# Managing Muckpile Fragmentation

Scott G. Giltner

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SCHOOL OF MINES 1874 COLORADO

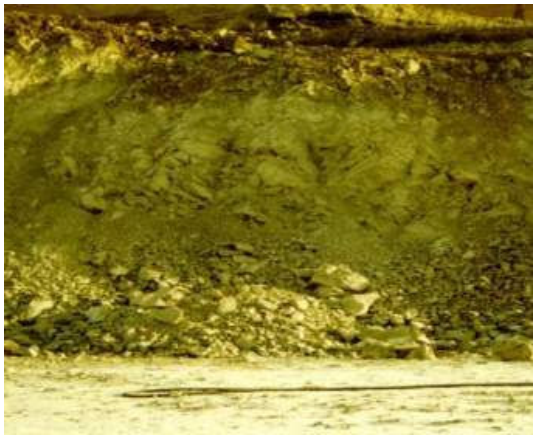
SANDVIK

# Topics to be Covered

- The purpose of drilling & blasting in producing crushed stone
- Relative cost of drilling & blasting vs other quarrying activities
- Cost/production opportunities offered with optimized fragmentation
- Factors affecting fragmentation
- Self-evaluation of fragmentation

QUARRY ACADEMY

# Why Drill and Blast ?

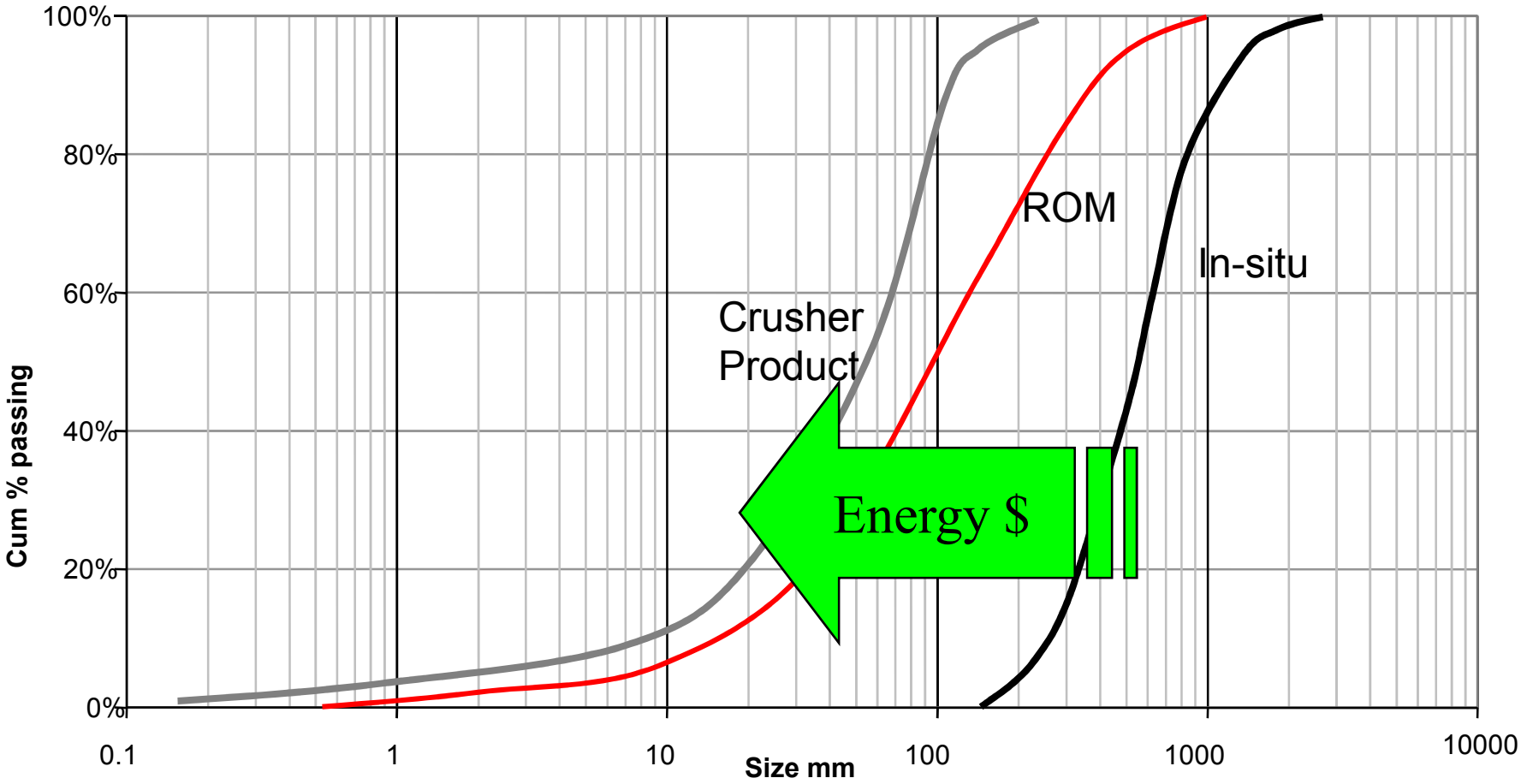


Blasting intensity

- **Drill and Blast is the first step in the breakage and separation process. Therefore, it impacts all the the subsequent downstream process efficiencies.**
- **Drill and Blast is still the most cost effective method to break and move the large volumes of rock – when done correctly!**

QUARRY ACADEMY

# Rock Breakage Phases




QUARRY ACADEMY

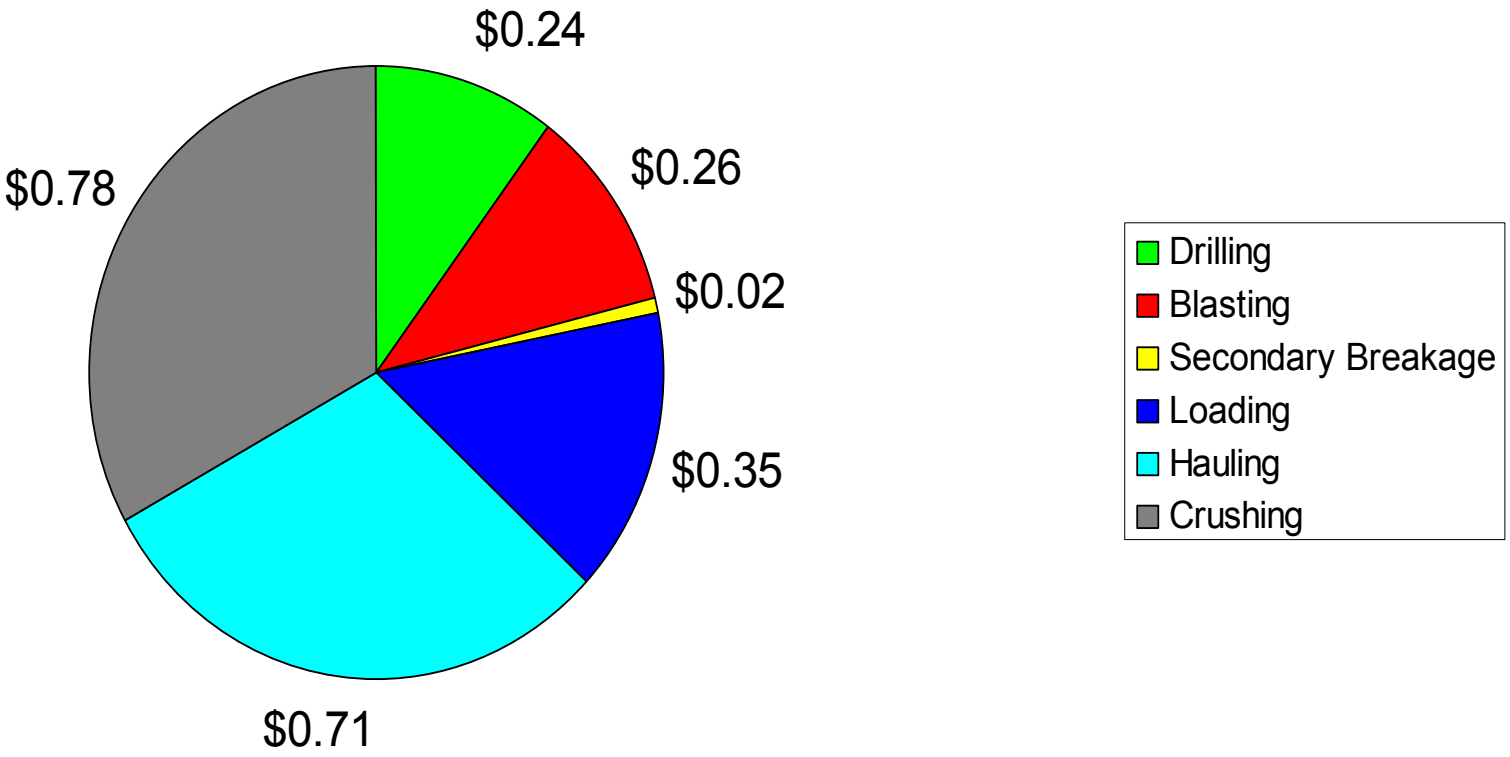
# Relative Energy and Costs

| | Specific energy kwh/t | Energy factor | Cost factor |
|---|---|---|---|
| Drill and Blast | 0.1 – 0.25 | 1 | 1 |
| Load and haul | 0.2 – 0.5 | 1 - 5 | 2 - 10 |
| Crushing | 1 – 2 | 4 - 20 | 2 - 10 |

Generally the harder the rock, the higher the factor.

QUARRY ACADEMY

# Drilling & Blasting - Leverage




QUARRY ACADEMY

# Drilling & Blasting - Leverage

- Drilling and blasting is the first step in the comminution processes
- A 10% increase in drilling and blasting cost can be compensated by
  - ✓ **4.6% reduction in excavation and hauling costs**

  ***or***

  - ✓ **6.4% reduction in crushing**

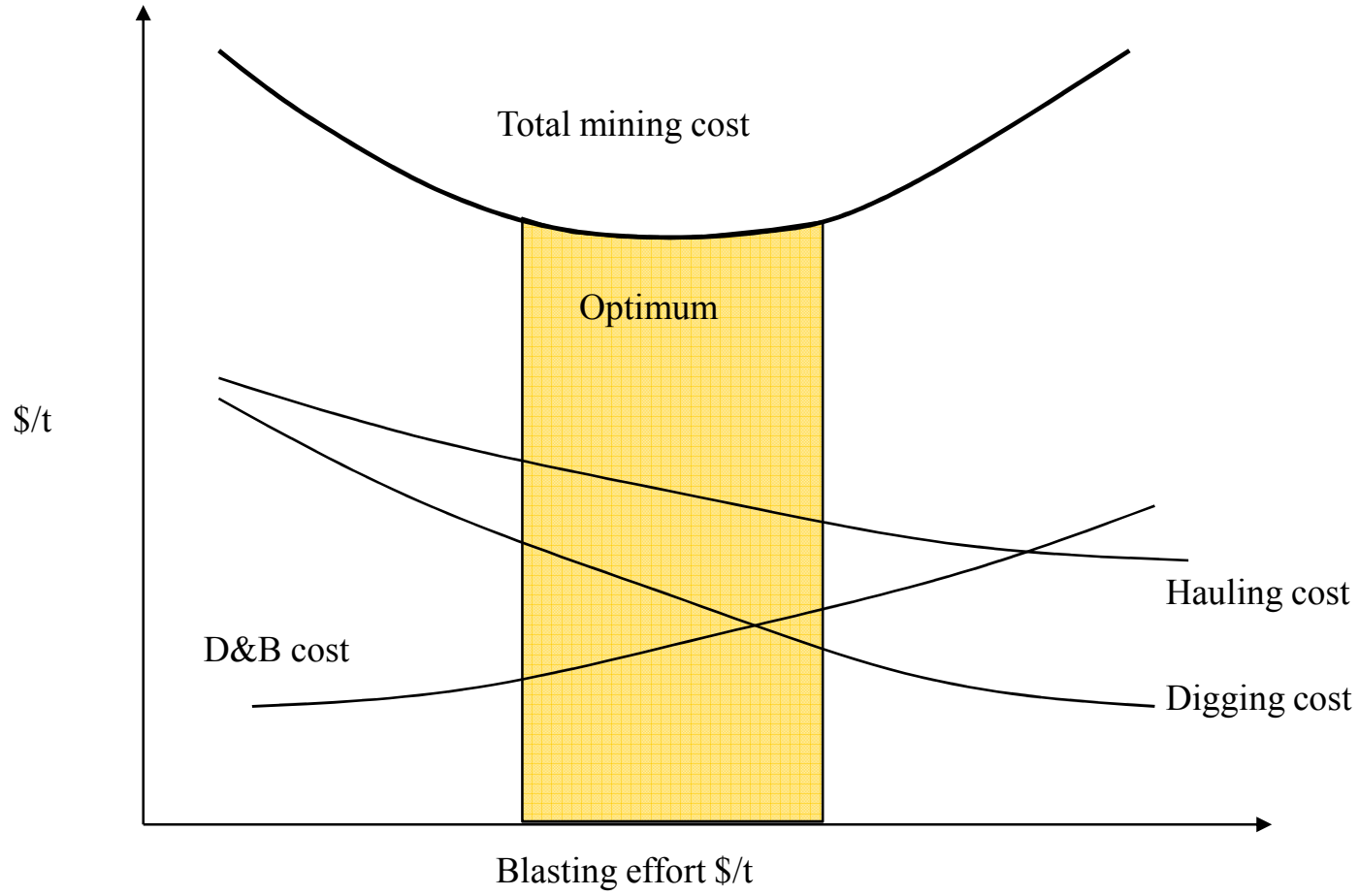
1¢ decrease in excavation/hauling = 2.2¢ increase in D&B

***or***

1¢ decrease in crushing/benefaction = 1.6¢ increase in D&B

QUARRY ACADEMY

# Fragmentation Optimization




QUARRY ACADEMY

# Common Fragmentation Issues

- Oversize breakage costs
- Excavator costs (diggability)
- Crusher costs (throughput)
- Recovery (fines)

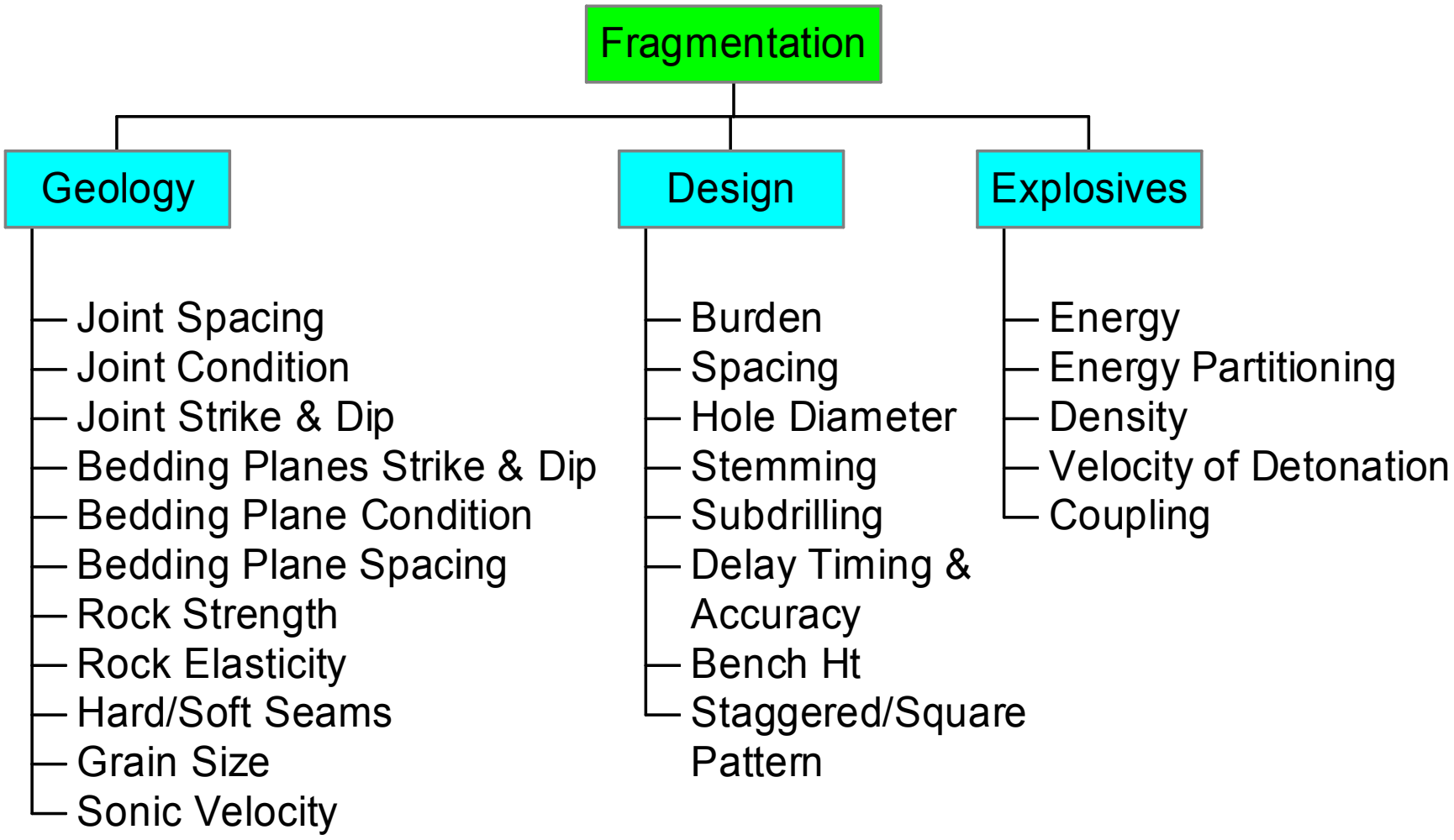
QUARRY ACADEMY

# Fragmentation Optimization Opportunities

- Better digging and bucket fill factors
- Consistent crusher throughput and power draw
- Reduction in blast induced damage
- Reduction in material losses ***(more saleable product)***
- Potential to produce better priced end product

QUARRY ACADEMY

# Factors Affecting Fragmentation




QUARRY ACADEMY

# Geology Factors

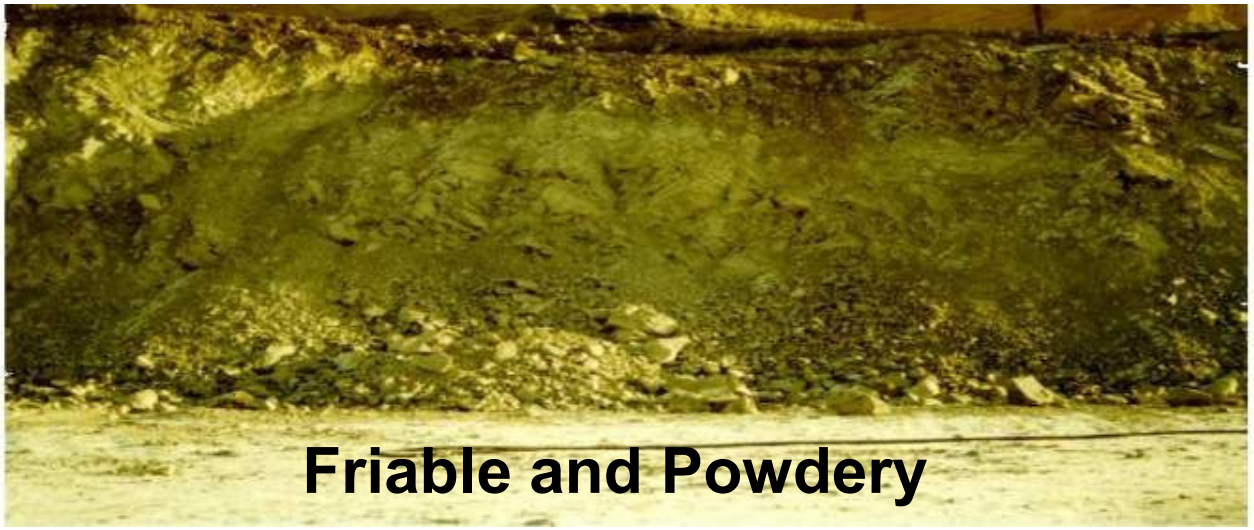
Structure describes the features which primarily determine the fragmentation performance of the rock mass.

- Jointing/Bedding
  - Defines maximum fragment size
  - Influences transmission of stress wave
  - Influences gas penetration
- Rock Strength & Elasticity
  - Determines how the rock mass responds to the explosive energy applied
  - Influences confinement on explosive

QUARRY ACADEMY

# Rock Structure

Block size < 0.7 ft (0.2 m)





Block size > 6.5 ft (2 m)

QUARRY ACADEMY

# Rock Structure

Block size
0.6 – 3 ft
(0.2 – 1 m)



Block size
0.3 – 0.8 ft
(0.1 – 0.25 m)

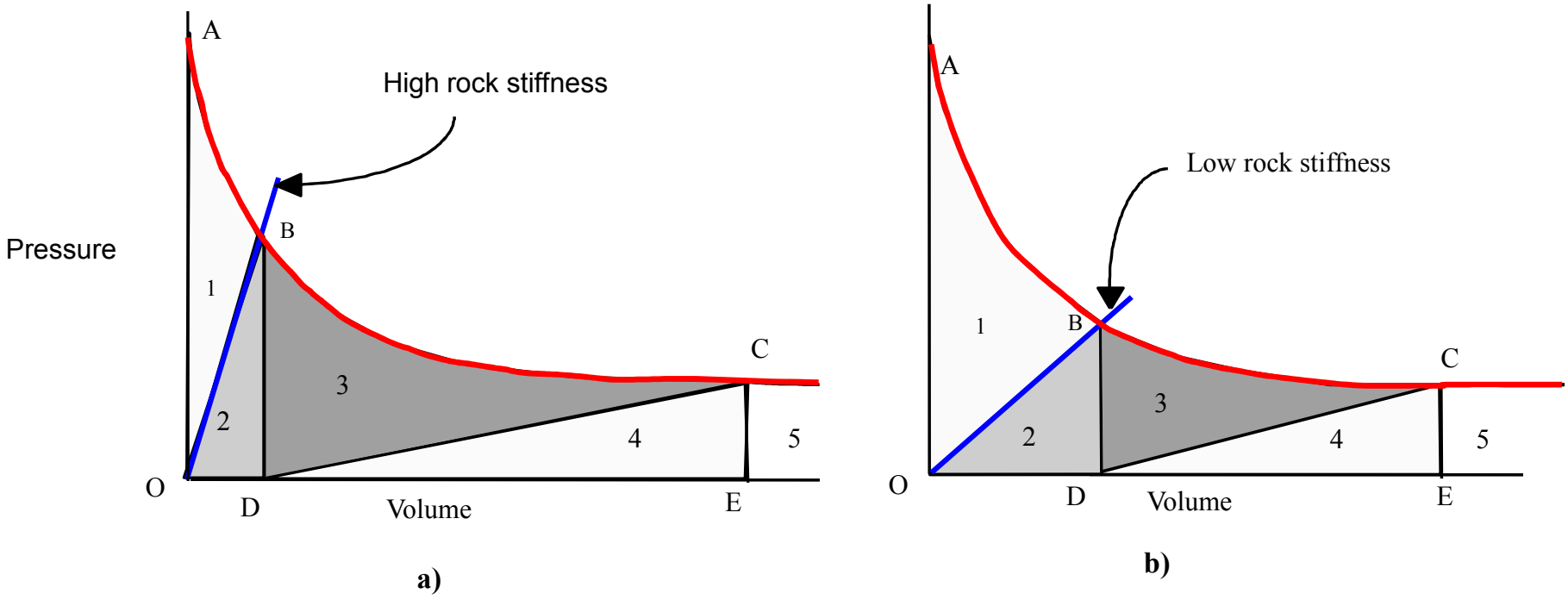
QUARRY ACADEMY

# Rock Properties

| Rock Type | Density ($g/cm^3$) | Compressive Strength (psi) | Tensile Strength (psi) | Young's Modulus (psi) | Poisson's Ratio | P Wave Velocity (ft/s) |
|---|---|---|---|---|---|---|
| Basalt | 2.9 | 21,610 | 1,595 | 8,992,340 | 0.27 | 17,155 |
| Dolomite | 2.5 | 7,977 | 435 | 4,061,057 | 0.32 | 13,202 |
| Gneiss | 2.8 | 32,488 | 2,030 | 11,748,600 | 0.22 | 18,805 |
| Granite | 2.7 | 26,977 | 1,305 | 6,236,623 | 0.33 | 15,892 |
| Limestone | 2.7 | 23,061 | 725 | 7,977,076 | 0.25 | 16,404 |
| Marble | 3.1 | 36,404 | 2,175 | 16,374,000 | 0.28 | 21,998 |
| Sandstone | 2.5 | 19,435 | 145 | 1,015,264 | - | 12,903 |
| Sandstone | 1.8 | 1,595 | 0 | 870,226 | 0.31 | 6,873 |
| Schist | 2.9 | 24,076 | 1,305 | 11,167,910 | 0.2 | 17,985 |
| Slate | 2.6 | 12,328 | 870 | 9,572,491 | 0.17 | 16,955 |
| Taconite | 2.9 | 36,404 | 2,465 | 13,488,510 | 0.25 | 20,144 |

QUARRY ACADEMY

# Rock Properties - Rock Stiffness

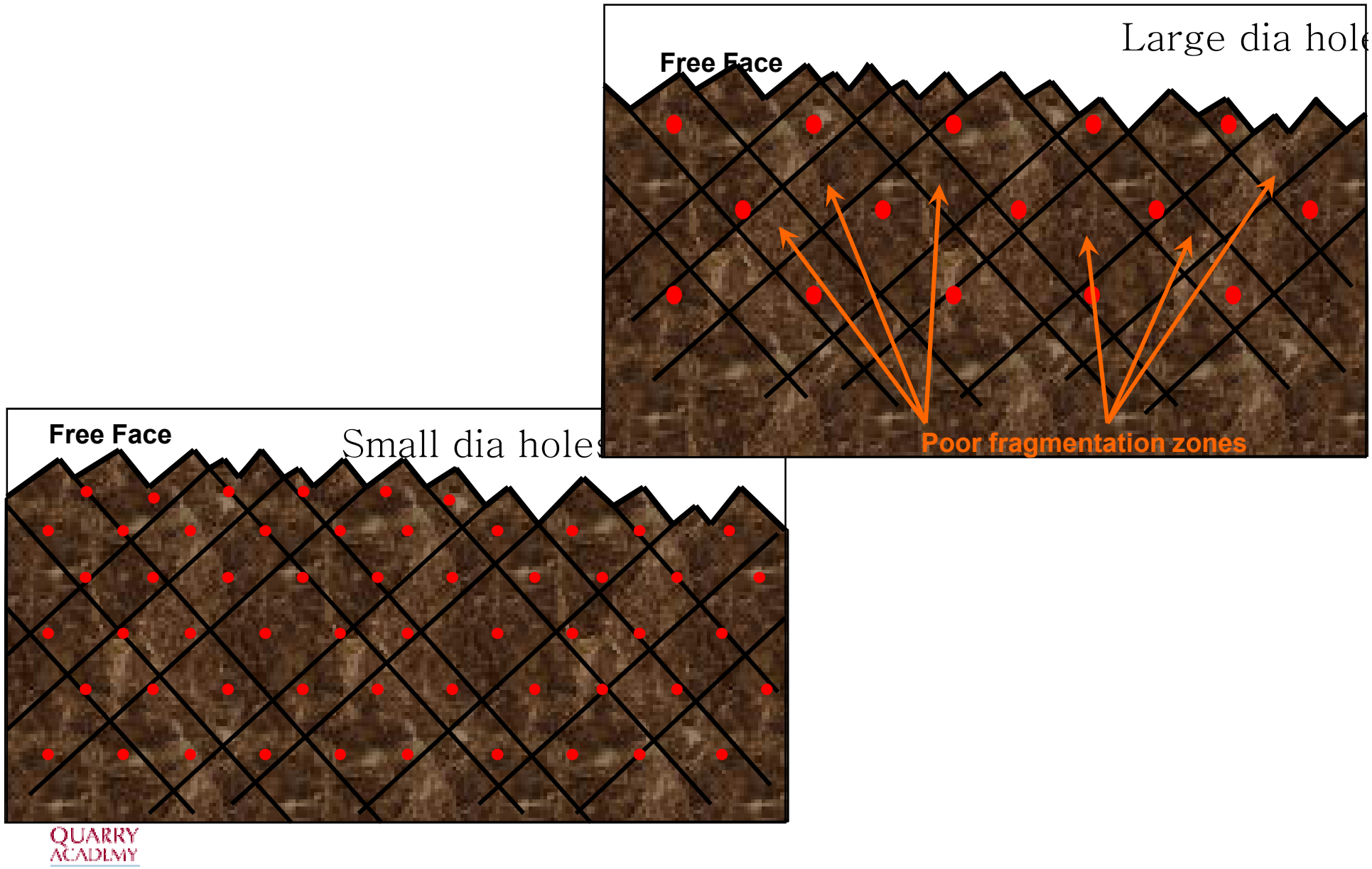


# Blast Design Factors

- **Hole Diameter**
  - **Influences energy distribution and burden stiffness**
- **Burden/Spacing**
  - **Influences energy distribution and burden stiffness**
  - **Relationship with joint spacing affects oversize**

QUARRY ACADEMY

# Hole Diameter & Burden/Spacing



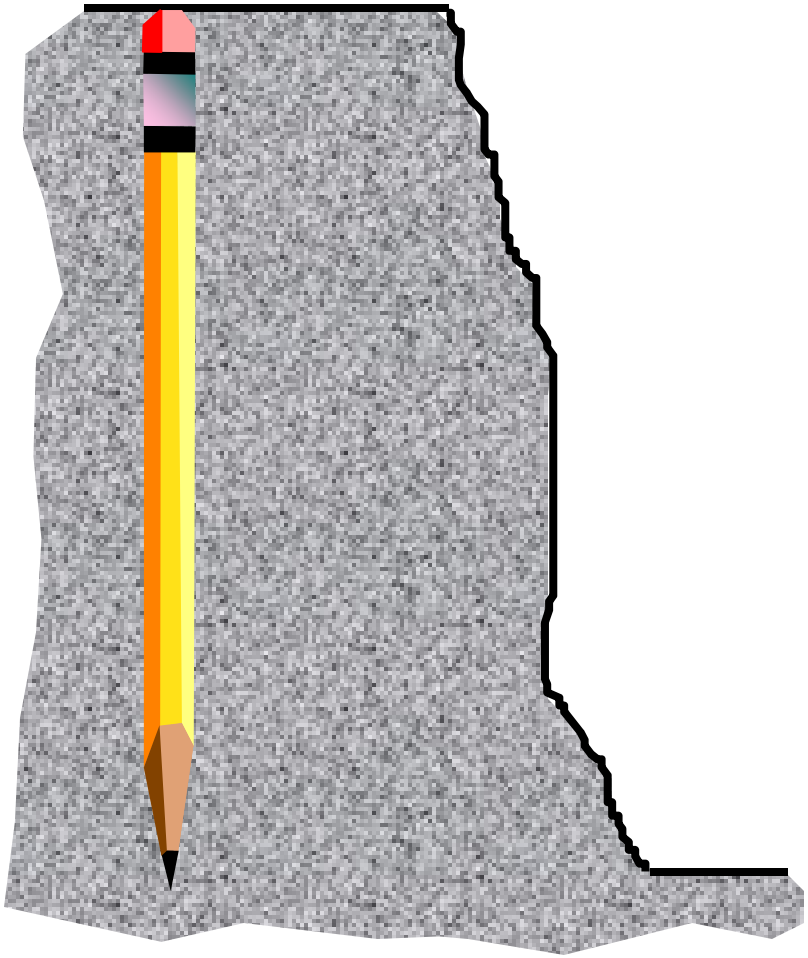

QUARRY ACADEMY

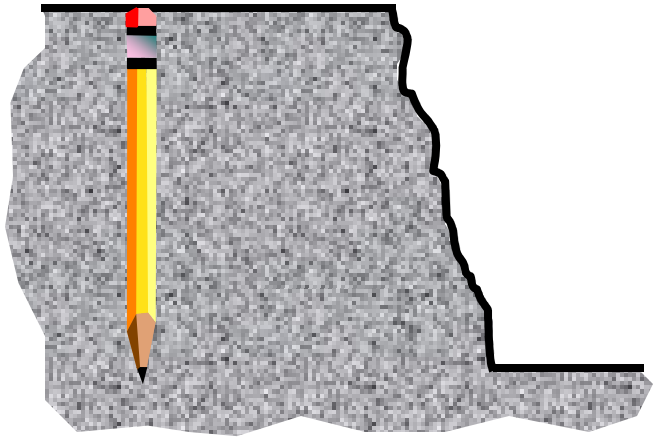
# Blast Design Factors

- Hole Diameter
  - Influences energy distribution and burden stiffness
- Burden/Spacing
  - Influences energy distribution and burden stiffness
  - Relationship with joint spacing affects oversize
- **Bench Height**
  - **Influences burden stiffness**

QUARRY ACADEMY

# Burden Stiffness





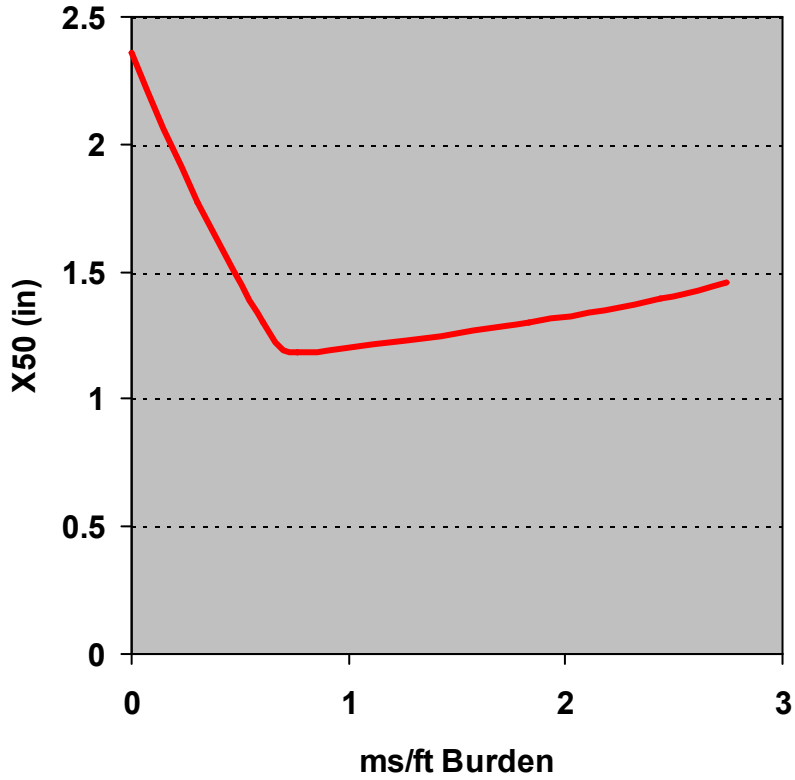
QUARRY ACADEMY

# Blast Design Factors

- Hole Diameter
  - Influences energy distribution and burden stiffness
- Burden/Spacing
  - Influences energy distribution and burden stiffness
  - Relationship with joint spacing affects oversize
- Bench Height
  - Influences burden stiffness
- **Delay Time & Accuracy**
  - **Influences interaction between detonating holes**

QUARRY ACADEMY

# Interhole Delay Time & Fragmentation




*(after Cunningham, 2005)*

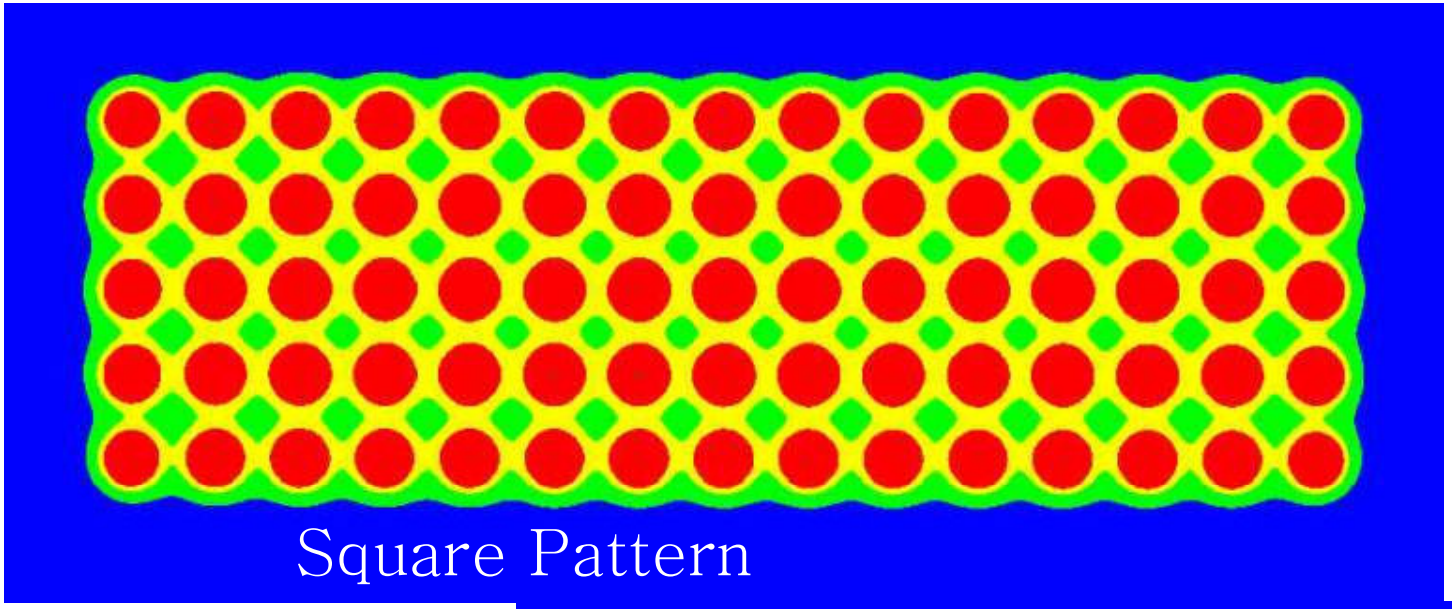
QUARRY ACADEMY

# Blast Design Factors

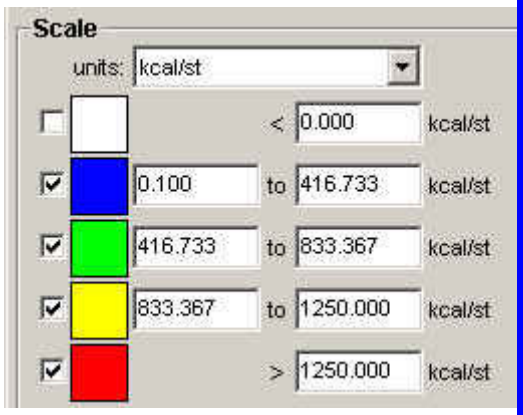
- Hole Diameter
  - Influences energy distribution and burden stiffness
- Burden/Spacing
  - Influences energy distribution and burden stiffness
  - Relationship with joint spacing affects oversize
- Bench Height
  - Influences burden stiffness
- Delay Time & Accuracy
  - Influences interaction between detonating holes
- **Staggered/Square pattern**
  - **Determines distribution of energy in rock mass**

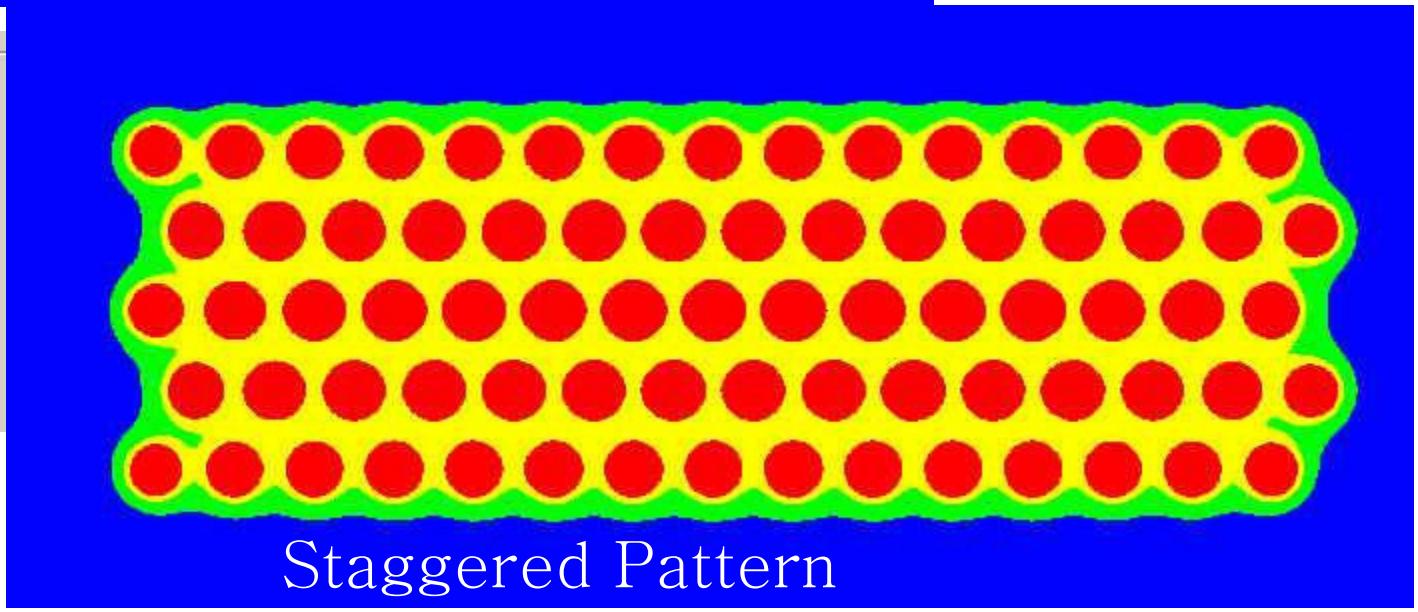
QUARRY ACADEMY

# Explosive Energy Distribution



Square Pattern



Staggered Pattern

QUARRY ACADEMY

# Explosives Factors

- Velocity of Detonation
  - Indication of energy available
  - Indicator of energy partitioning (shock vs gas)
  - Determines how explosive energy is applied to rock mass
- Density
  - Influences total explosive energy available in a hole
- Coupling
  - Influences transfer of explosive energy to rock mass

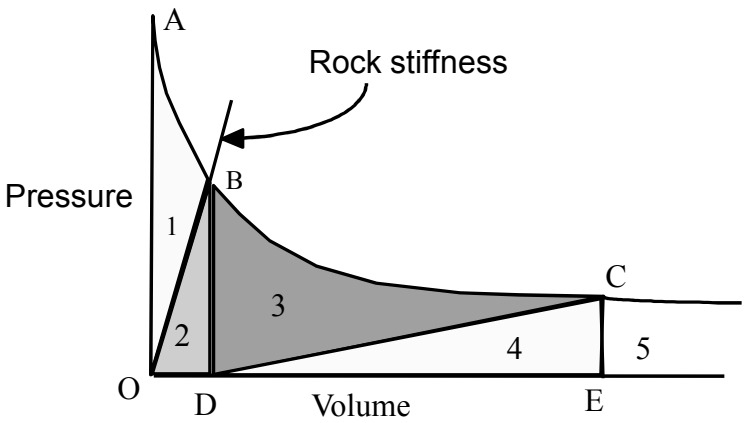
QUARRY ACADEMY

# Explosive Selection

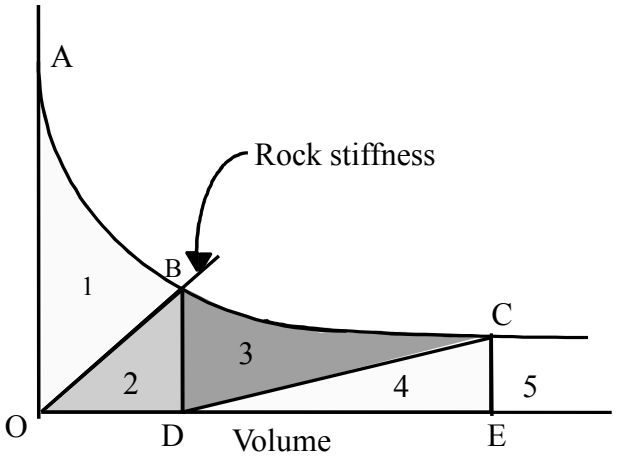
## Hard and Brittle Rock

## Soft and Plastic Rock

**High VOD**

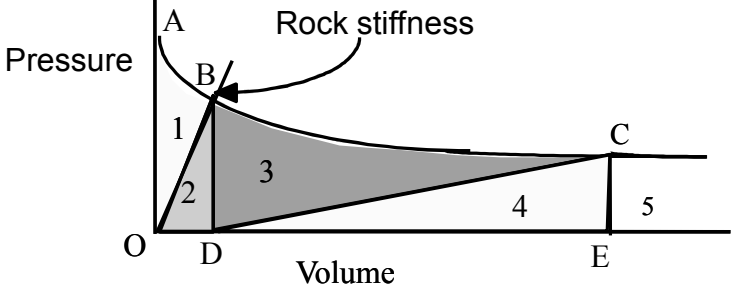



a)

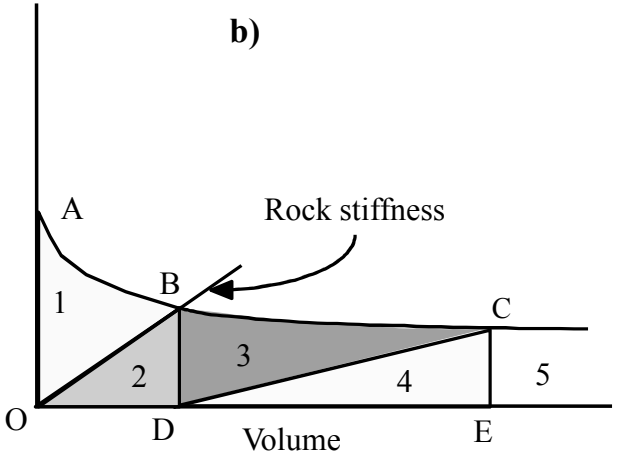



b)

**Low VOD**



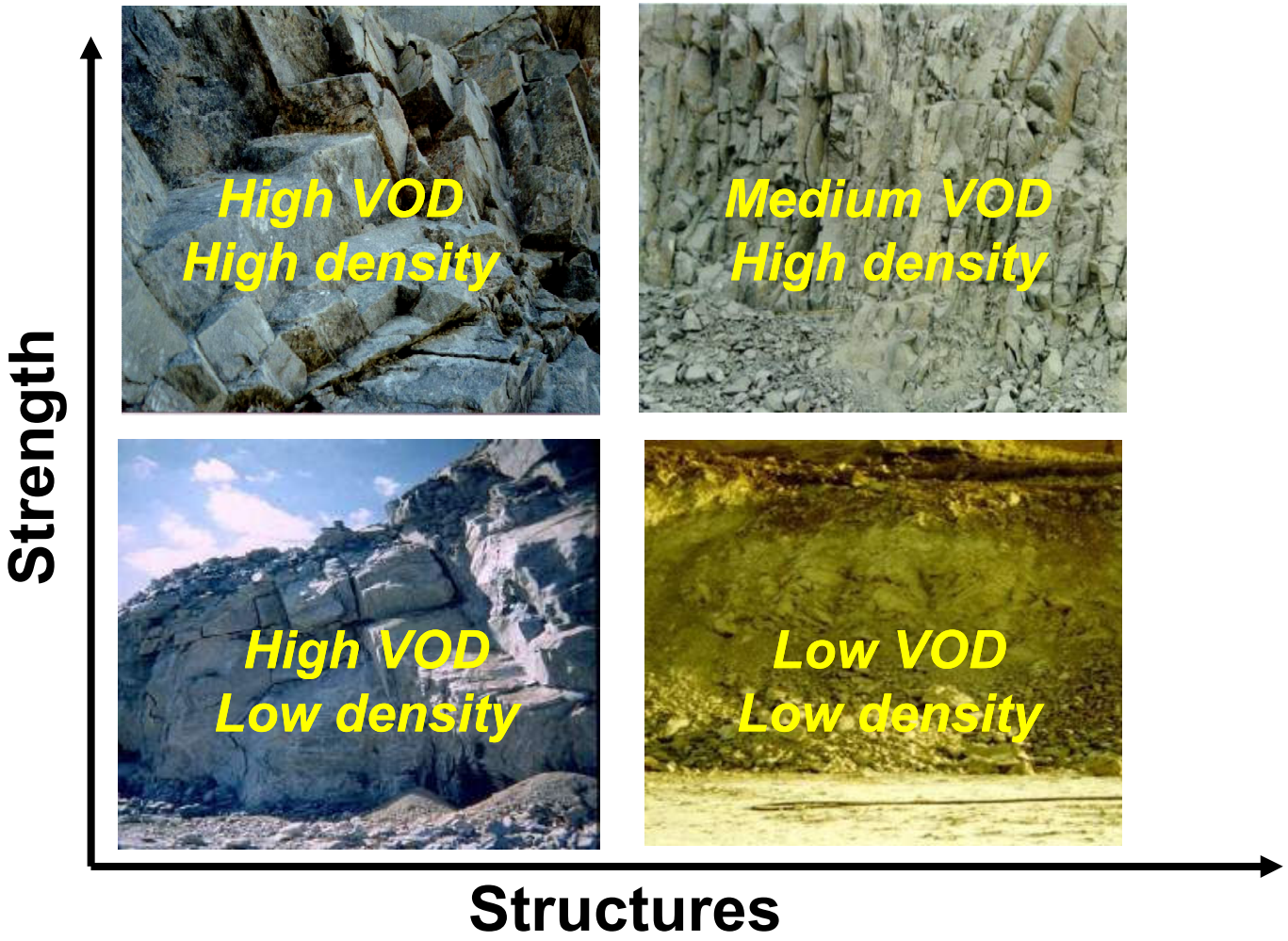

c)




d)

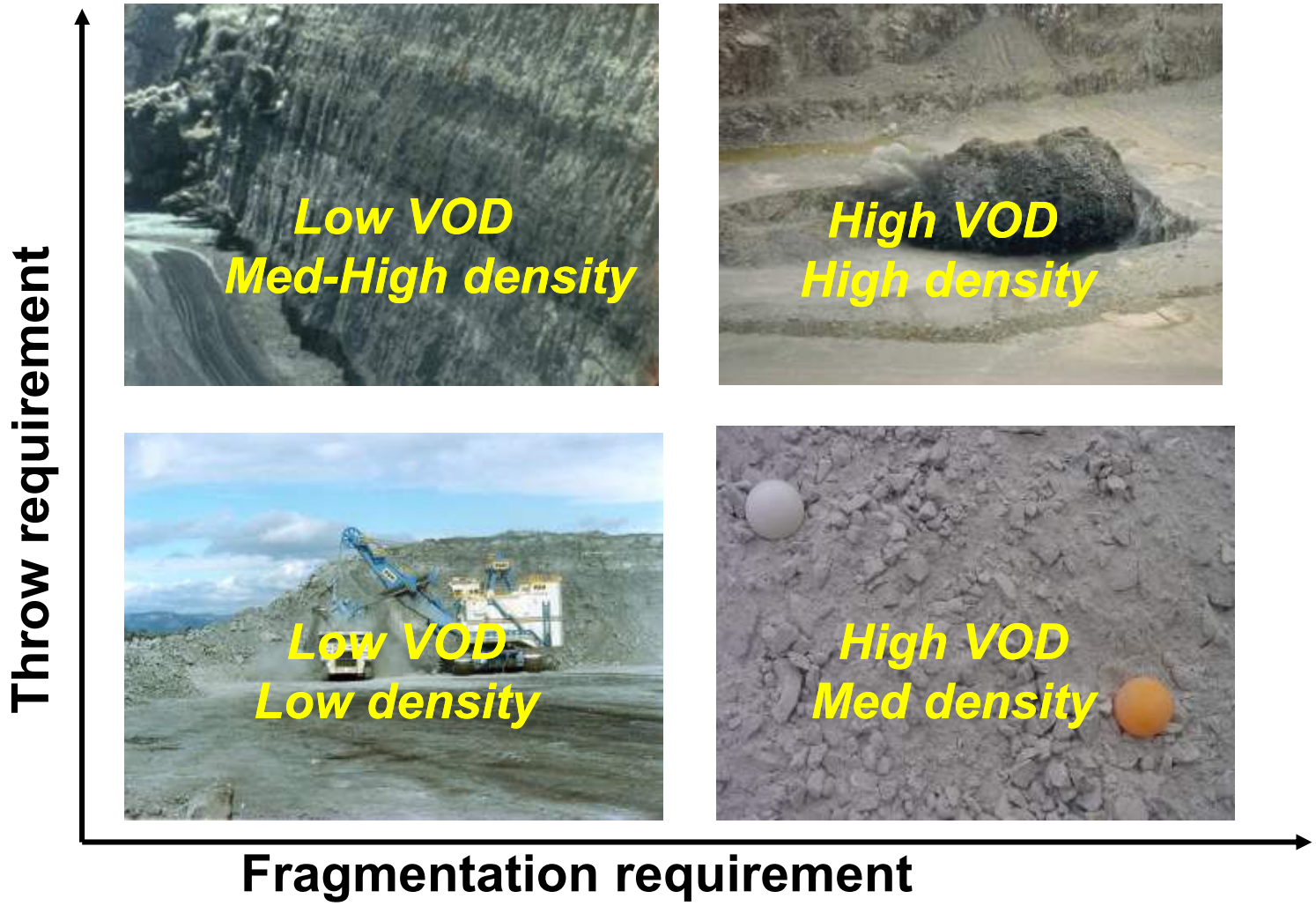
QUARRY ACADEMY

# Explosive Selection to Meet Rock Structure and Strength Properties




QUARRY ACADEMY

# Explosive Selection to Meet Blast Objectives




QUARRY ACADEMY

# In Summary Fragmentation Results..

- **Have significant impact on quarry economics**

## Therefore Fragmentation Optimisation …..

- **Should consider all the downstream processes rather than just drill and blast costs**
- **Should consider quality as well as quantity**
- **Should be site specific**
- **Should be flexible to cope with site specific changes and market conditions**

QUARRY ACADEMY

# ‘Take Home’ Questions on Fragmentation

- Does the shovel/loader bucket fill with a single smooth pass?
- Does the shovel/loader remain stable during digging (no rocking or violent movements)?
- Does the muckpile flow during digging?
- Do the haul trucks dump at the crusher without delay?
- Is the throughput and power draw of the crusher consistent?
- Is secondary breakage required on a regular basis?
- Are the desired product sizes produced without waste (fines or other unsaleable/low profit products)?

QUARRY ACADEMY

# www.quarryacademy.com


Improving Processes. Instilling Expertise.

DYNO
Dyno Nobel


SANDVIK