# Blasting Review

## Baron Fidler

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SCHOOL OF MINES 1874 COLORADO

SANDVIK

When Vince Lombardi was asked how he would make the Green Bay Packers a championship Team, he replied “we will be brilliant on the basics”.

**Your success in Life will be in direct proportion to your commitment to excellence, no matter what our chosen field.**

# Sometimes Wanting to be Excellent is not Enough

- **Mine Managers sometimes hard to work with**
  - ✓ **Threats of losing business**
  - ✓ **Likes the competition**

- **Drillers also want to be excellent, but sometimes does not understand the importance of**
  - ✓ **Drill logs**
  - ✓ **Hole placement**
  - ✓ **Hole alignment**

# Burden & Spacing

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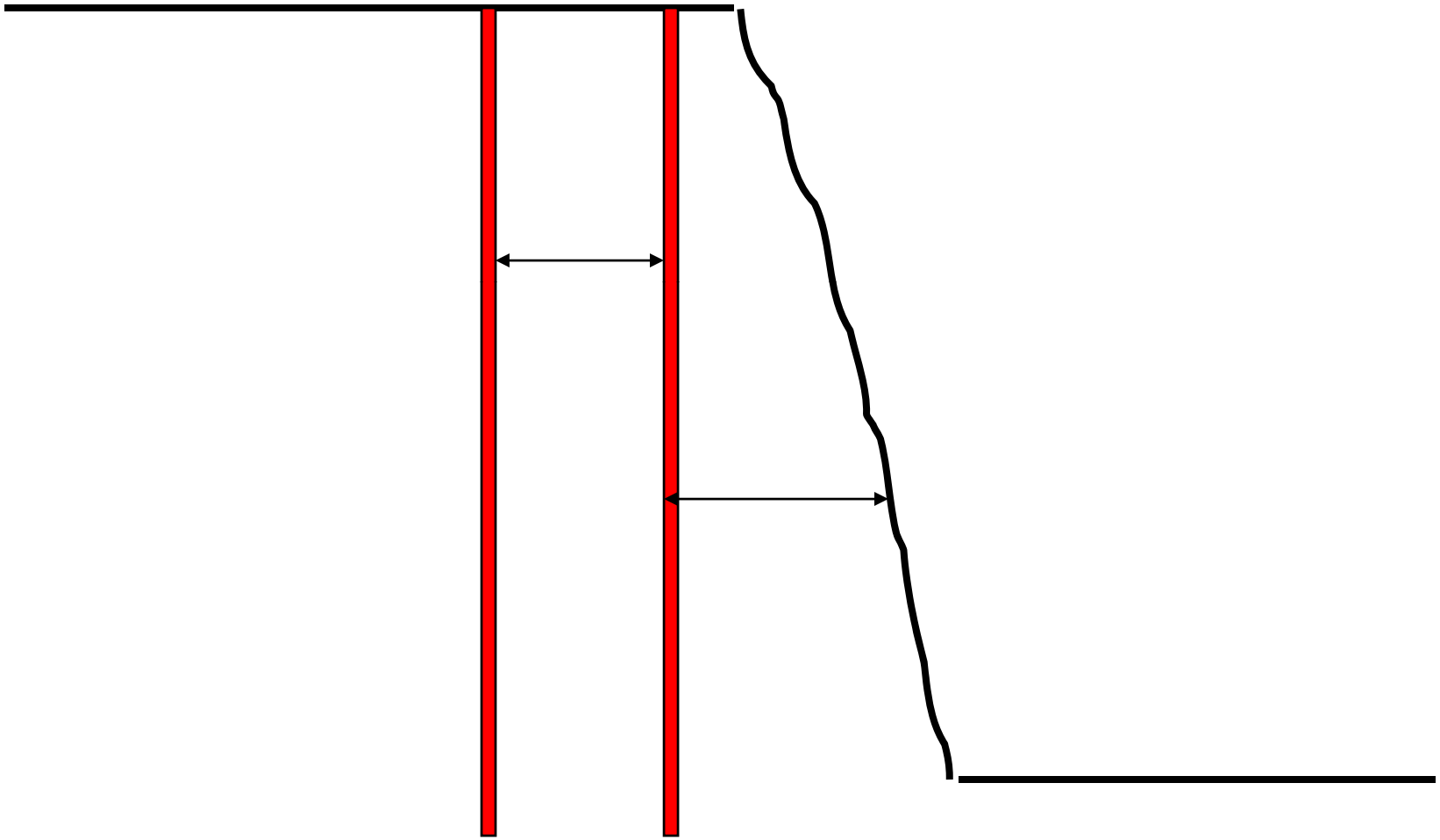
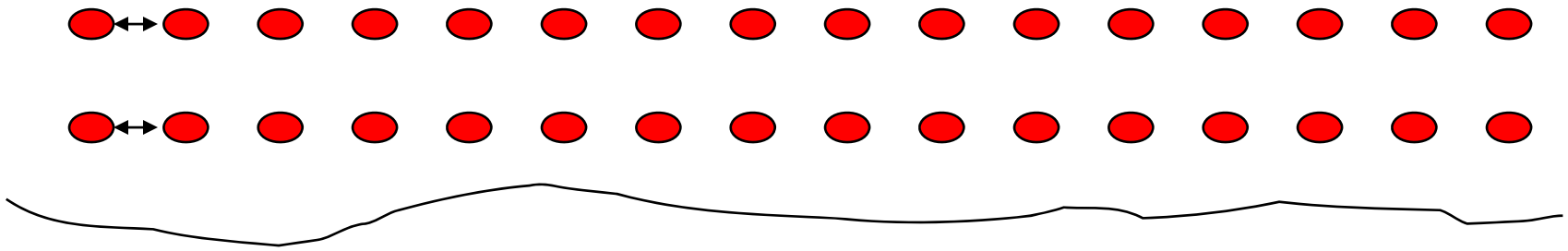
# Burden

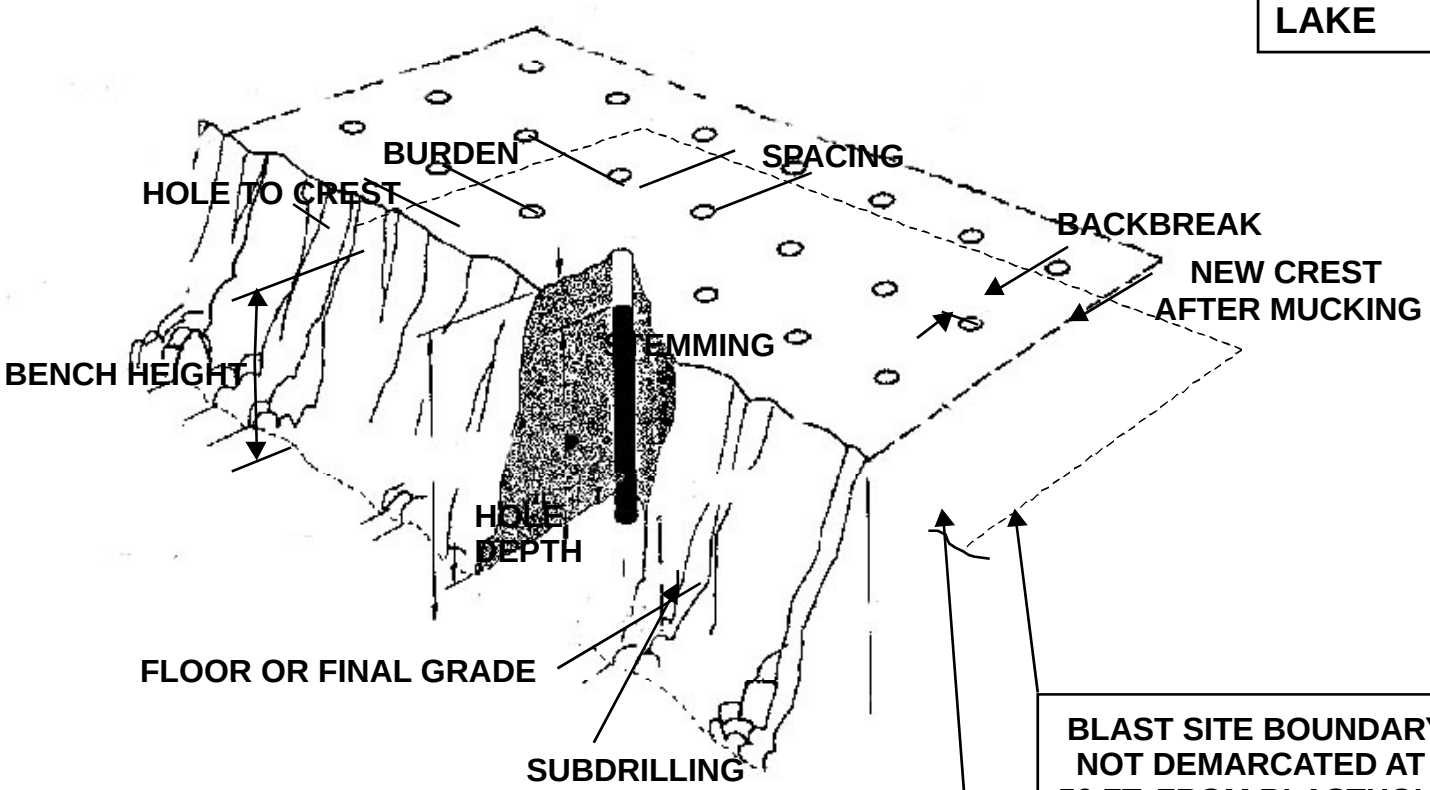


# Spacing



# Blast Site Terminology

DANGER ZONE
WITHIN AT LEAST
6 FT. OF OPEN FACE OR
LAKE




BLAST SITE BOUNDARY
NOT DEMARCATED AT
50 FT. FROM BLASTHOLES

BLAST SITE BOUNDARY
DEMARCATED
30 FT. FROM BLASTHOLES

# Blast Mechanics

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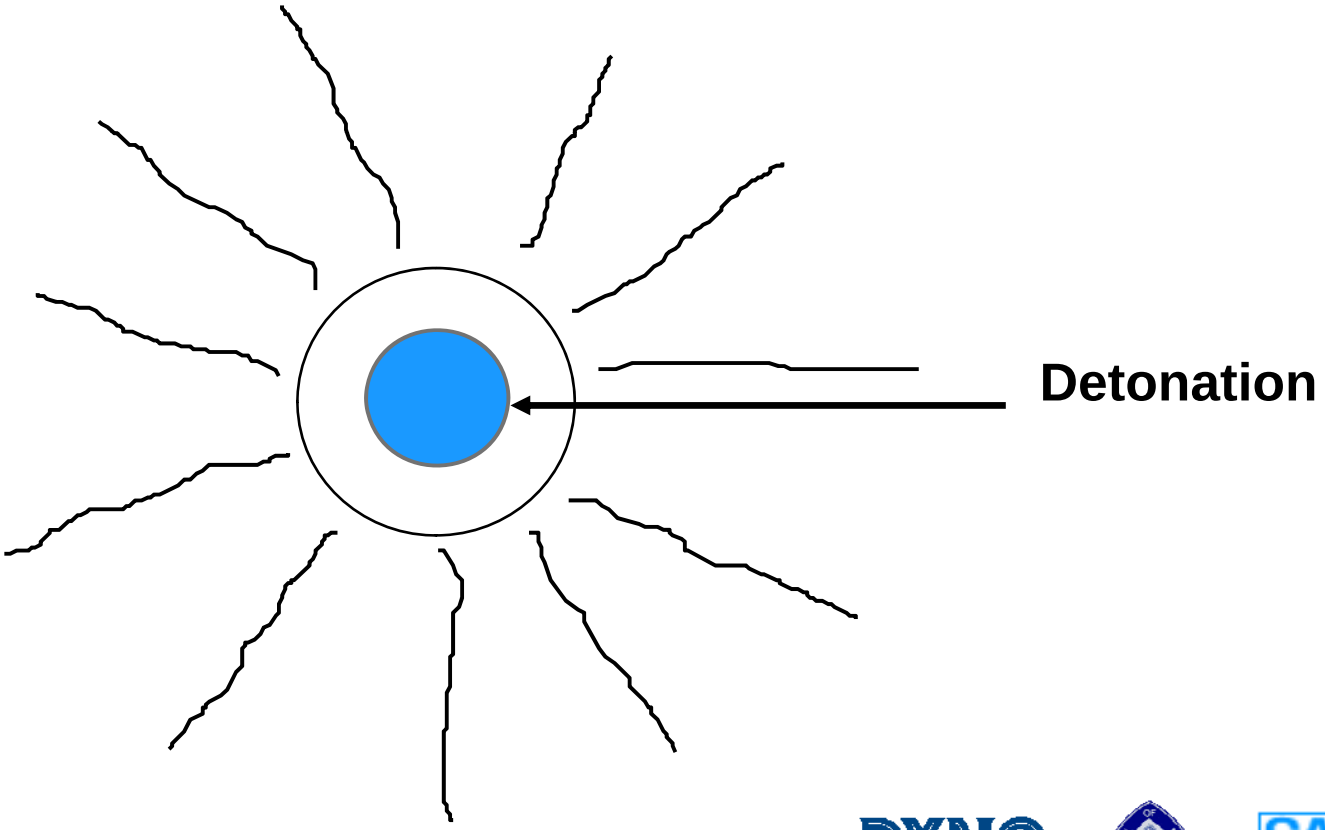
# Four Uses of Explosives

- **There are four basic types of work performed by explosives when loaded into rock**
  - ⇦ **Fragmentation**
  - ⇦ **Rock movement or heave**
  - ⇦ **Ground vibration**
  - ⇦ **Airblast**

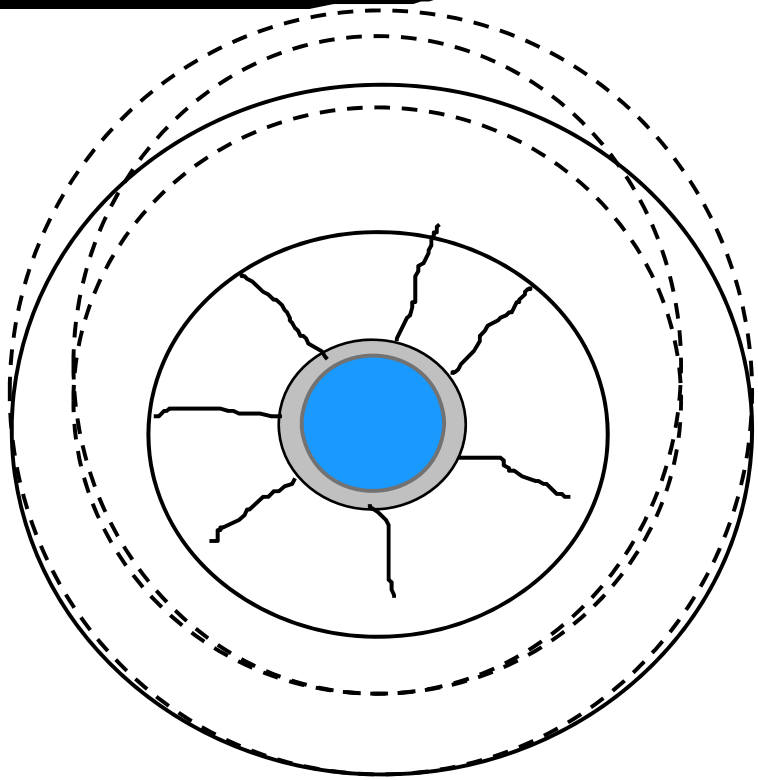
# Fragmentation Process

**Radial cracks form from borehole**



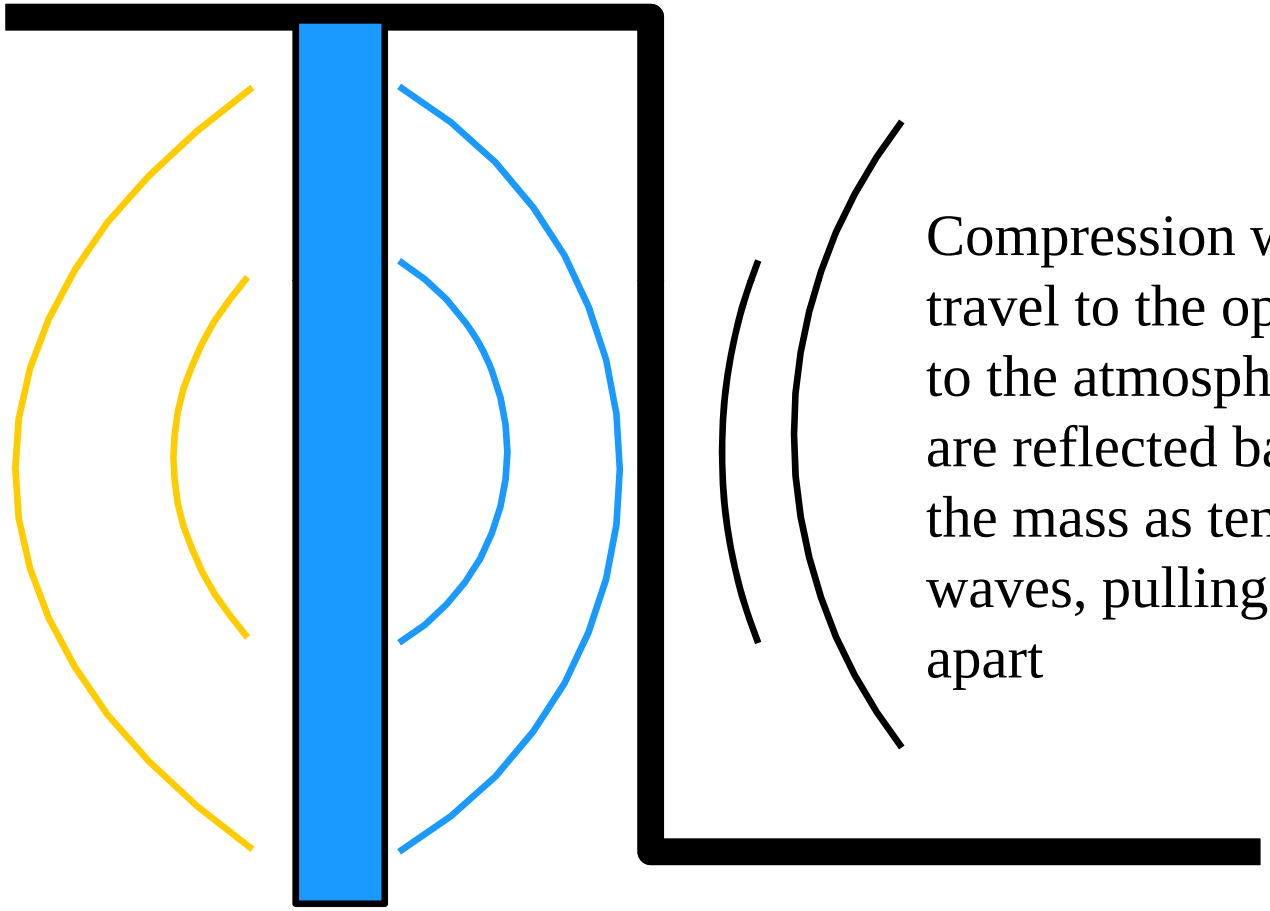
# Fragmentation Process

**Compression waves travel from borehole**



# Fragmentation Process

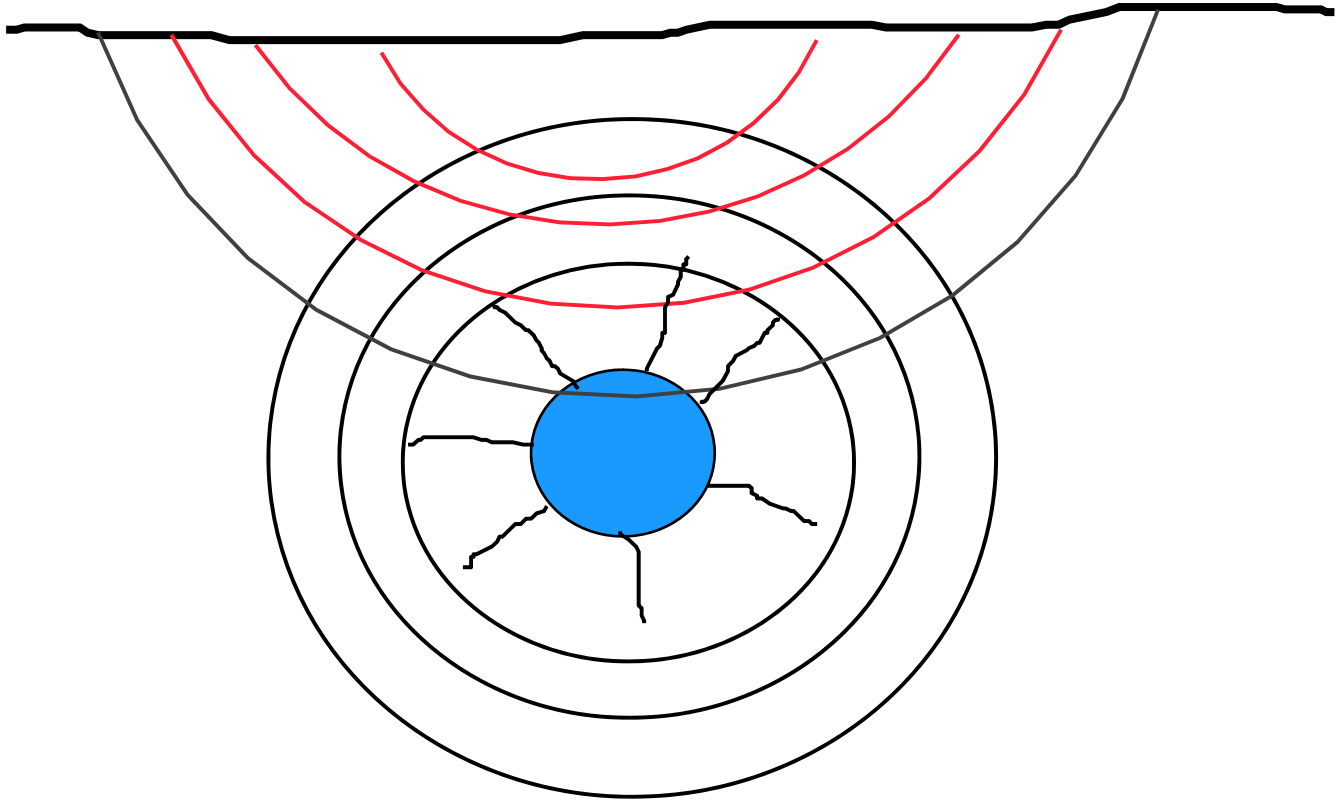
Compression waves leave the blasthole at firing time



Compression waves travel to the open face, to the atmosphere and are reflected back into the mass as tension waves, pulling the rock apart

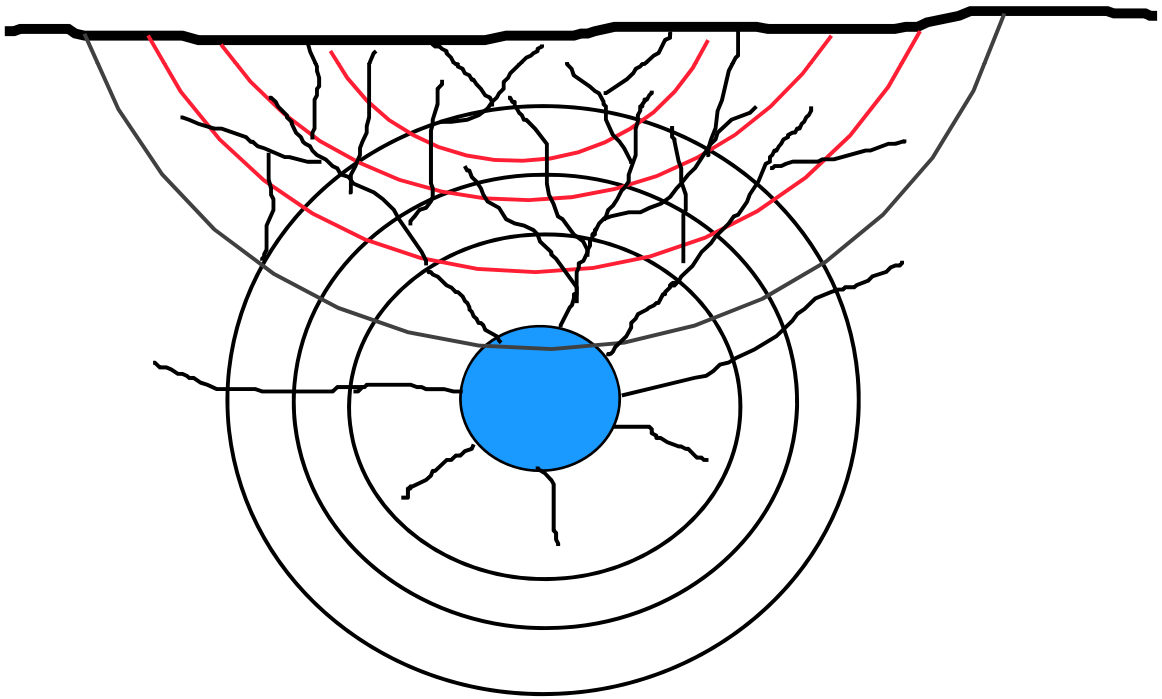
# Fragmentation Process

Waves reflected as tensile waves



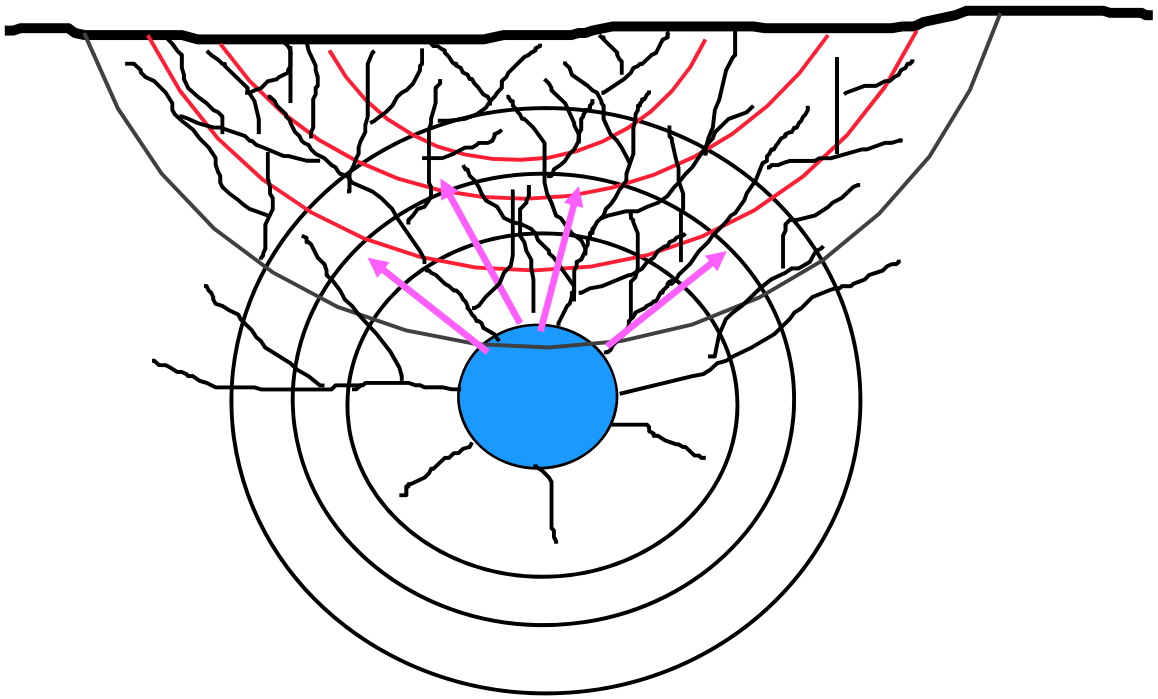
# Fragmentation Process

Tensile waves increase fracture network from free face

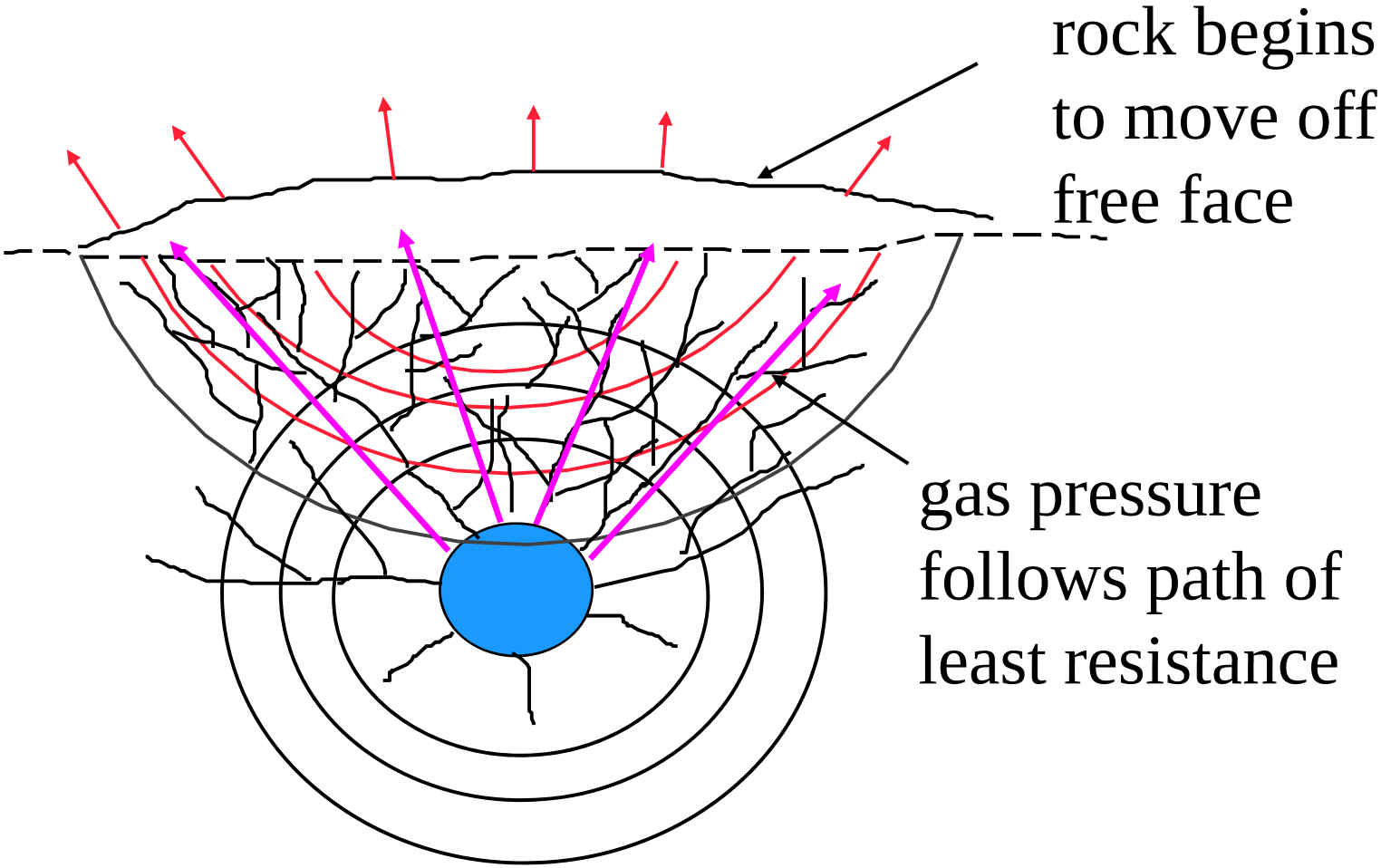


# Fragmentation Process

Borehole pressure energizes cracks, propagating crack network



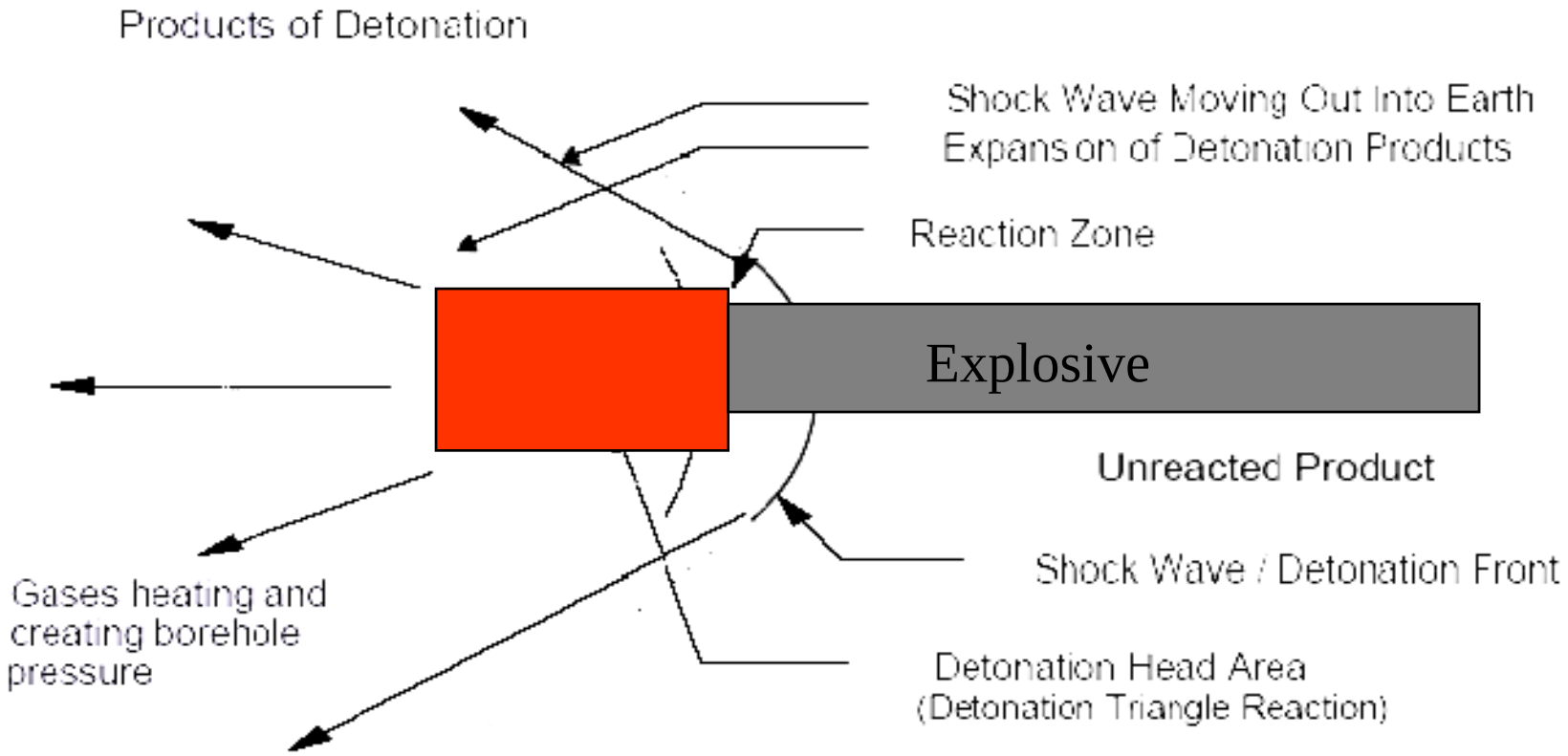
# Fragmentation Process



# Detonation and Borehole Pressure

- **Detonation Pressure is the initial pressure and is created by the supersonic shock front moving out from the detonation zone.**
- **The detonation pressure gives the explosive its shattering action in the vicinity of the borehole**
- **Detonation Pressure is followed by a sustained pressure and is known as borehole pressure.**

# Detonation and Borehole Pressure



# Detonation Pressure – Feet

The VOD and density of the explosive determine the detonation pressure produced in a borehole.

$$\text{Detonation Pressure (kbar)} = \frac{0.2322\ \rho_e\ (\text{VOD})^2}{1{,}000{,}000}$$

*1 bar = 14.504psi*

# Borehole Pressure Equation

$$P_b = 1.69 \text{x} 10^{-3} \rho_e D^2 \left( \sqrt{C} \frac{d_c}{d_h} \right)^{2.6}$$

$P_b$ = borehole pressure in psi
$\rho_e$ = specific gravity of explosive
D = detonation velocity of explosive in ft/s
$d_h$ = borehole diameter in inches
$d_c$ = charge diameter in inches
C = percentage of the total column loaded (expressed as a decimal)

# Comparisons

- **Problem – Which is better? Lets compare both detonation and borehole pressure with 80% of hole loaded.**

  - ✓ **5-inch Blastex in 6.5-inch blast hole**
    - 1.24 g/cc
    - 15,000 velocity f/s

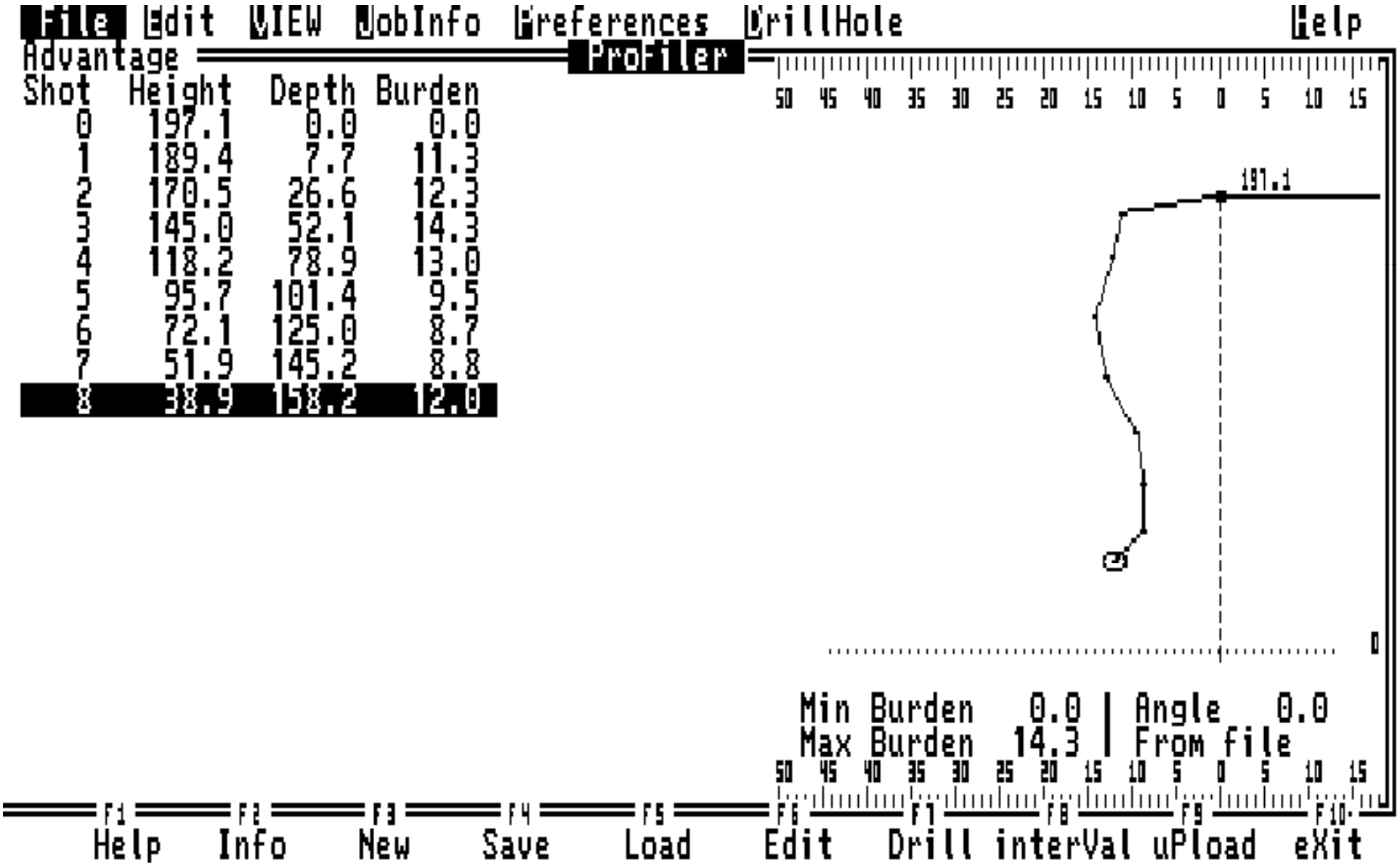
    Detonation p = 939,624.23 psi
    Borehole p = 178,342.63 psi

  - ✓ **6.5-inch column of ANFO**
    - 0.85 g/cc
    - 14,000 f/s

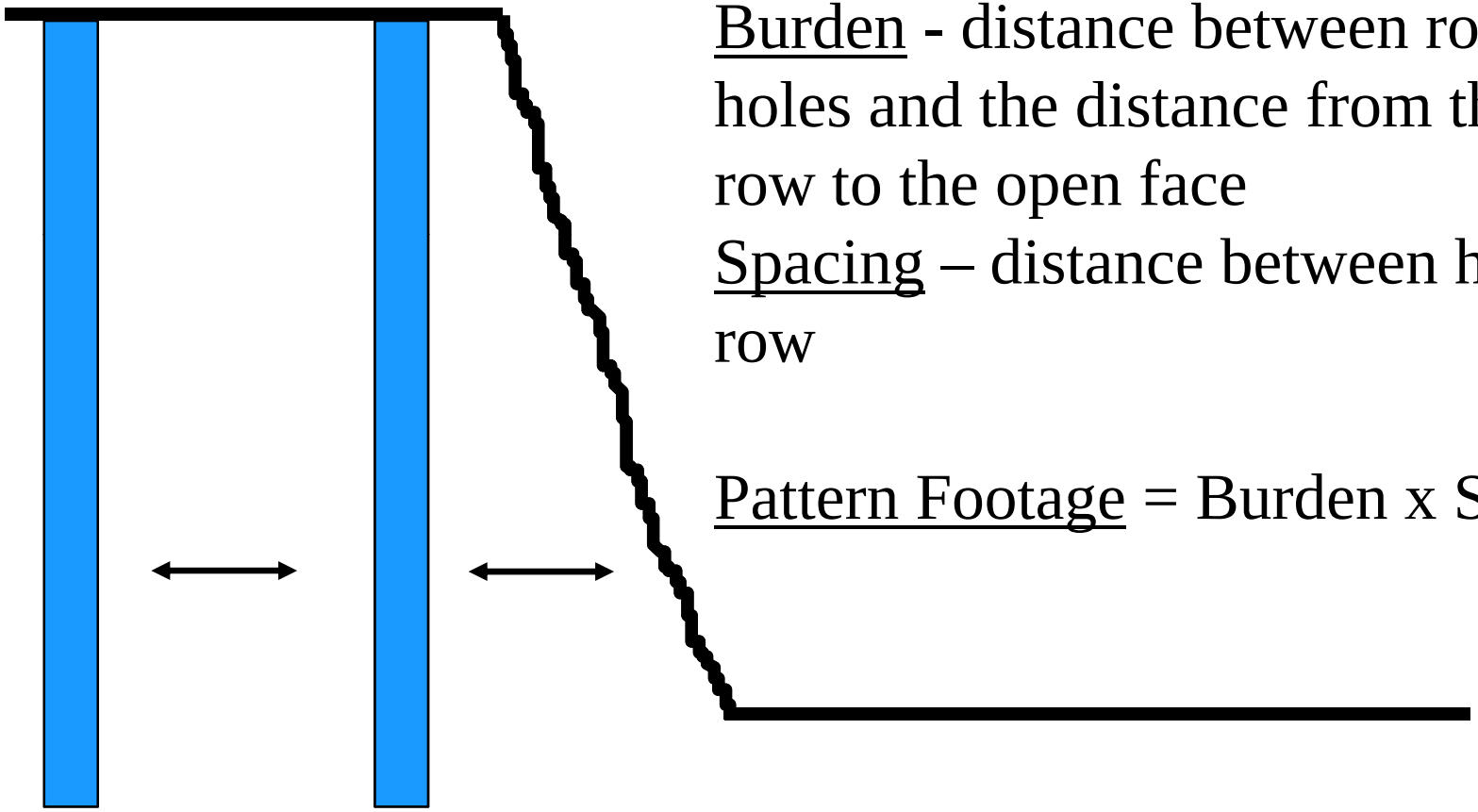
    Detonation p = 561,080.27 psi
    Borehole p = 210,658.35 psi

# String Line

# Burden


File Edit VIEW JobInfo Preferences DrillHole Help
Advantage Profiler
Shot Height Depth Burden
0 197.1 0.0 0.0
1 189.4 7.7 11.3
2 170.5 26.6 12.3
3 145.0 52.1 14.3
4 118.2 78.9 13.0
5 95.7 101.4 9.5
6 72.1 125.0 8.7
7 51.9 145.2 8.8
8 38.9 158.2 12.0
50 45 40 35 30 25 20 15 10 5 0 5 10 15
197.1
0
Min Burden 0.0 | Angle 0.0
Max Burden 14.3 | From file
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10
Help Info New Save Load Edit Drill interVal uPload eXit

# Pattern Footage

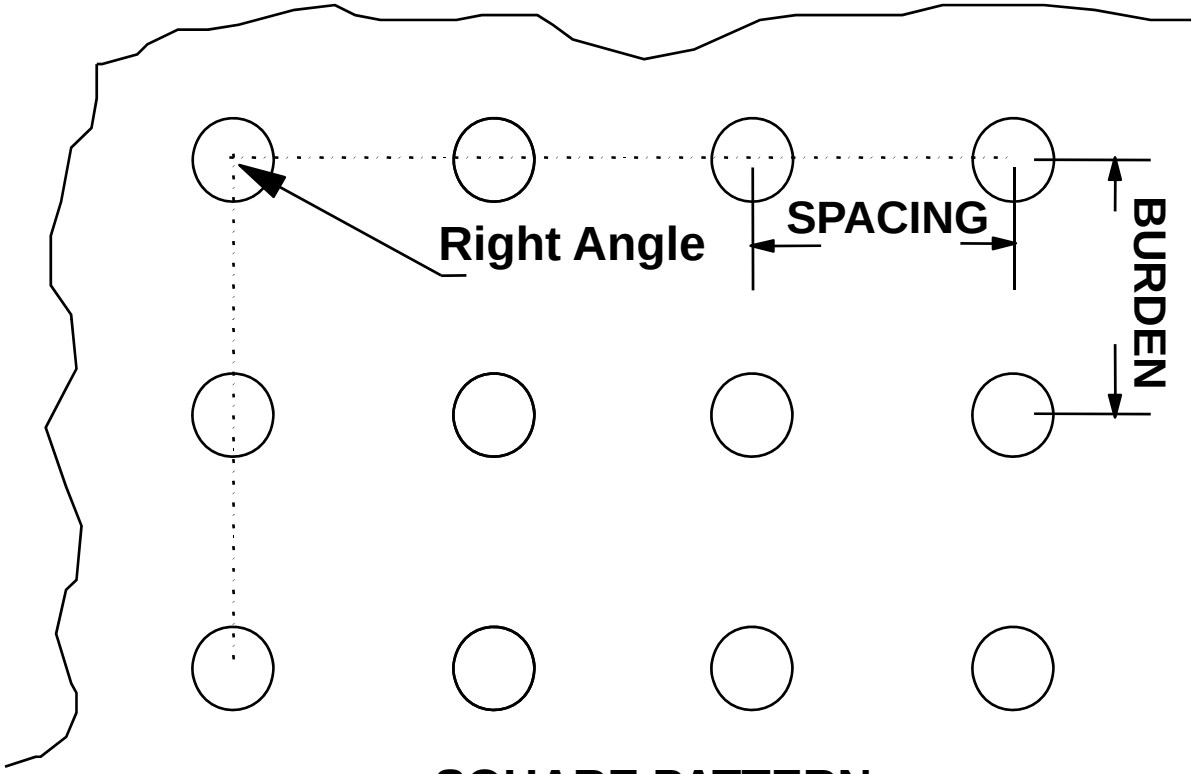


Burden - distance between rows of holes and the distance from the front row to the open face

Spacing – distance between holes in a row

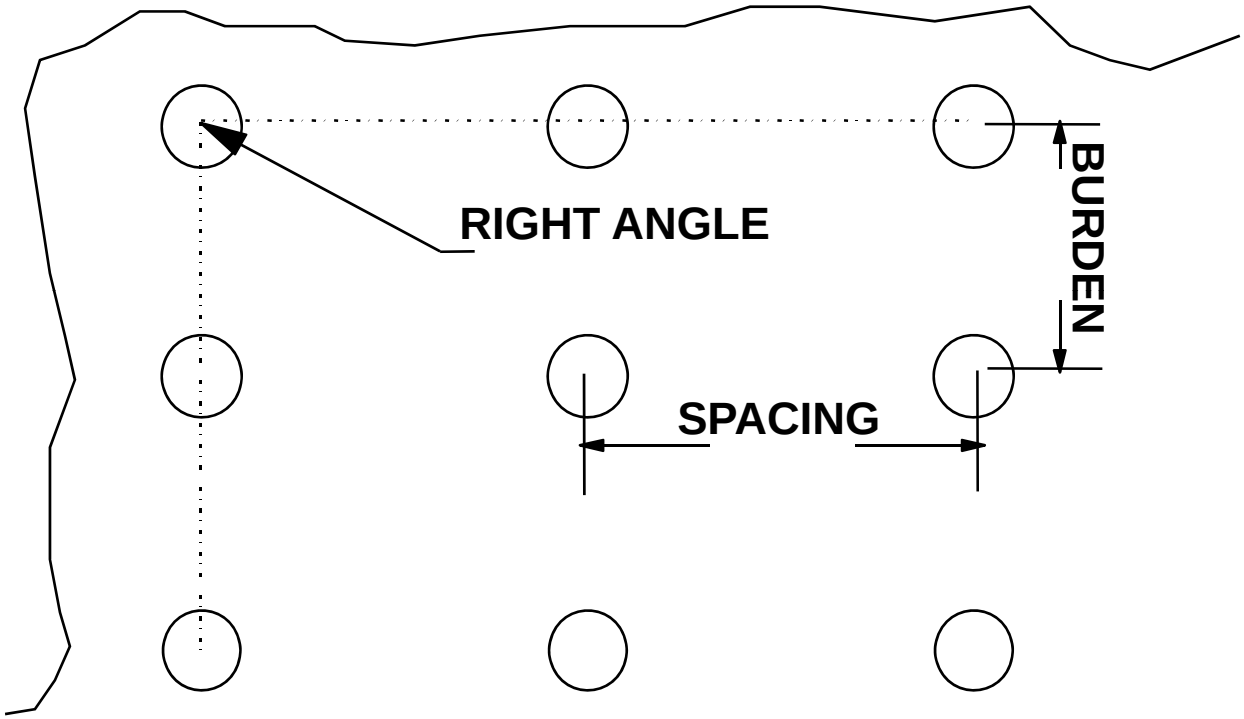
Pattern Footage = Burden x Spacing

# Drill and Blast Pattern - Square




**SQUARE PATTERN**
**BURDEN = SPACING**

# Drill and Blast Pattern - Rectangular

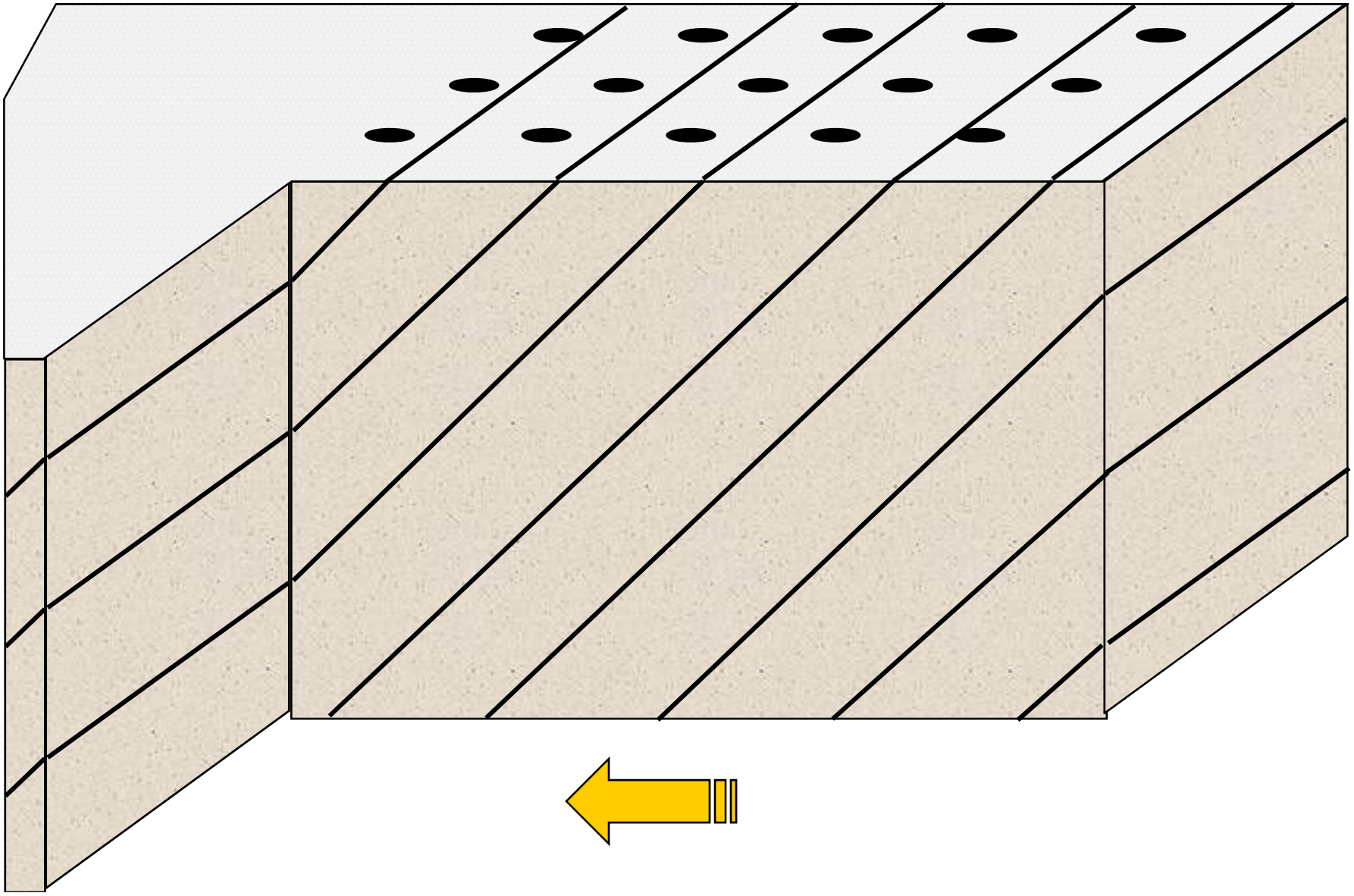



**RECTANGULAR PATTERN**

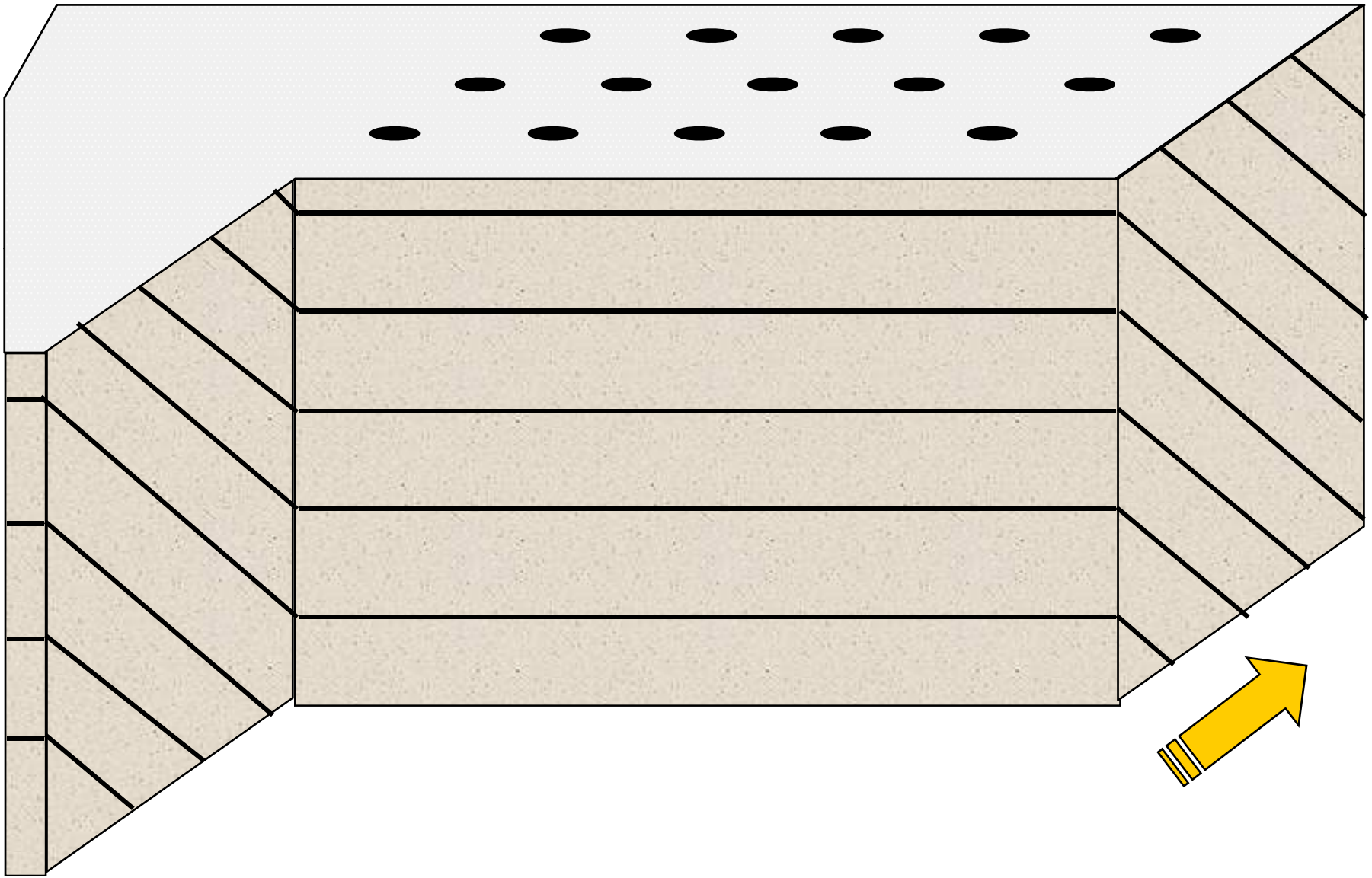
**BURDEN UNEQUAL TO SPACING**

# Other Blasting Problems

# Seams Play An Important Role



# Seams Play An Important Role



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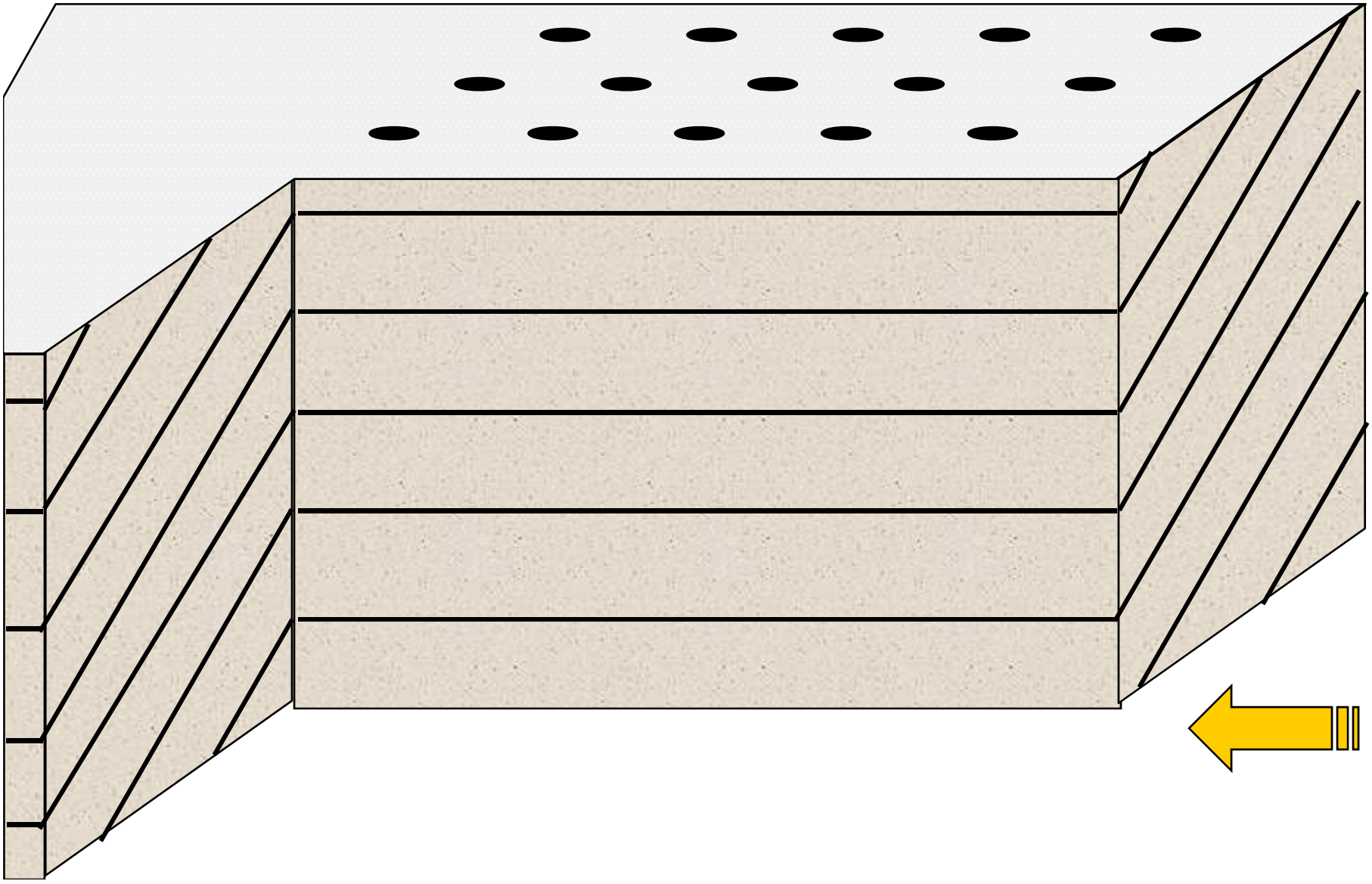

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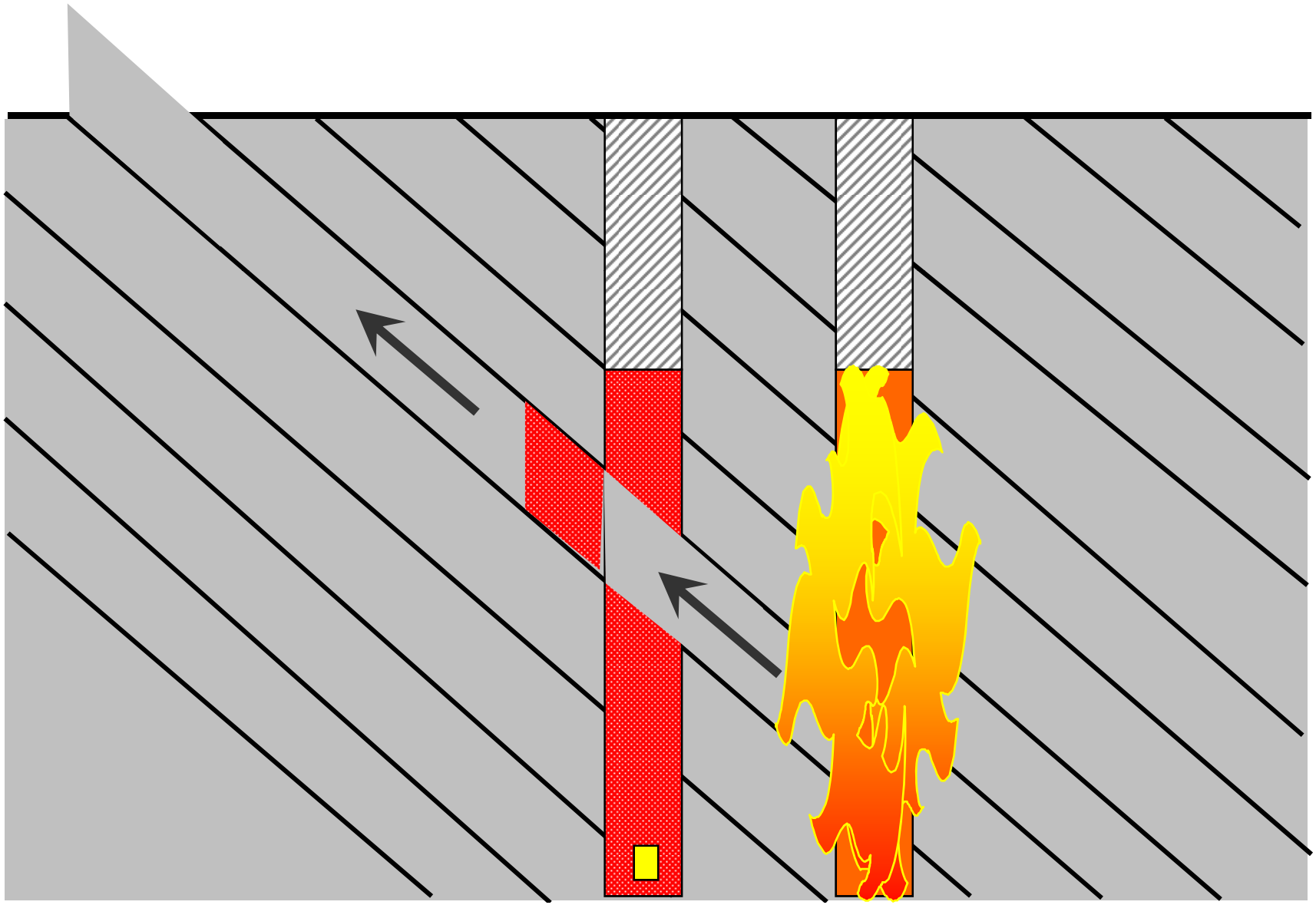

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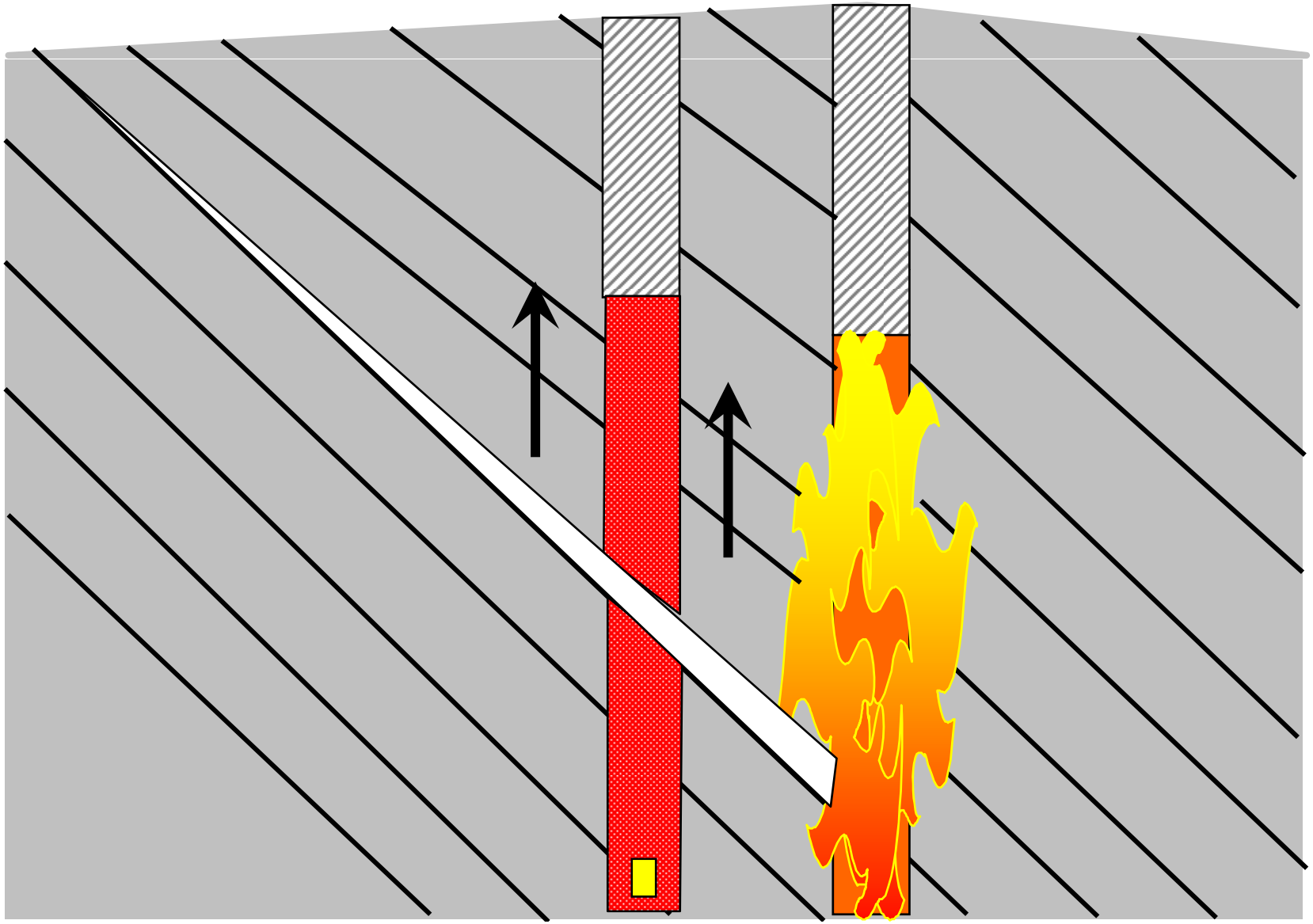
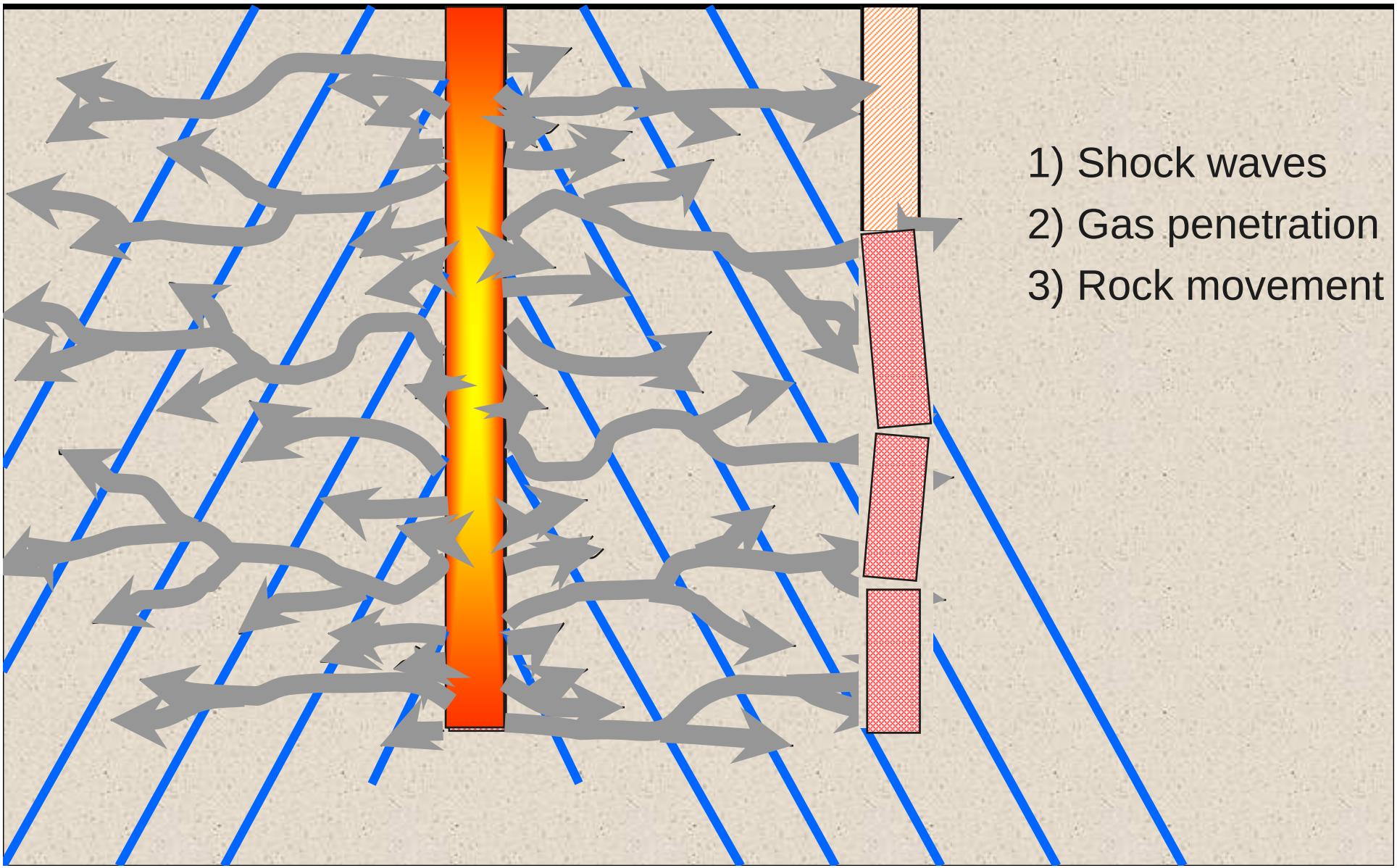
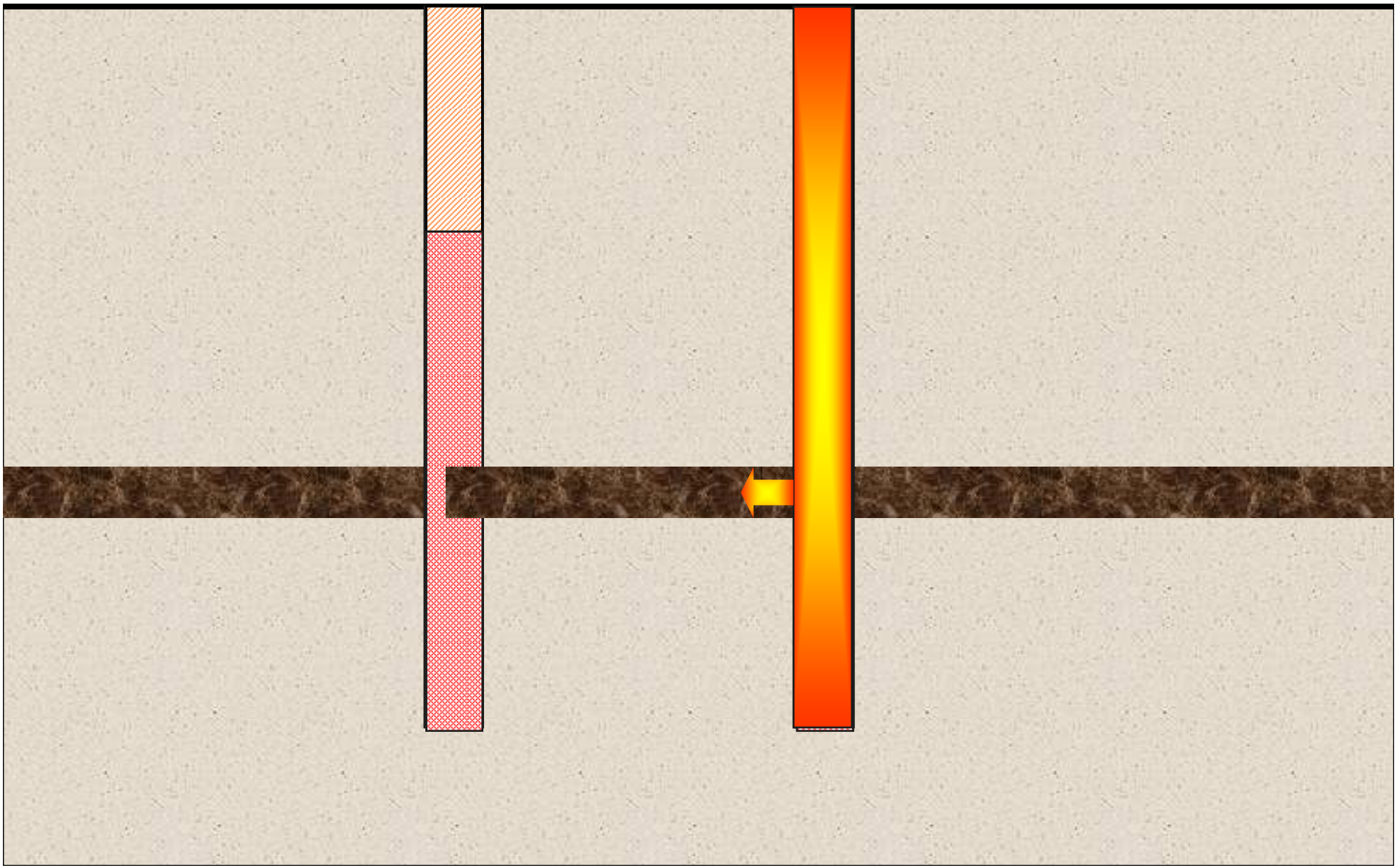


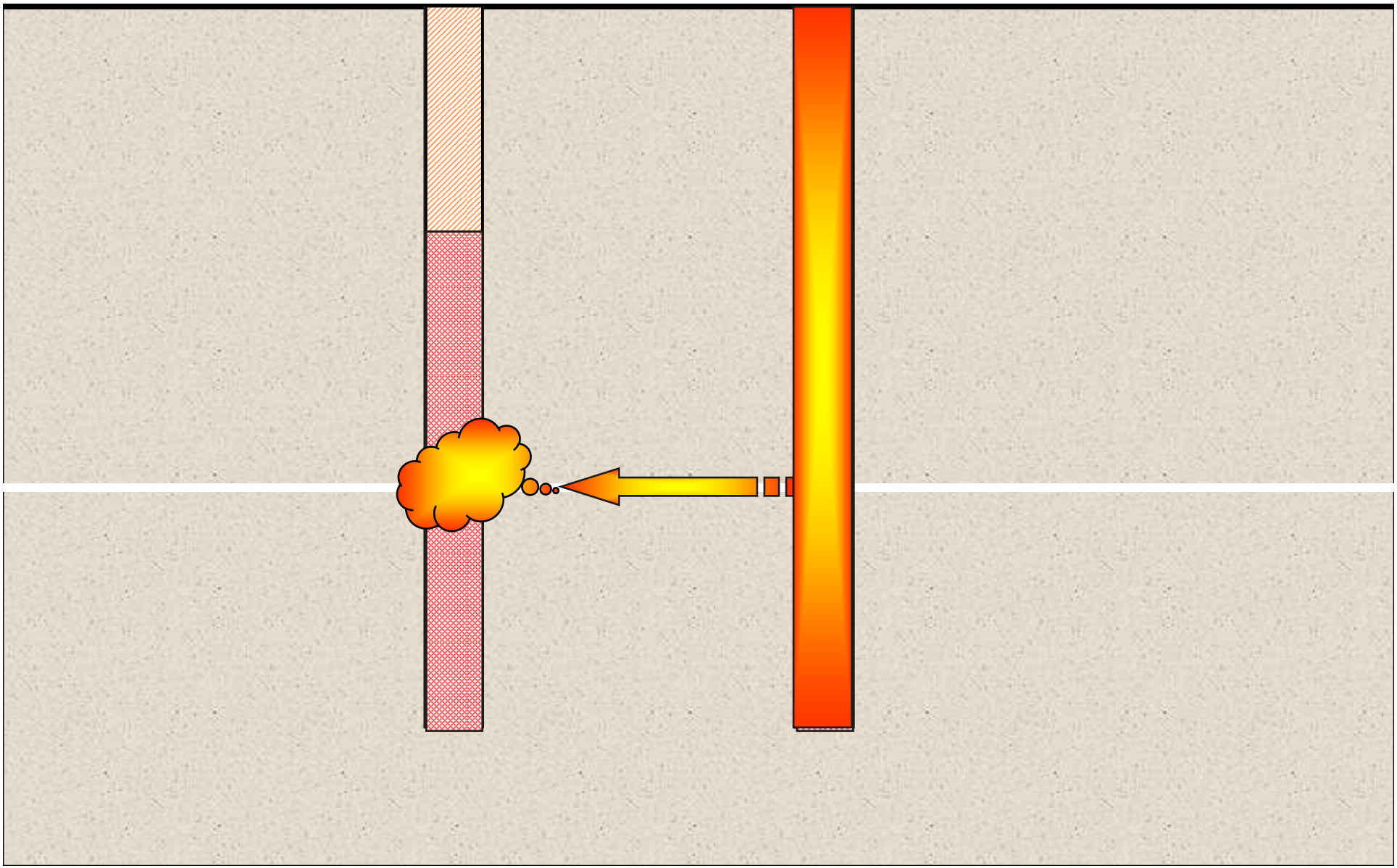
# Potential Interactions Between Neighboring Holes



# Rock Movement Along Weak Bands



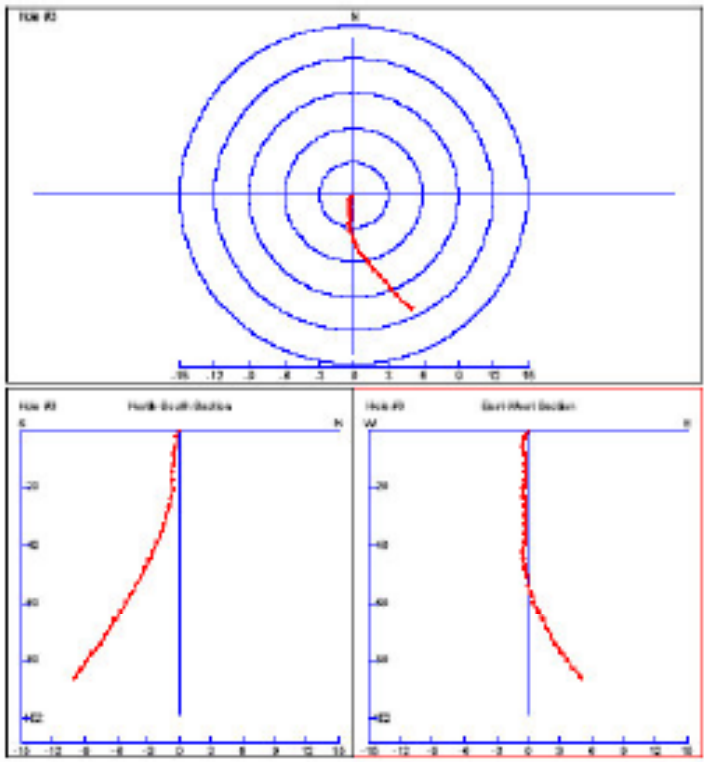
# Effect of Gas Penetration Along Joint



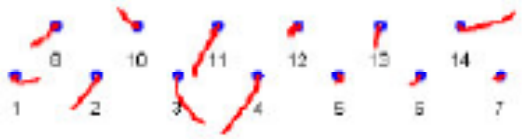
# Burden Can Be Changed

**Findings/Conclusions:**

The primary focus of the investigation was to determine the amount of borehole deviation. This was accomplished using a Boretrak® on an adjacent blast pattern where holes had been drilled. It was discovered that many of the holes had deviation towards the face as well as towards each other. Specifically, hole three in the front row of holes shows deviation of six feet to the right and twelve feet to the front. Hole four in the front row showed deviation of seven feet to the left and twelve feet to the front.



The information clearly shows that boreholes could intersect and that the deviation would reduce the front row burdens resulting in an explosive energy release.

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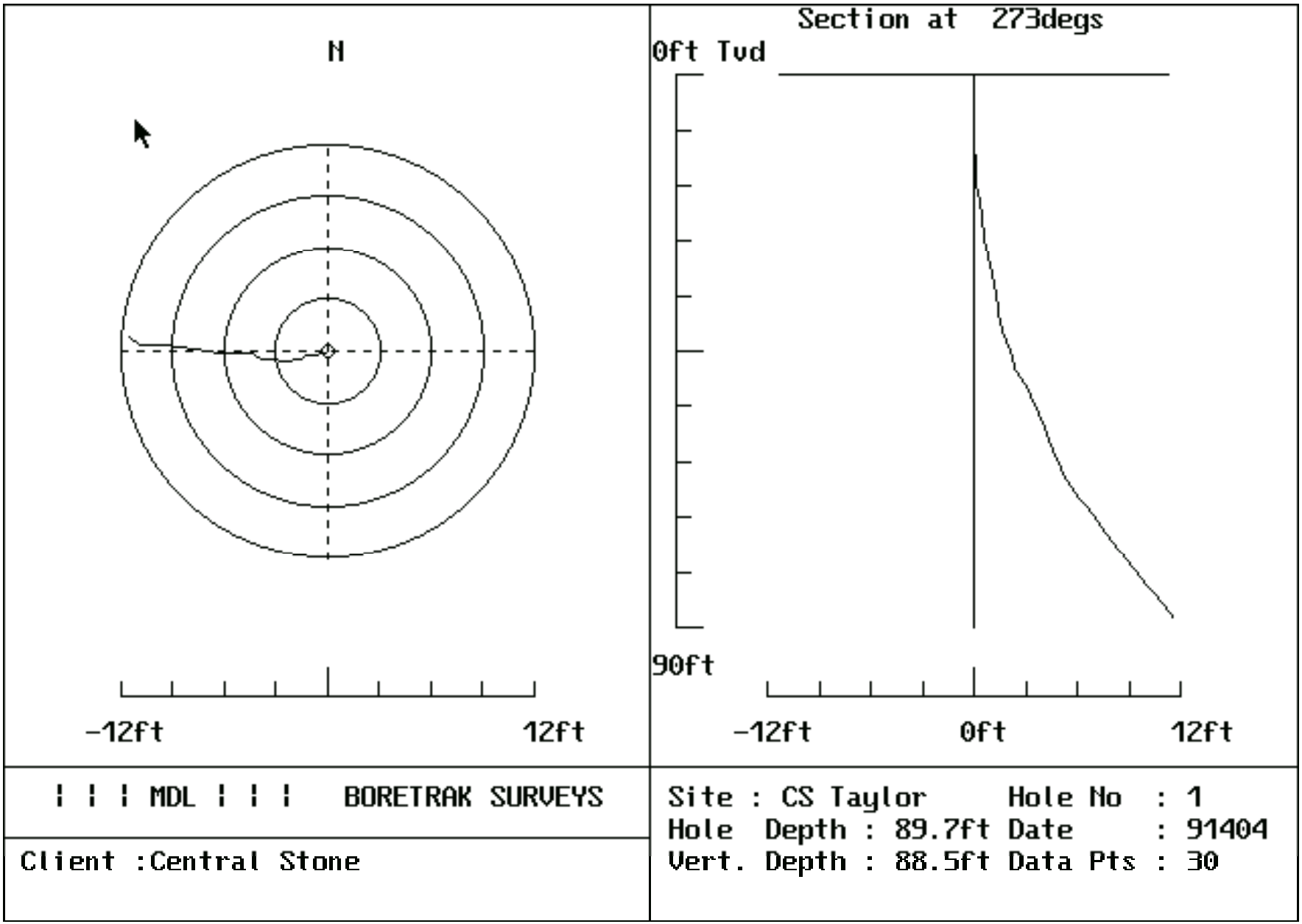
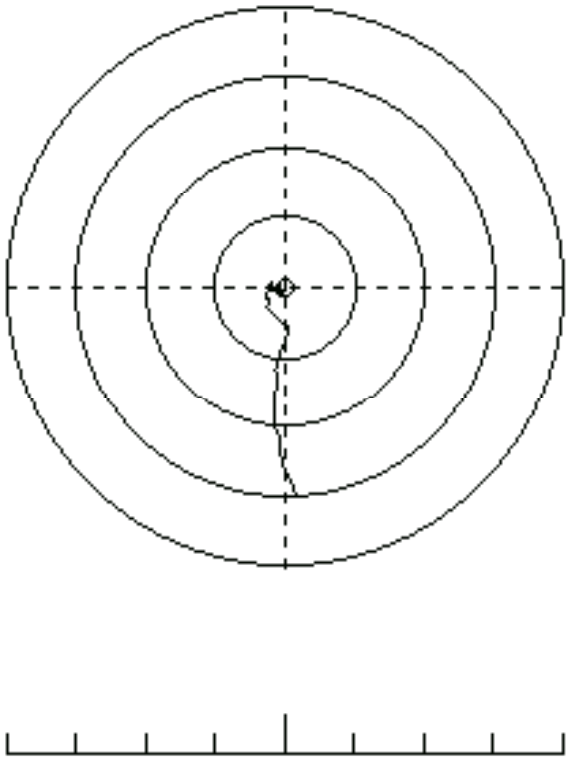
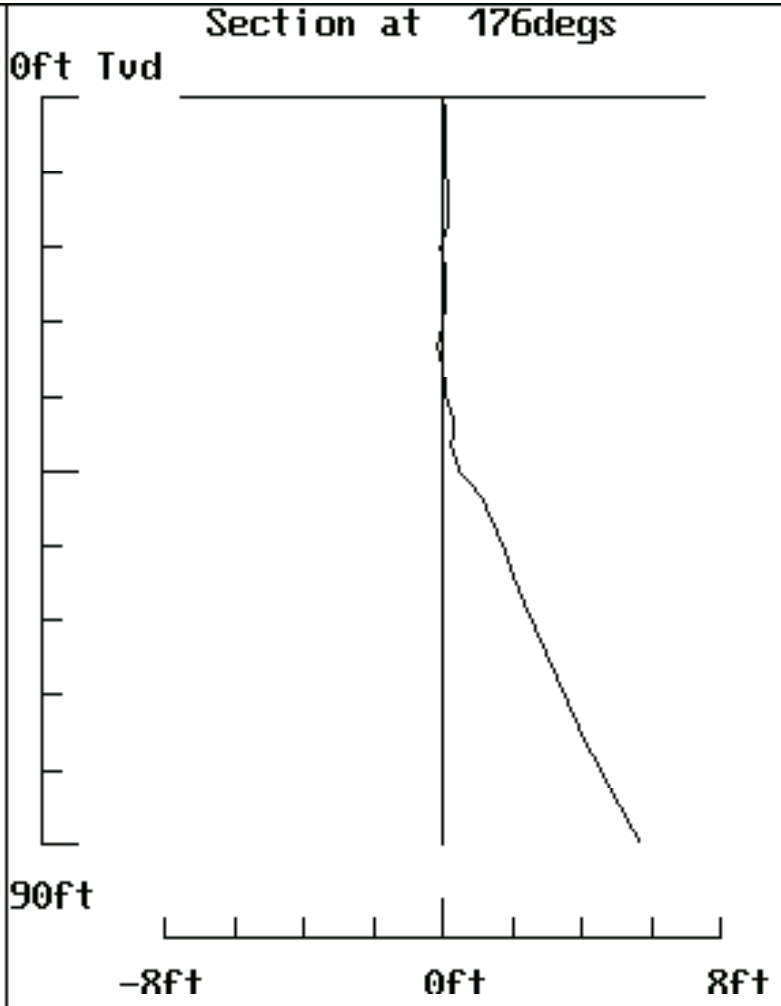

N
-12ft
12ft
Section at 273degs
0ft Tvd
90ft
-12ft
0ft
12ft
| | | MDL | | |
BORETRAK SURVEYS
Client :Central Stone
Site : CS Taylor
Hole No : 1
Hole Depth : 89.7ft
Date : 91404
Vert. Depth : 88.5ft
Data Pts : 30




| | | | MDL | | | | BORETRAK SURVEYS

Client :Central Stone

Site : CS Taylor Hole No : 3
Hole Depth : 90ft Date : 91404
Vert. Depth : 89.6ft Data Pts : 30

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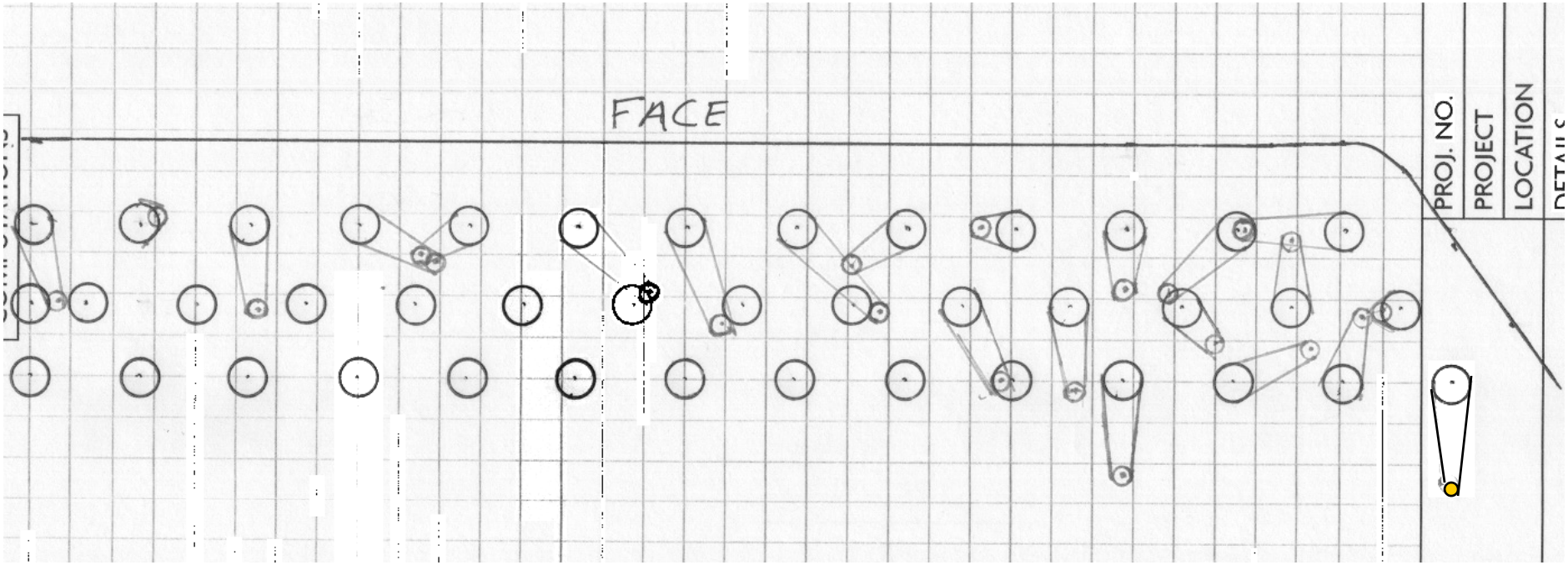
# Throw Rocks in the Air and Paint Them!

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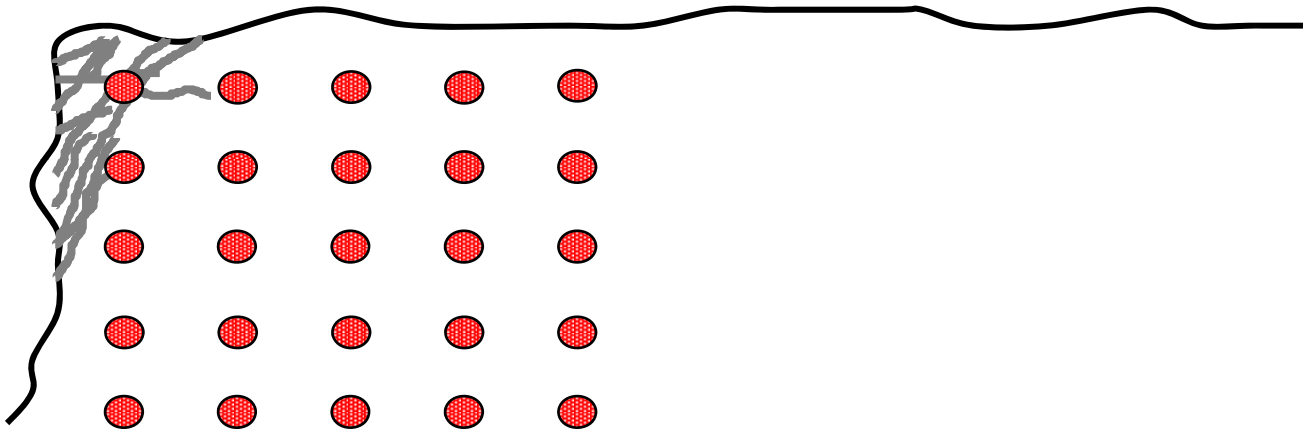
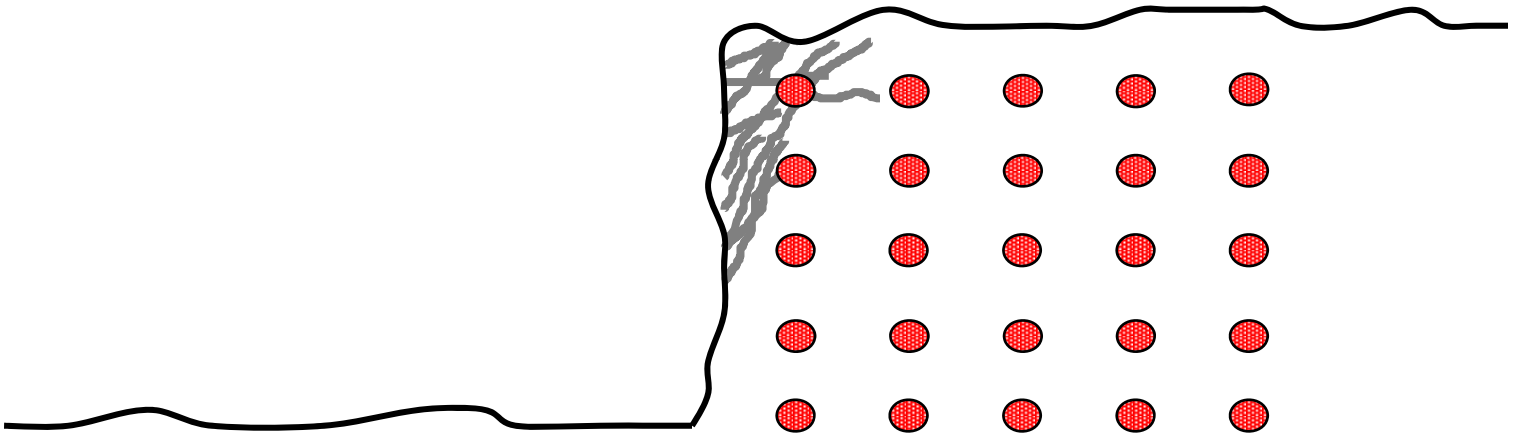
# Blast Management

## Open Corner Damage



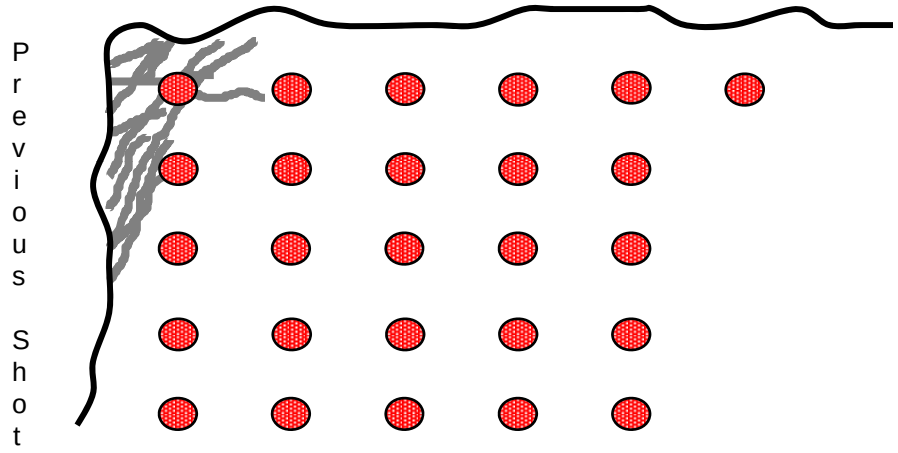
# Blast Management

## Open Corner Damage



# Blast Management

## Open Corner Damage - Band-Aid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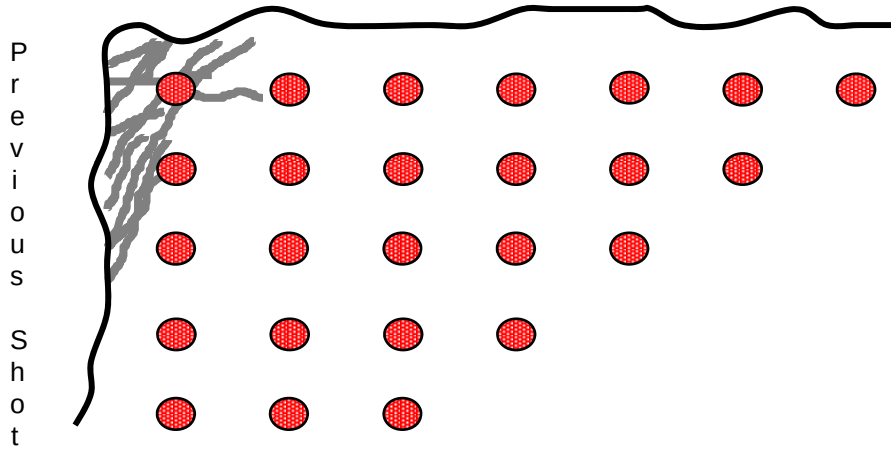
# Blast Management

## Open Corner Damage - Solution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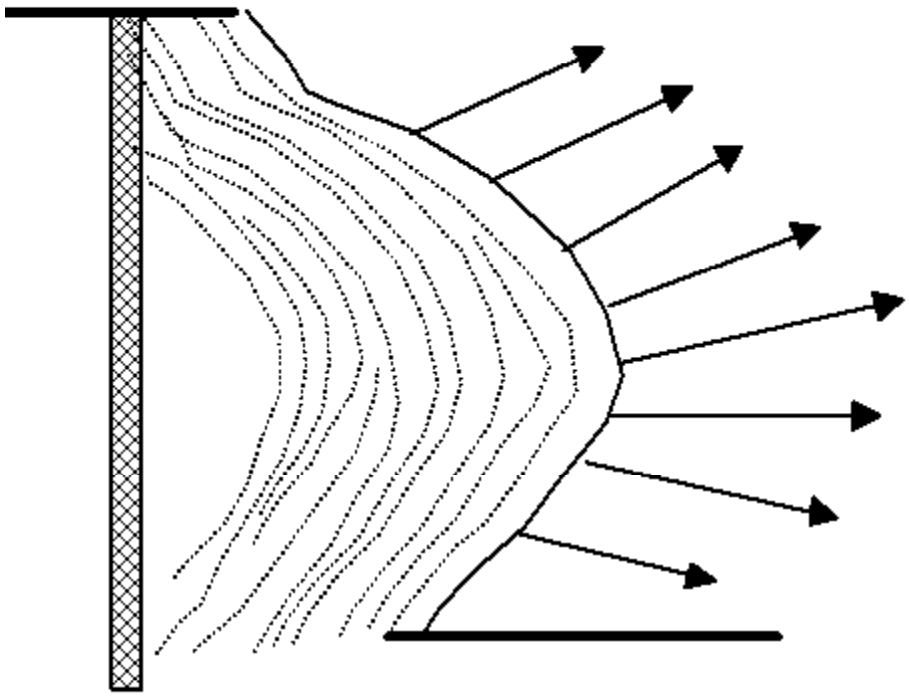
# Blast Management

## Optimizing Explosive Energy Confinement

**Adequate Confinement**
**Good Face Movement**



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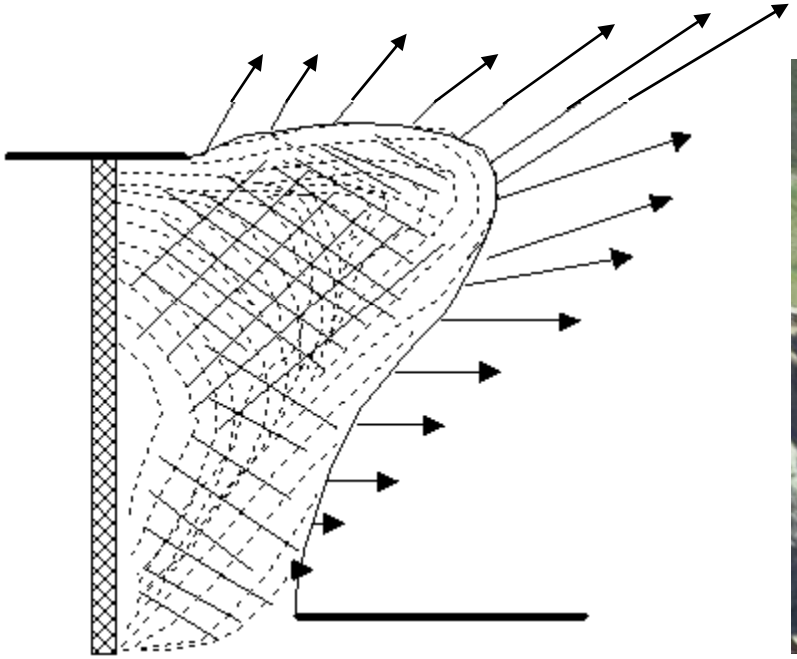
# Blast Management

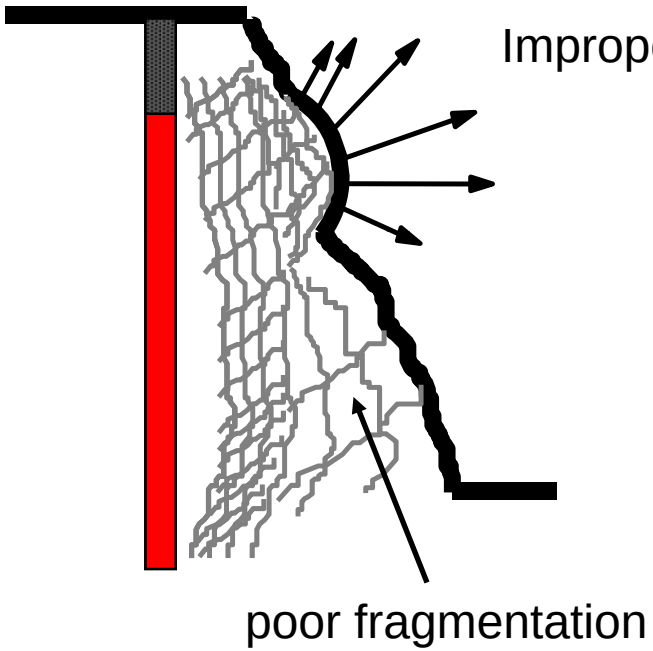
## Optimizing Explosive Energy Confinement



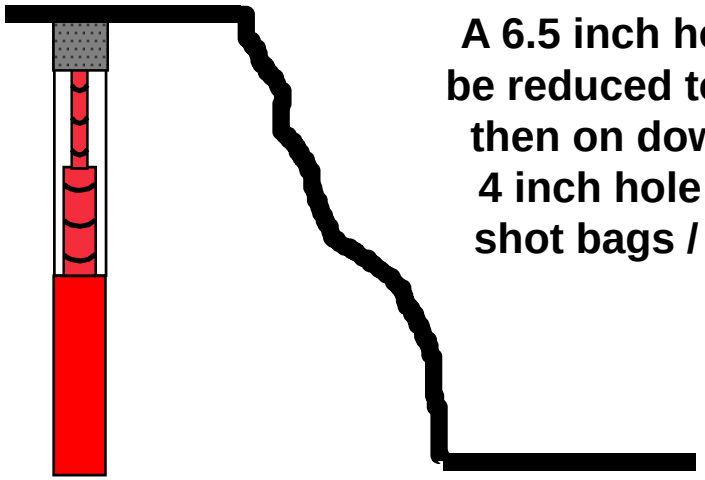
**Inadequate Confinement**
**Improper Face Movement**

# Blast Management

## Optimizing Explosive Energy Confinement




**Optimized**



**A 6.5 inch hole can be reduced to 5 inch then on down to a 4 inch hole using shot bags / sticks**

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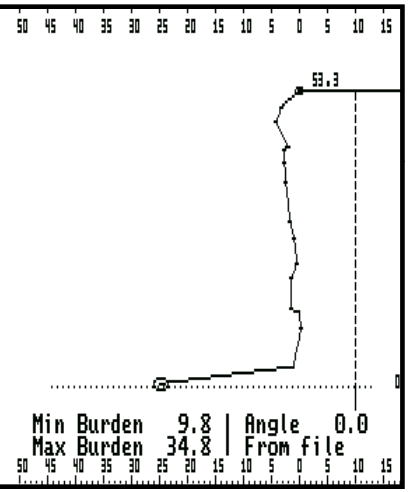
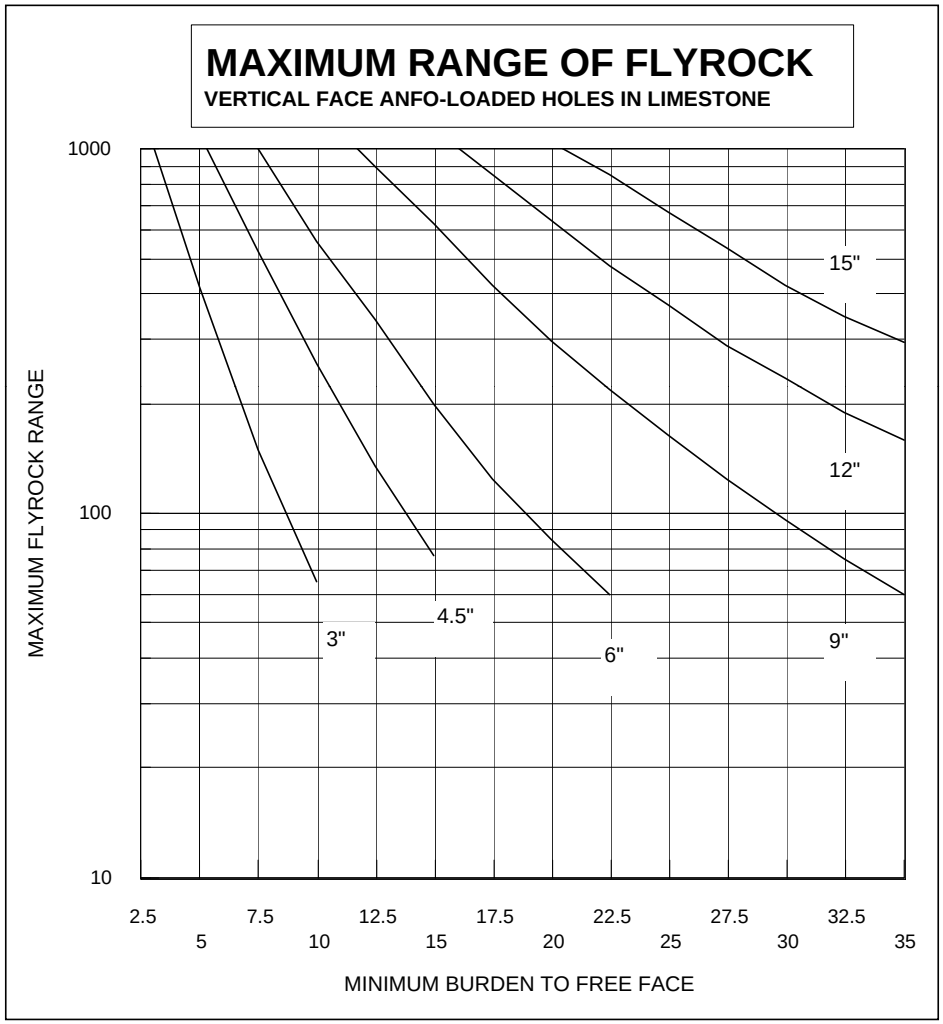
# Blast Management

## Flyrock Nomograph Limestone

| Shot | Height | Depth | Burden |
|---|---|---|---|
| 0 | 53.3 | 0.0 | 10.0 |
| 1 | 50.3 | 3.0 | 13.3 |
| 2 | 47.7 | 5.7 | 14.2 |
| 3 | 43.4 | 9.9 | 12.1 |
| 4 | 43.0 | 10.3 | 12.8 |
| 5 | 40.4 | 12.9 | 12.7 |
| 6 | 36.7 | 16.7 | 12.4 |
| 7 | 29.8 | 23.6 | 11.8 |
| 8 | 26.5 | 26.8 | 11.1 |
| 9 | 22.2 | 31.2 | 10.6 |
| 10 | 19.7 | 33.7 | 11.4 |
| 11 | 14.3 | 39.1 | 11.6 |
| 12 | 13.8 | 39.5 | 10.3 |
| 13 | 10.6 | 42.8 | 9.8 |
| 14 | 3.5 | 49.8 | 11.3 |
| 15 | 0.6 | 52.8 | 34.8 |




**Example:**

5.5” diameter hole planned for 13 ft burden

@ 43 ft depth likelihood of ~450 ft flyrock distance.

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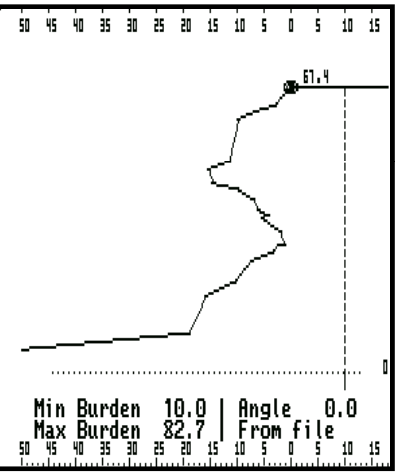
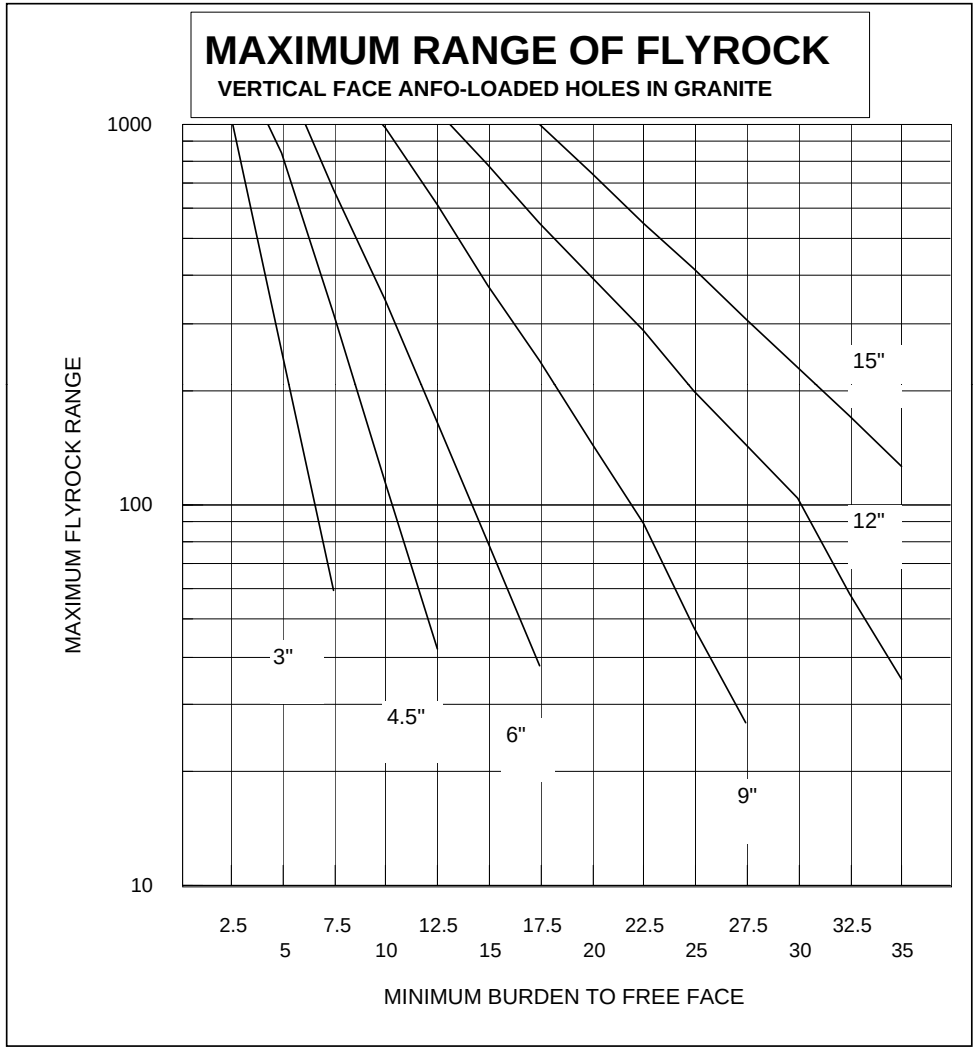
# Blast Management

## Flyrock Nomograph Granite

| Shot | Height | Depth | Burden |
|---|---|---|---|
| 0 | 67.4 | 0.0 | 10.0 |
| 1 | 63.1 | 4.3 | 13.0 |
| 2 | 61.5 | 5.9 | 16.2 |
| 3 | 60.1 | 7.3 | 19.8 |
| 4 | 49.4 | 18.0 | 21.4 |
| 5 | 47.8 | 19.6 | 25.3 |
| 6 | 44.6 | 22.8 | 24.6 |
| 7 | 43.1 | 24.3 | 20.1 |
| 8 | 40.6 | 26.8 | 17.1 |
| 9 | 38.0 | 29.4 | 15.9 |
| 10 | 36.8 | 30.6 | 14.3 |
| 11 | 36.0 | 31.4 | 15.3 |
| 12 | 32.9 | 34.5 | 11.9 |
| 13 | 30.2 | 37.3 | 11.3 |
| 14 | 30.1 | 37.3 | 12.3 |
| 15 | 27.8 | 39.6 | 13.5 |
| 16 | 26.1 | 41.3 | 17.2 |
| 17 | 21.1 | 46.3 | 20.5 |
| 18 | 17.8 | 49.7 | 25.7 |
| 20 | 8.7 | 58.8 | 29.0 |




**Example:**

6.5” diameter hole planned for 16 ft burden

@ 37 ft depth likelihood of ~400 ft flyrock distance.

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# Tons, Cubic Yards, & Powder Factors

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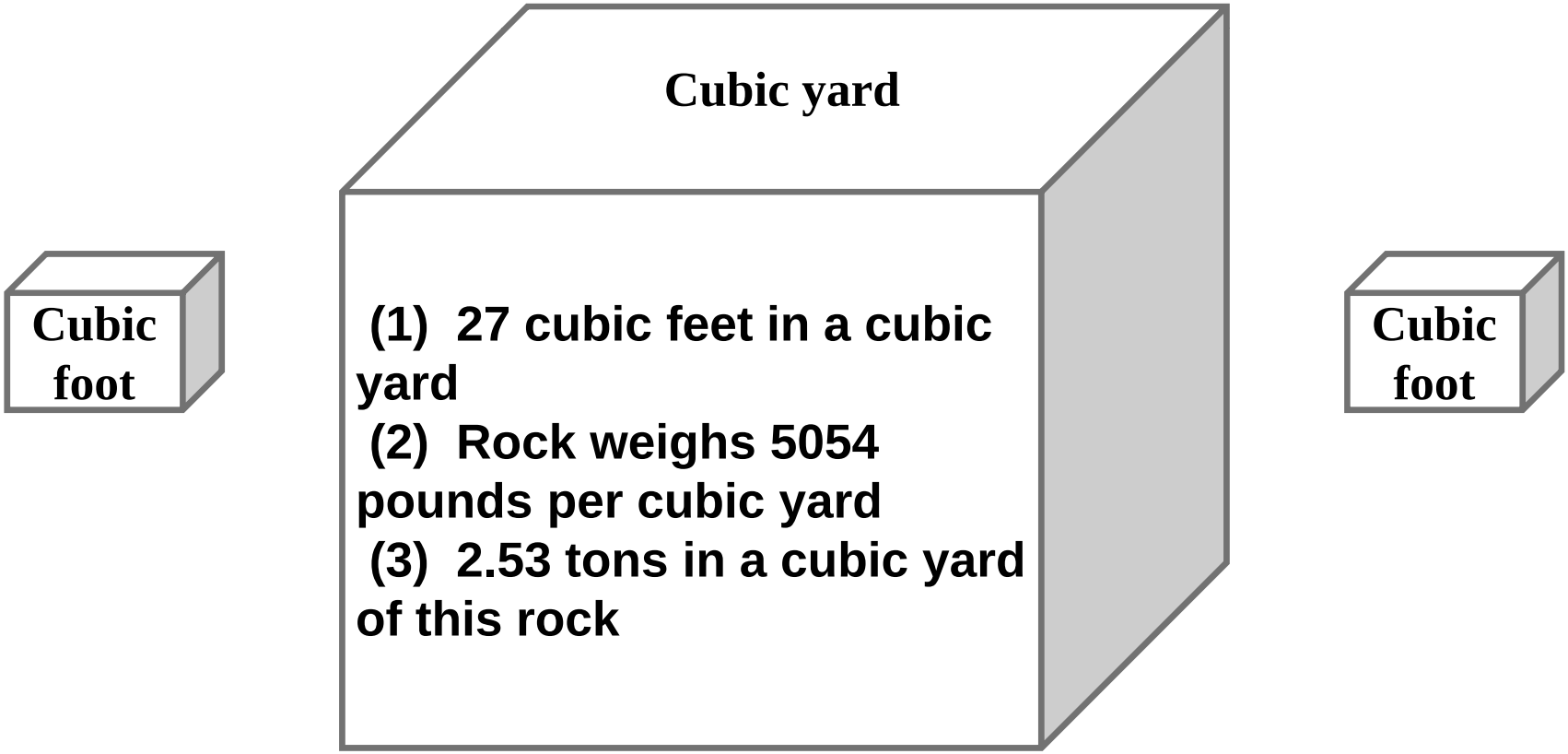
# Water Vs. Rock Weight

Water has a density of 1 g/cc and a cubic foot weighs 62.4 lbs.

A rock having a density of 3 g/cc weighs 187.2 lbs/ft^3.



# Yards$^3$ & Tons for One Hole

$$\text{Cubic Yards} = \frac{\text{Burden} \times \text{Spacing} \times \text{Face Height}}{27}$$

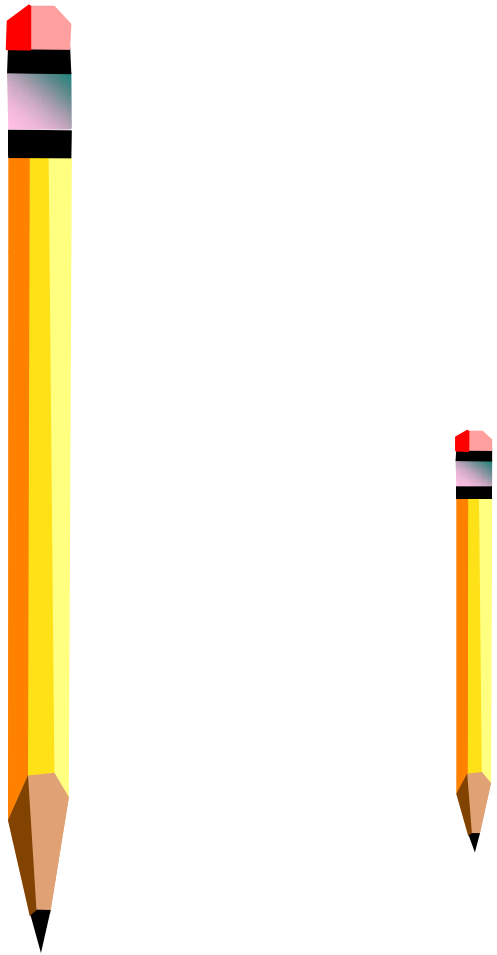
$$\text{Tons} = \text{Yards}^3 \times .8424 \times \text{Rock Sg.}$$

# Pounds of Explosives Per Foot of Borehole

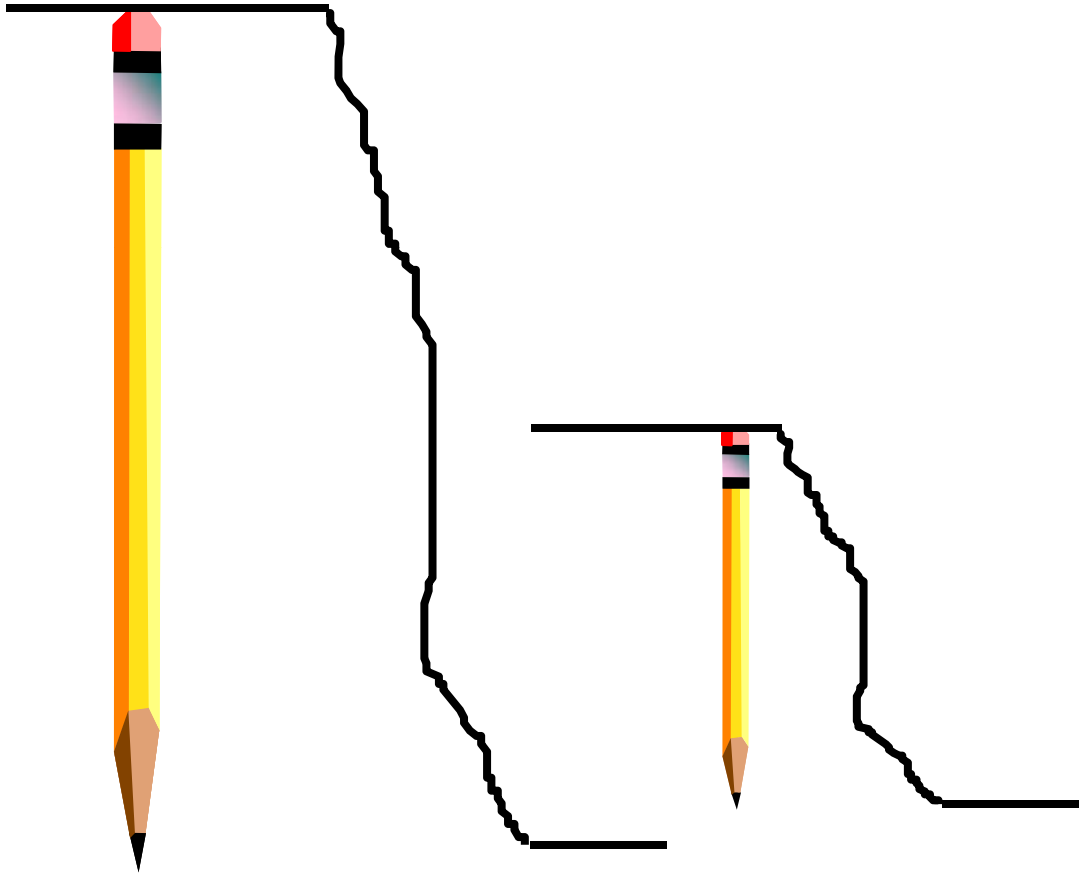
$$\text{Explosive Dia.}^2 \times .3405 \times \text{Explosive Density}$$

Explosive Diameter in inches

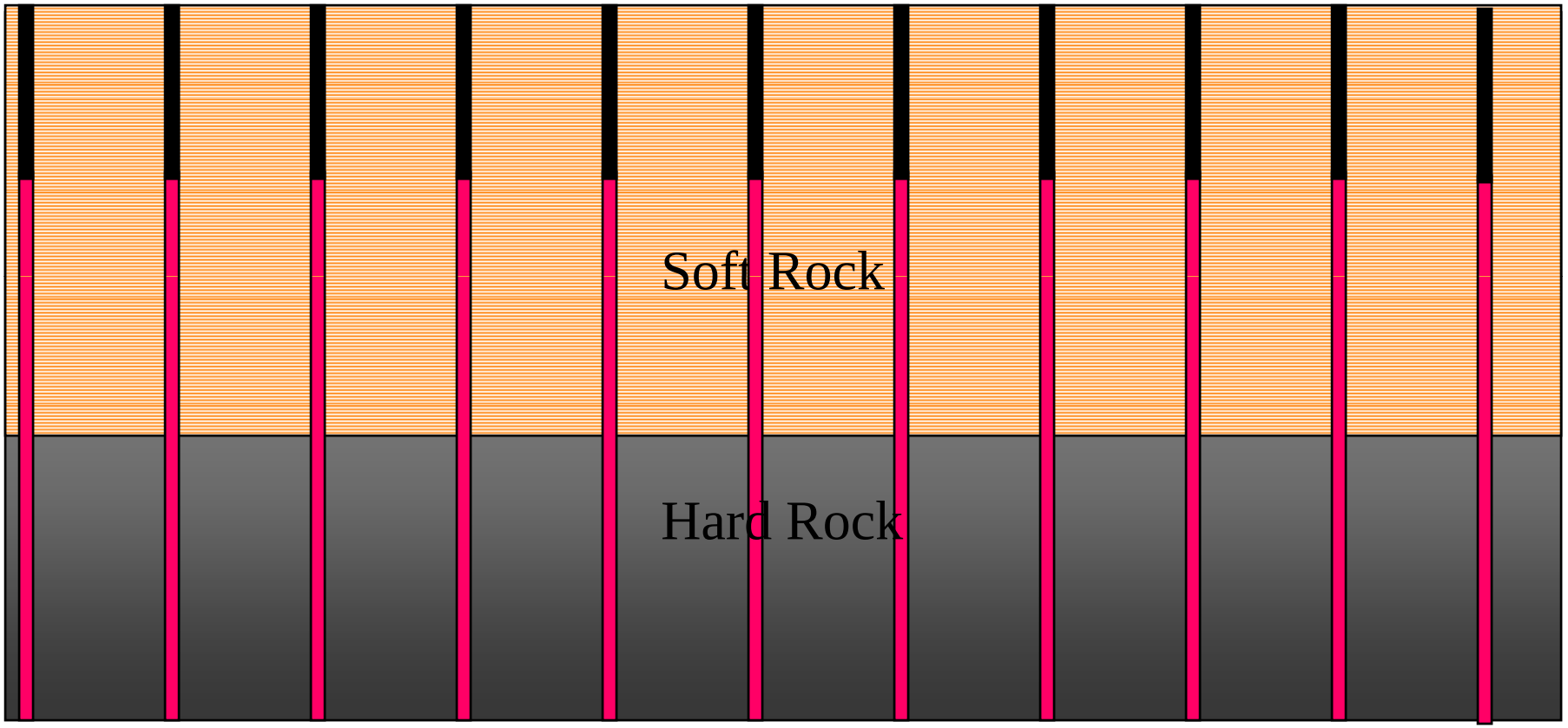
# Length makes the difference



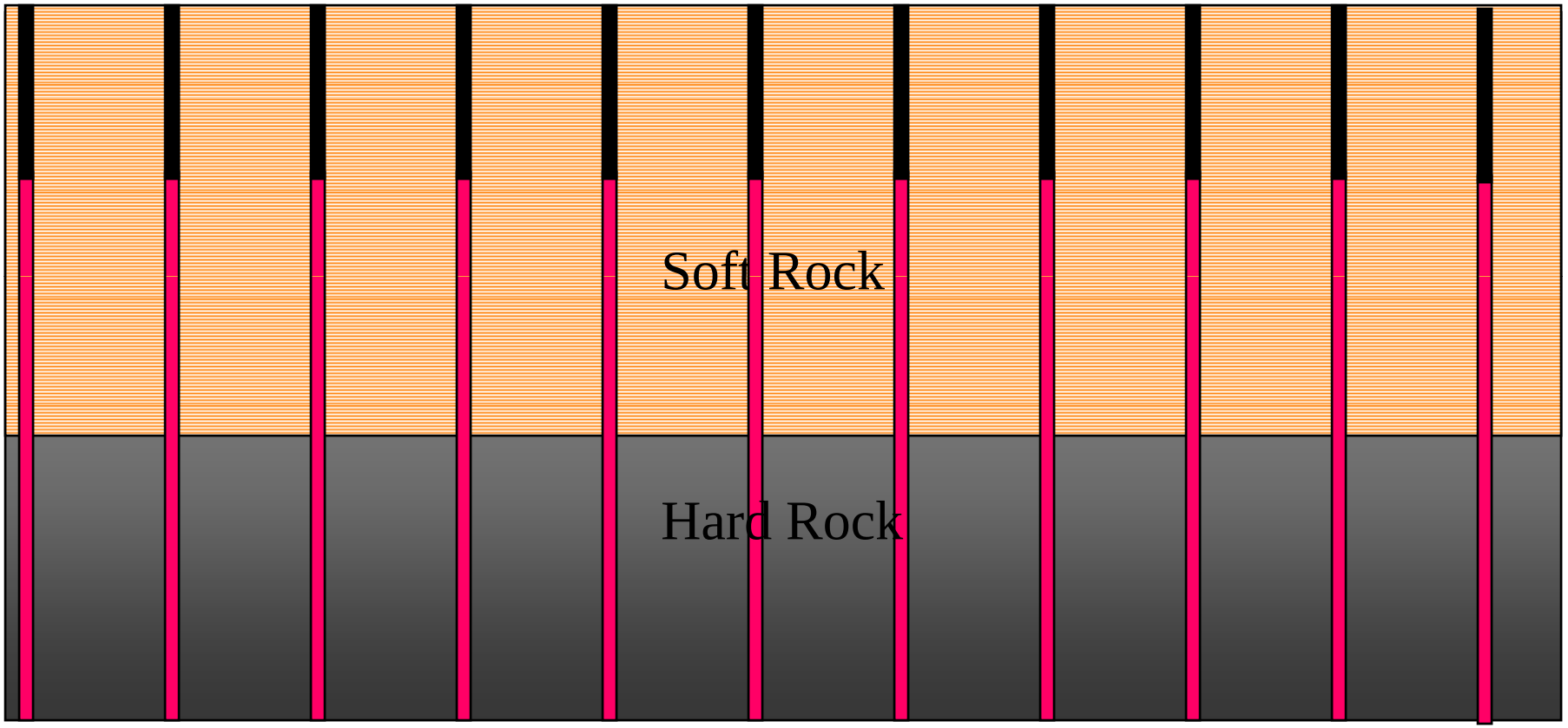
# Length Makes the Difference



# What Should The Pattern Be?



# Where Should The Primer Be Located?



# **Pattern Footage Granite (**Step #1)

Divide the face height by the hole diameter to get one of the following empirical constants

| | | | | |
|---|---|---|---|---|
| **13.23 OR GREATER** | | | **=** | **(A)1200** |
| **9.45** | **TO** | **13.22** | **=** | **(B) 906** |
| **4.80** | **TO** | **9.44** | **=** | **(C) 806** |
| **2.62** | **TO** | **4.79** | **=** | **(D) 484** |
| **1.84** | **TO** | **2.61** | **=** | **(E) 282** |

*"Face height could be the depth of a cut or a decked hole and in cases of decked holes, the length of the powder column is added to the length of the deck".*

# Pattern Footage Granite

Step #2

$$\left(\frac{\text{Hole diameter}}{12}\right)^2$$

Step #3

Multiply the result of step #2 by the proper empirical constant from step #1

*The result of step #3 equals the pattern footage for that hole diameter versus that particular face height.*

# Pattern Footage Granite

Step #4 for Square patterns

$$\text{Burden or spacing} = \sqrt{\text{Pattern footage}}$$

Step #4 for Rectangle patterns

$$\text{Burden} = \sqrt{\text{Pattern footage}} \times .85$$

$$\text{Spacing} = \frac{\text{Pattern footage}}{\text{Burden}}$$

# Pattern Footage Limestone or Shale

Divide the face height by the hole diameter to get one of the following empirical constants

| | | | |
|---|---|---|---|
| **13.23 OR GREATER** | | | **= (A) 1560** |
| **9.45** | **TO** | **13.22** | **= (B) 1177** |
| **4.80** | **TO** | **9.44** | **= (C) 1047** |
| **2.62** | **TO** | **4.79** | **= (D) 629** |
| **1.84** | **TO** | **2.61** | **= (E) 366** |

*"Face height could be the depth of a cut or a decked hole and in cases of decked holes, the length of the powder column is added to the length of the deck".*

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# Pattern Footage Limestone or Shale

Step #2

$$\left(\frac{\text{Hole diameter}}{12}\right)^2$$

Step #3

Multiply the result of step #2 by the proper empirical constant from step #1

*The result of step #3 equals the pattern footage for that hole diameter versus that particular face height.*

# Pattern Footage Limestone or Shale

Step #4 for Square patterns

$$\text{Burden or spacing} = \sqrt{\text{Pattern footage}}$$

Step #4 for Rectangle patterns

$$\text{Burden} = \sqrt{\text{Pattern footage}} \times .93$$

$$\text{Spacing} = \frac{\text{Pattern footage}}{\text{Burden}}$$

# Before Emperical E

# After Emperical E

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# Using The Empirical “E”

Depth of burial is
sufficient to prevent excessive upward movement

# Empirical “E” Is a Great Tool, but Must Understand the Limitations

- **Very borehole diameter dependent**
  - ✓ **To determine borehole depth simply multiply the minimum and maximum numbers by the hole diameter from the chart**
- **Important to remember that you load only 30% of the hole depth…….**

**1.84 To 2.61 = 282 for Granite**
**1.84 To 2.61 = 366 for Limestone**

# Empirical “E” Is a Great Tool, but Must Understand the Limitations (Cont.)

6.5” hole in Granite rock requires a hole depth between 11.96 and 16.96-feet

When grade control is a must: Divide the desired grade by the minimum number in the Empirical “E”

Example: Hole depth can be no deeper than 4-feet
4/1.84 = 2.17 or 2-inch borehole

| | | | | |
|---|---|---|---|---|
| **1.84** | **TO** | **2.61** | **=** | **(E) 282** |

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