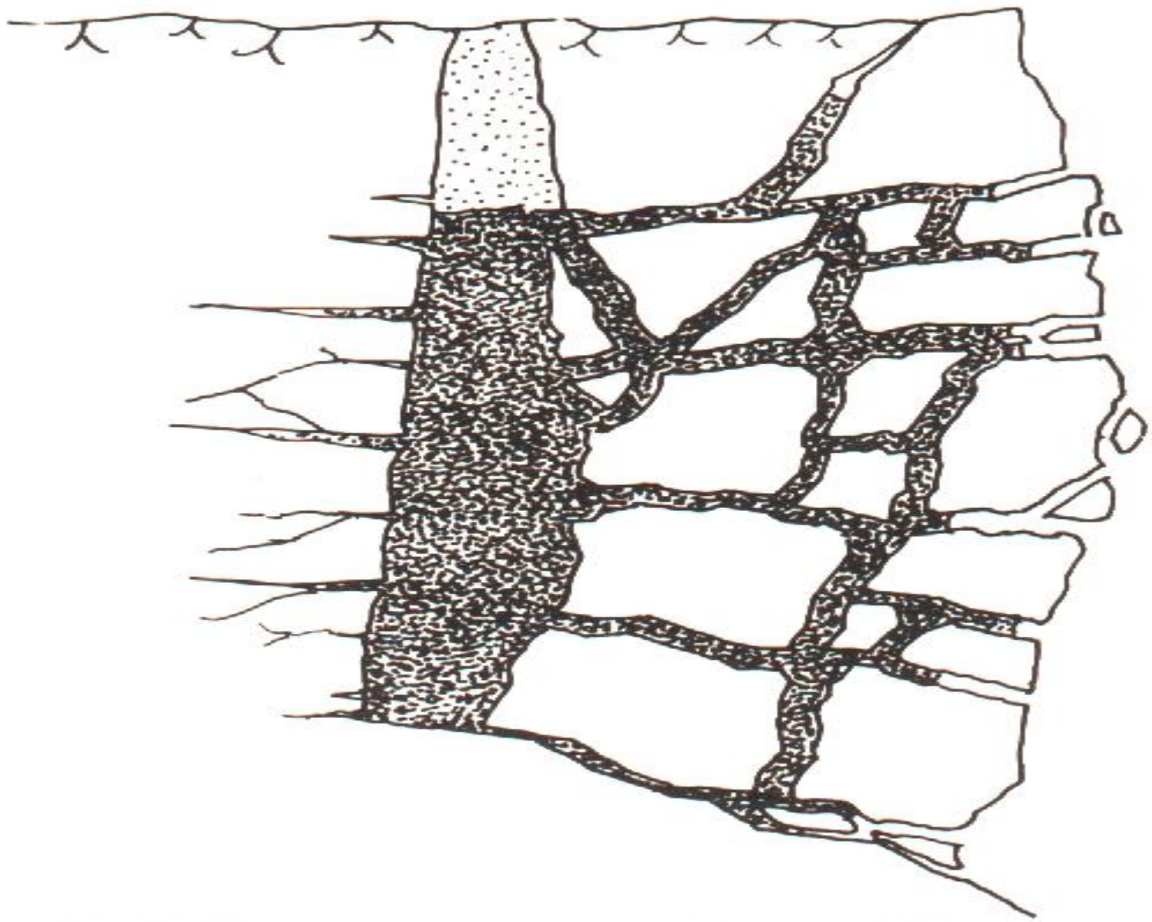


3rd stage:

The released gas volume “enters” the cracks under high pressure - expanding the cracks.

If the distance between the blast-hole and the free face is correctly designed, the rock between the blast-hole and the free face will yield and be thrown forward.

3rd stage



Explosive reaction

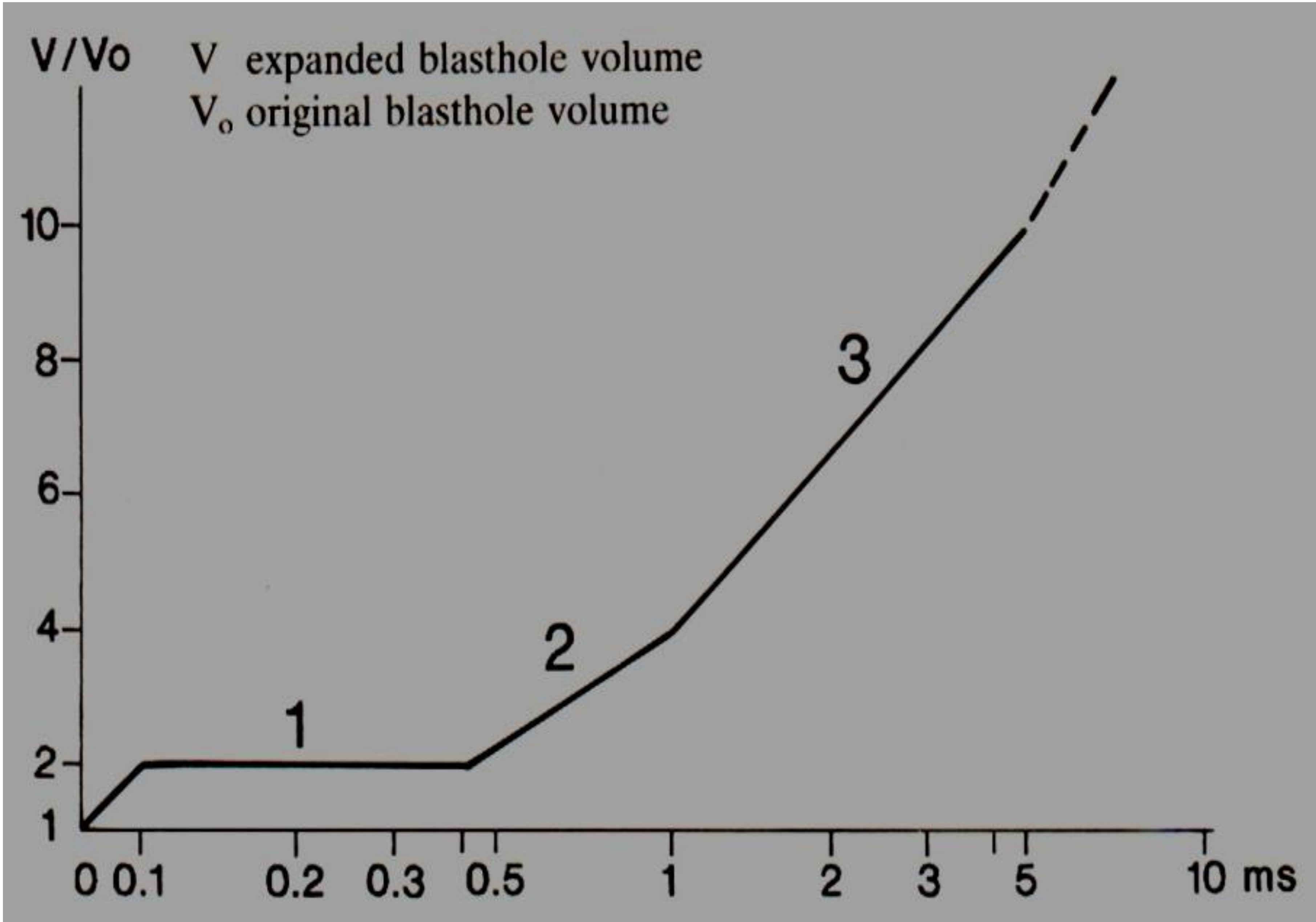
The explosives reaction in the blast hole is very fast and the effective work of the explosive is considered completed when the blast-hole volume has expanded to 10 times its original volume which takes approximately 5 milliseconds

Expansion of the blast-hole is related to time

From initiation of shockwave, the blast-hole expands to double its original volume (2Vo). The blast-hole will stay at this volume for relatively long time (0.1 to 0.4 ms) before radial cracks start to open.

Expansion vs time

- Besides the natural cracks are new cracks formed mainly by interaction between the stress field around the blast hole and tensile stresses formed by reflection of the outgoing shockwave at the free face.
- Reaction products expand from blast hole (which volume is now quadrupled) into the cracks. Fragmentation starts.
- Gas expands further and accelerates the rock mass.


V/Vo
V expanded blasthole volume
V₀ original blasthole volume
10
8
6
4
2
1
1
2
3
0 0.1
0.2
0.3
0.5
1
2
3
5
10 ms

Revision Questions

1. With reference to blasting, explain briefly:

   a) Priming, (b) initiation, and c) controlled blasting

2. How is the rate of propagation of explosive chemical reaction affect pressure and shock wave distribution?

3. With help of diagrams, describe the blasting theory

4. Calculate the fictitious hole diameter, given spacing between uncharged and charged holes as 0.3m and number of blast-holes as 4.

   (*Apply* $D = d \times \sqrt{n}$)

Class assignment

If a 4.5m by 3.6m drive is to be developed 150m long in pegmatite with 250MPa strength:

1. Describe a suitable drilling method to be applied including the type of prime mover, rods and bits
2. With help of diagrams, explain how free face will be created
3. Design a blasting pattern for a good fragmentation, throw and an advance of not less than 3.0m
4. Calculate the tonnage of rock to be excavated, given SG of 2.7
5. Calculate the amount of explosives required, given PF of 0.7 kg/m^3

End of blasting topic

Solution

Using: $a = 1.5d$

Where: a = spacing and d = diameter of empty drilled large hole.

$0.3 = 1.5d$ therefore $d = 0.3/1.5 = 0.2$

Applying: $D = d \times \sqrt{n}$

$D = 0.2 \times \sqrt{4}$

$D = 0.2 \times 2 = 0.4$

Therefore Fictitious empty large hole diameter = 0.4m