Fragmentation Management for the Downstream Value Chain

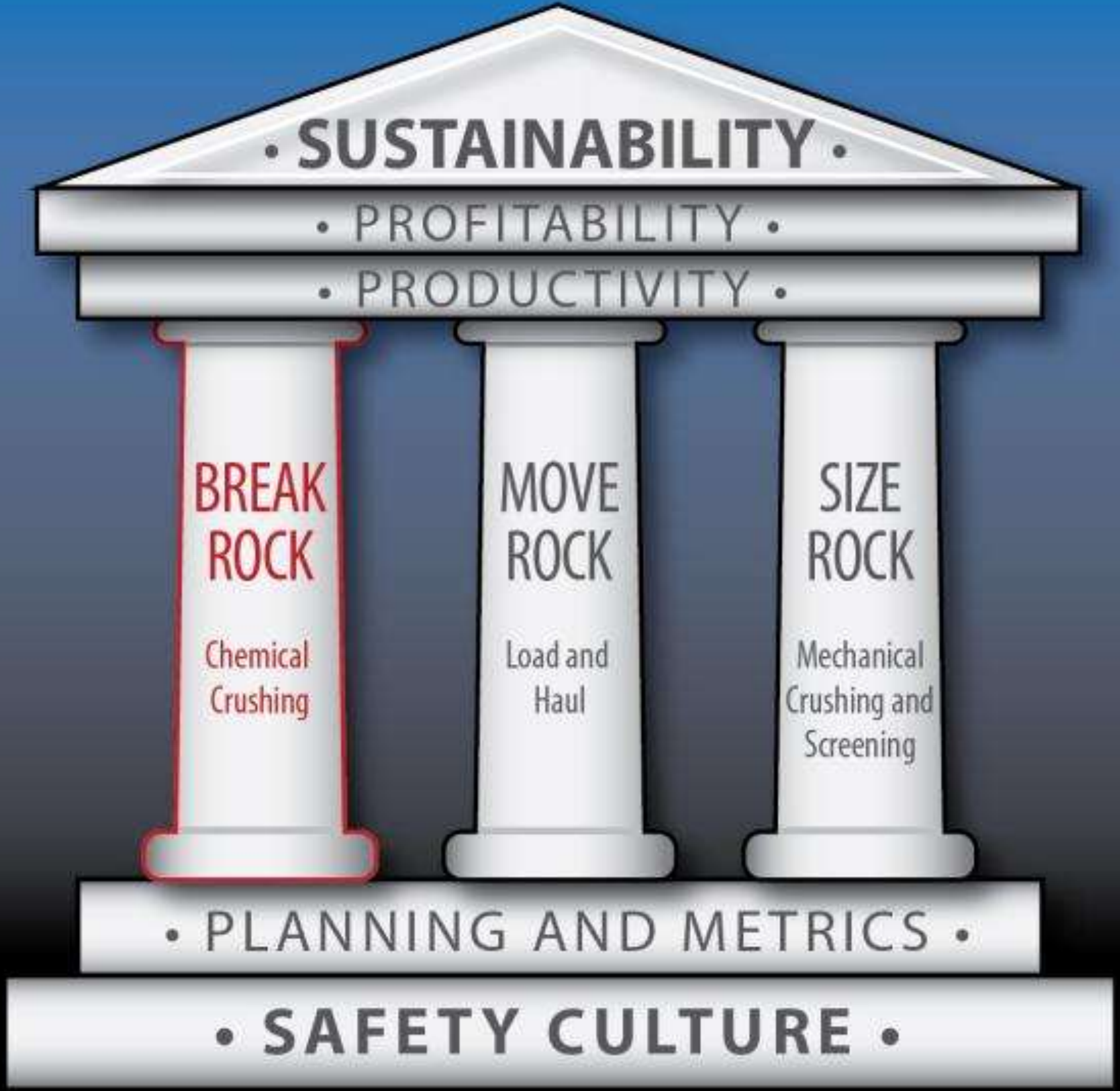
Scott G. Giltner

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

Dyno Nobel

SANDVIK



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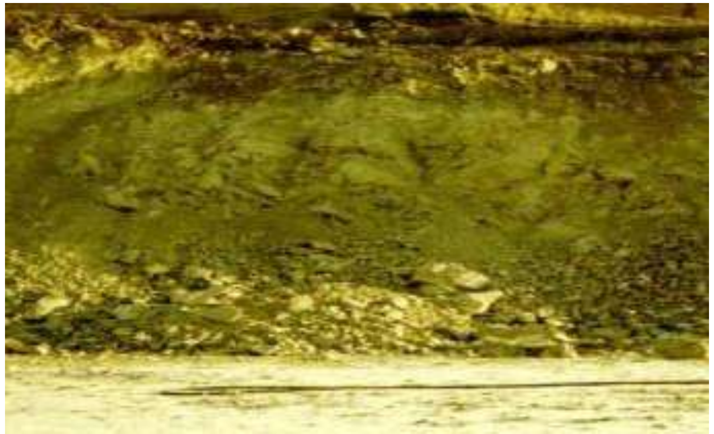
Topics to Be Covered

- 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

Why Drill and Blast ?



Blasting Intensity

- **Drill and Blast is the first step in the breakage and separation process. Therefore, it impacts all 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!**

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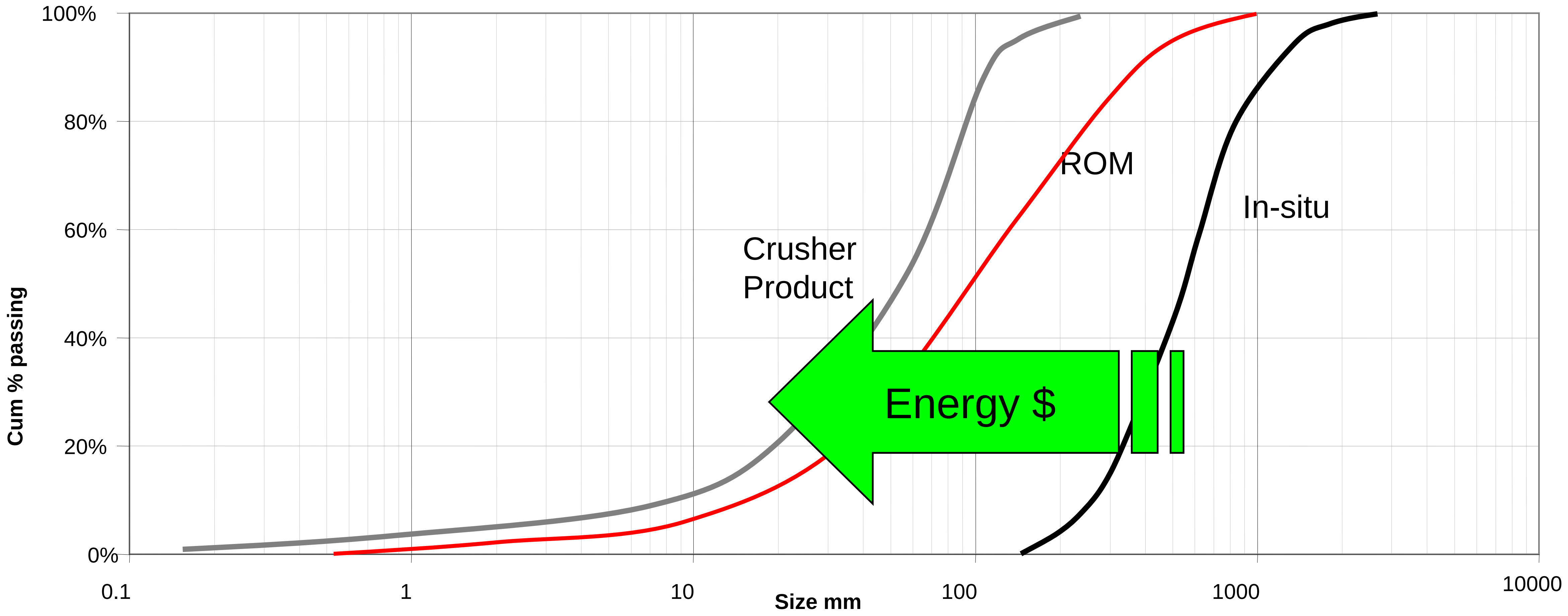
Rock Breakage Phases



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

Lighten Up

Generally the harder the rock, the higher the factor.

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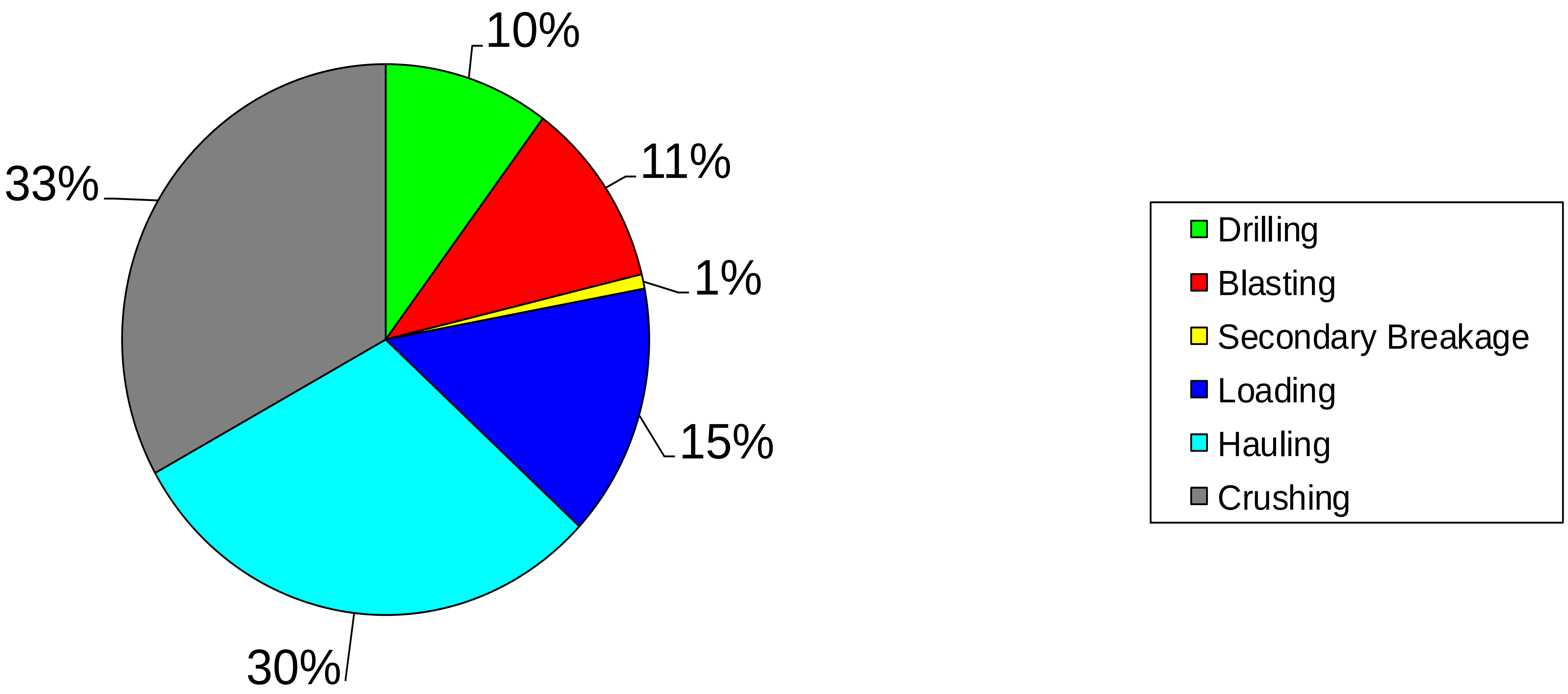
Drilling & Blasting Cost - Leverage



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Drilling & Blasting Cost - 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

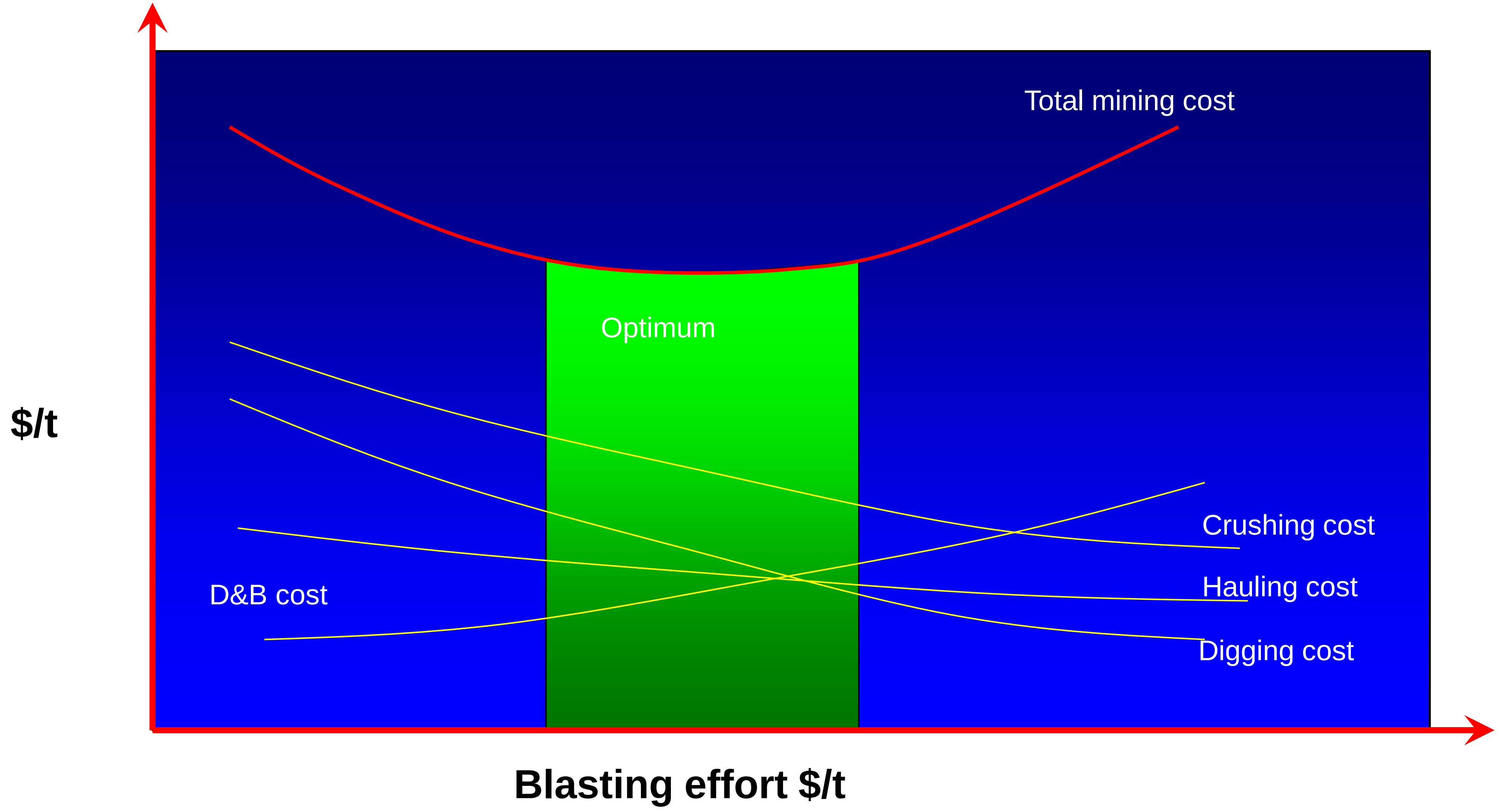
  - ✓ **6.4% reduction in crushing**

1% decrease in excavation/hauling = 2.1% increase in D&B

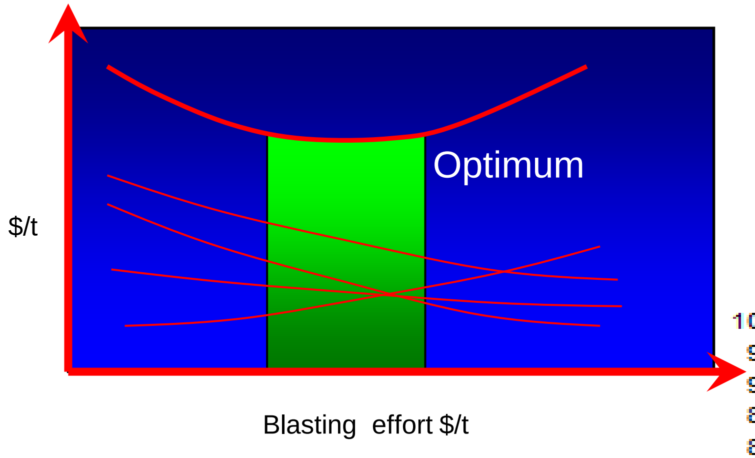
or

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

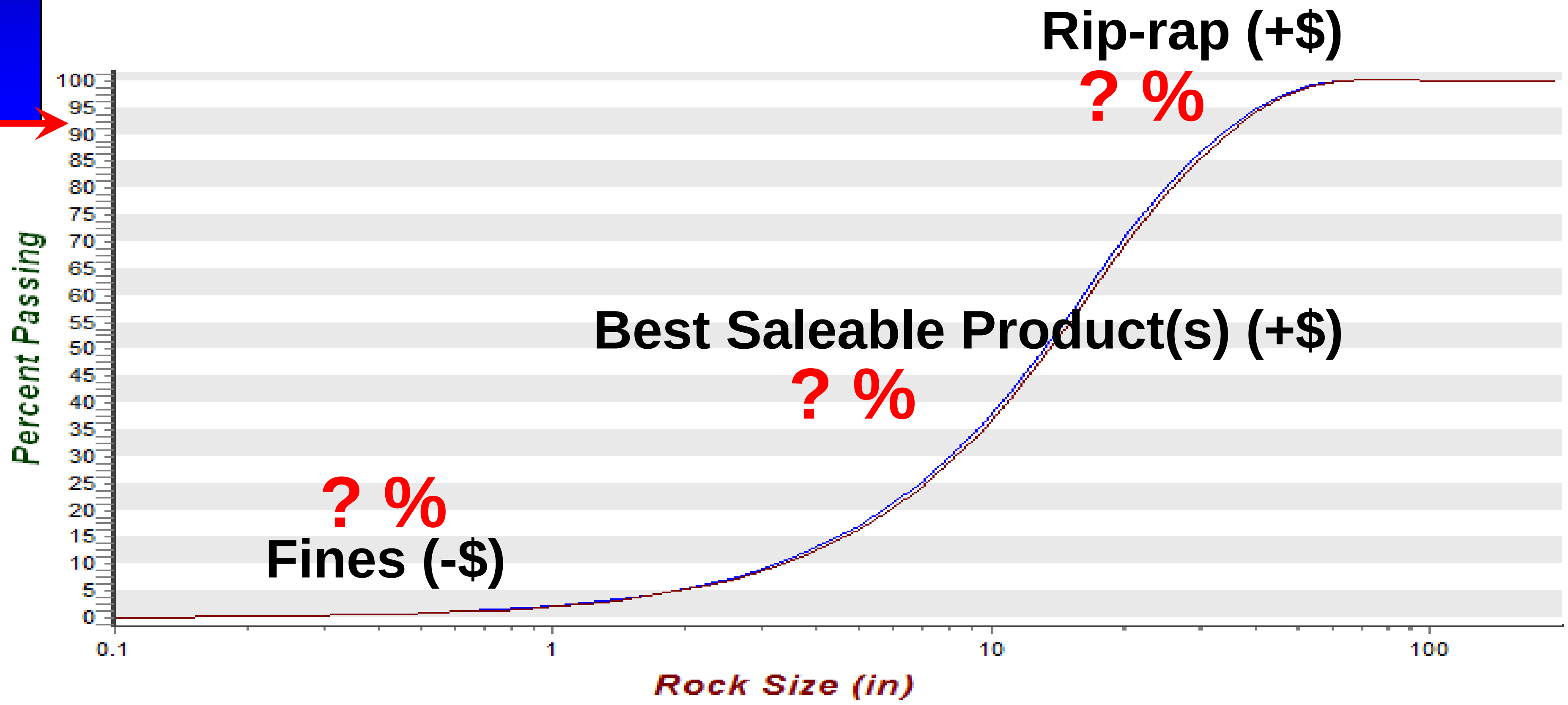
Traditional Blast Optimization



Fragmentation Management



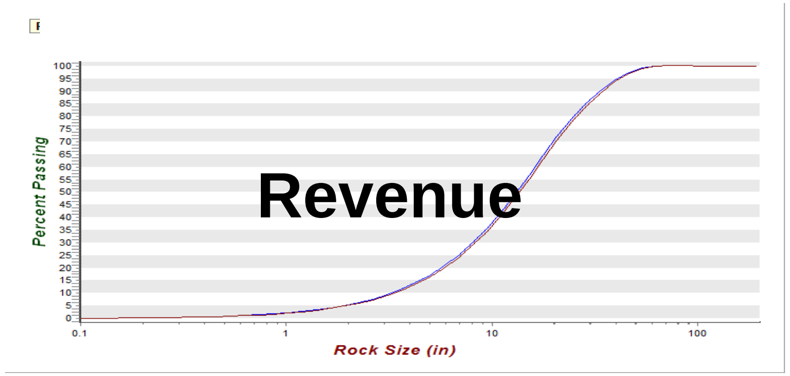
Profit = Revenue - Cost



Fragmentation Management

Profit = Revenue - Cost

Profit =



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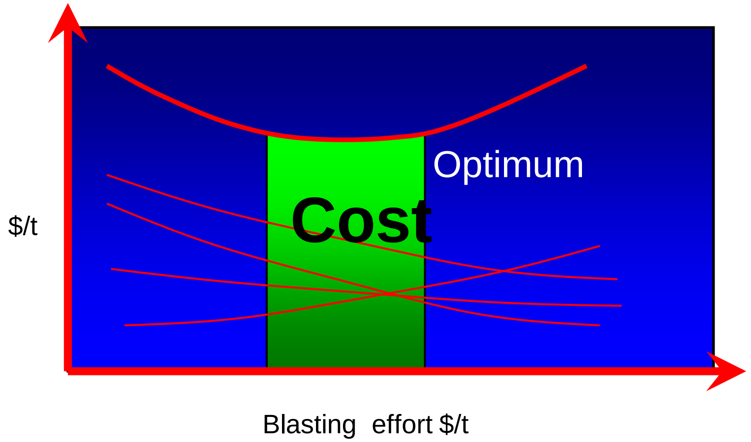

Common Fragmentation Issues

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

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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

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Factors Affecting Fragmentation

Fragmentation

- Geology
  - Joint Spacing
  - Joint Condition
  - Joint Strike & Dip
  - Bedding Planes Strike & Dip
  - Bedding Plane Condition
  - Bedding Plane Spacing
  - Rock Strength
  - Rock Elasticity
  - Hard/Soft Seams
  - Grain Size
  - Sonic Velocity
- Design
  - Burden
  - Spacing
  - Hole Diameter
  - Stemming
  - Subdrilling
  - Delay Timing & Accuracy
  - Bench Ht
  - Staggered/Square Pattern
- Explosives
  - Energy
  - Energy Partitioning
  - Density
  - Velocity of Detonation
  - Coupling

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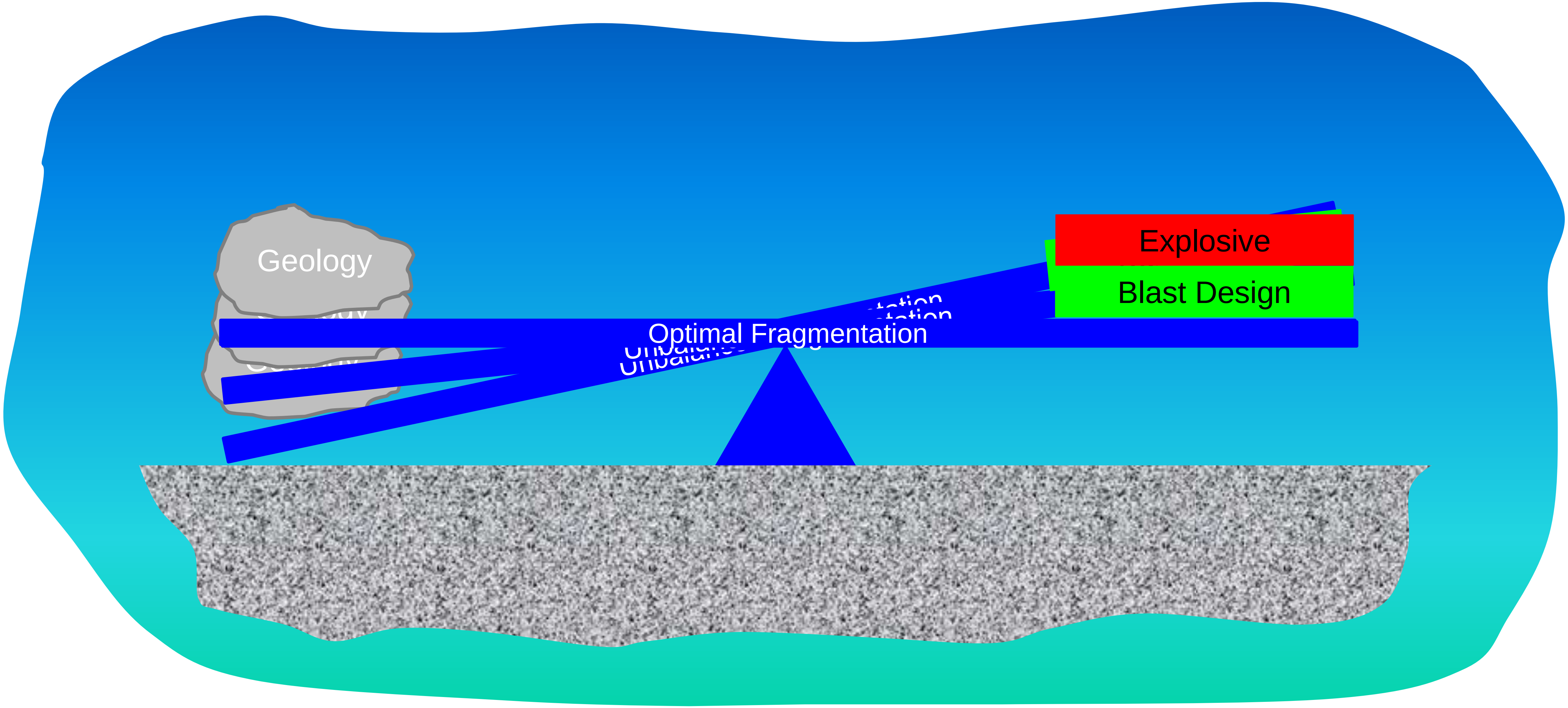
Balancing for Fragmentation



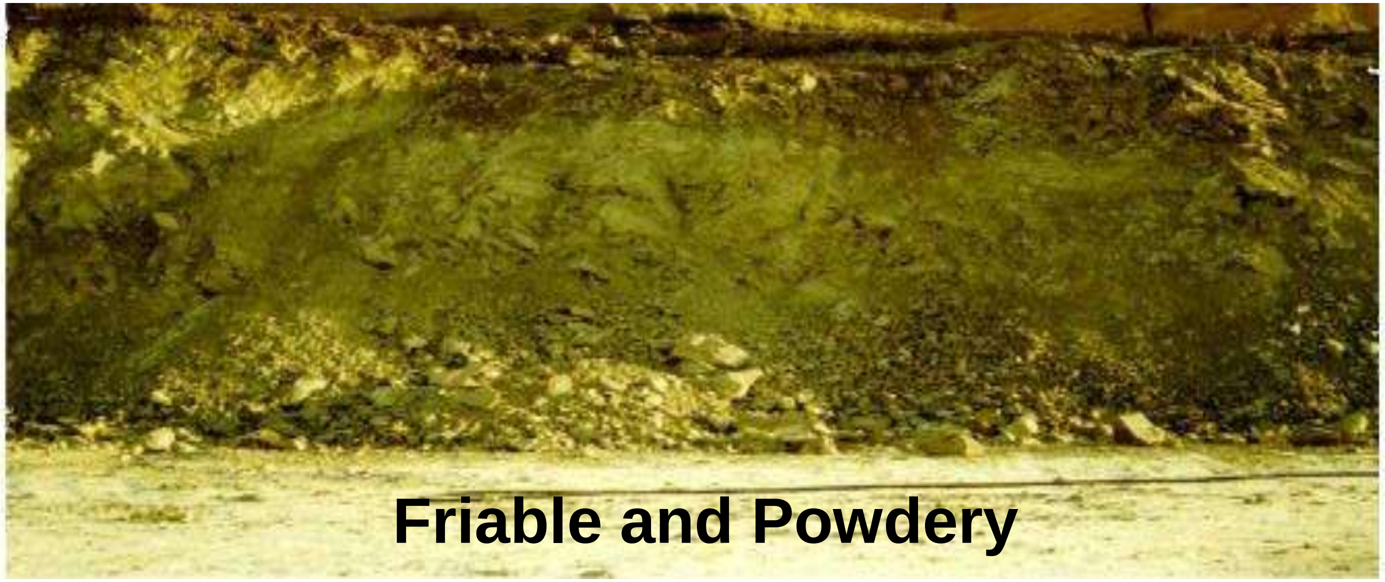
Geology Factors

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

Rock Structure

Block size < 0.7 ft (0.2 m)



Block size > 6.5 ft (2 m)

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Rock Structure

Block size 0.6 – 3 ft
(0.2 – 1 m)

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

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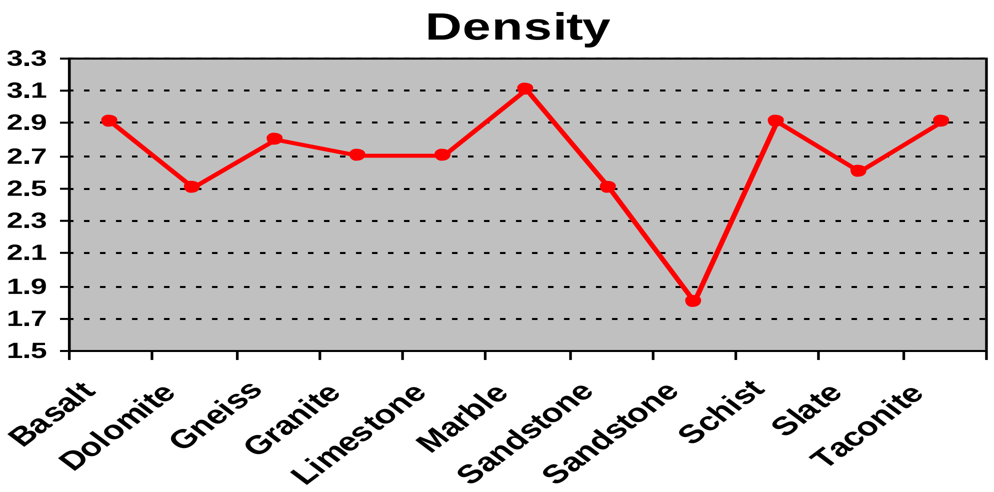
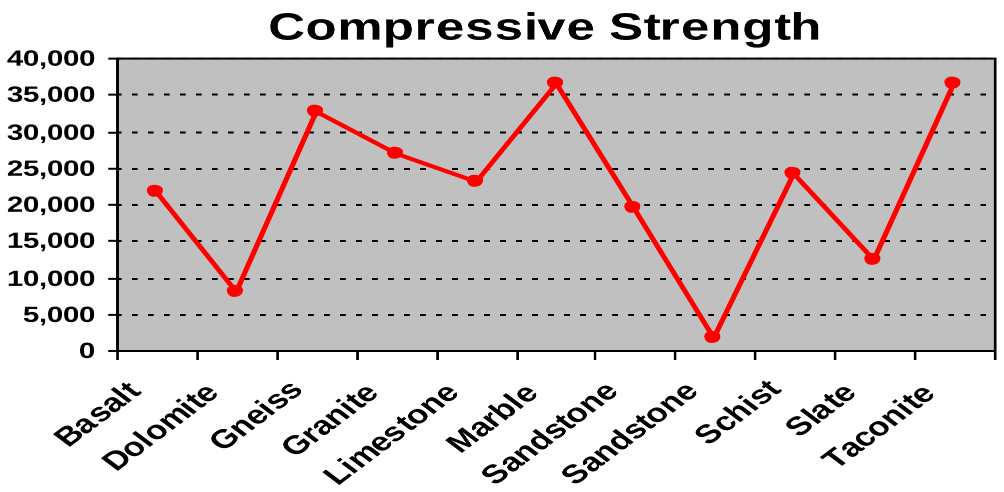
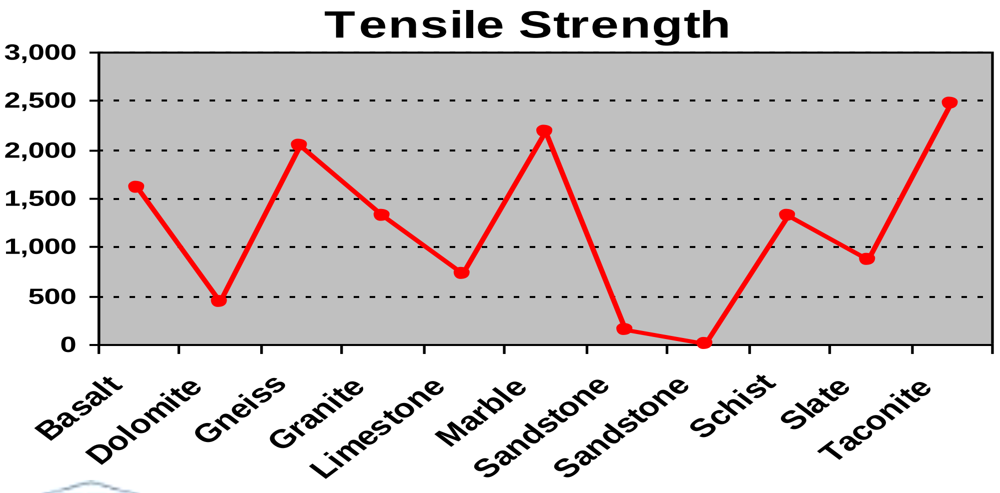
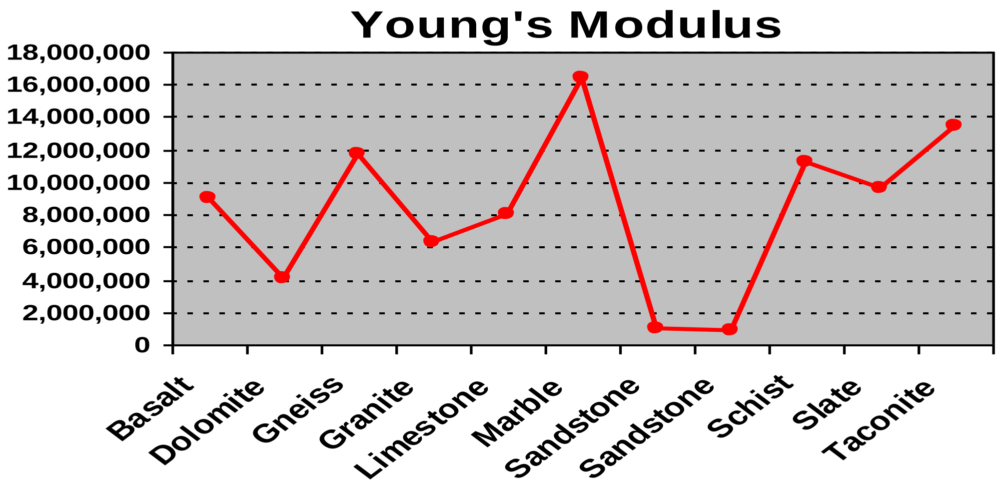
Rock Properties









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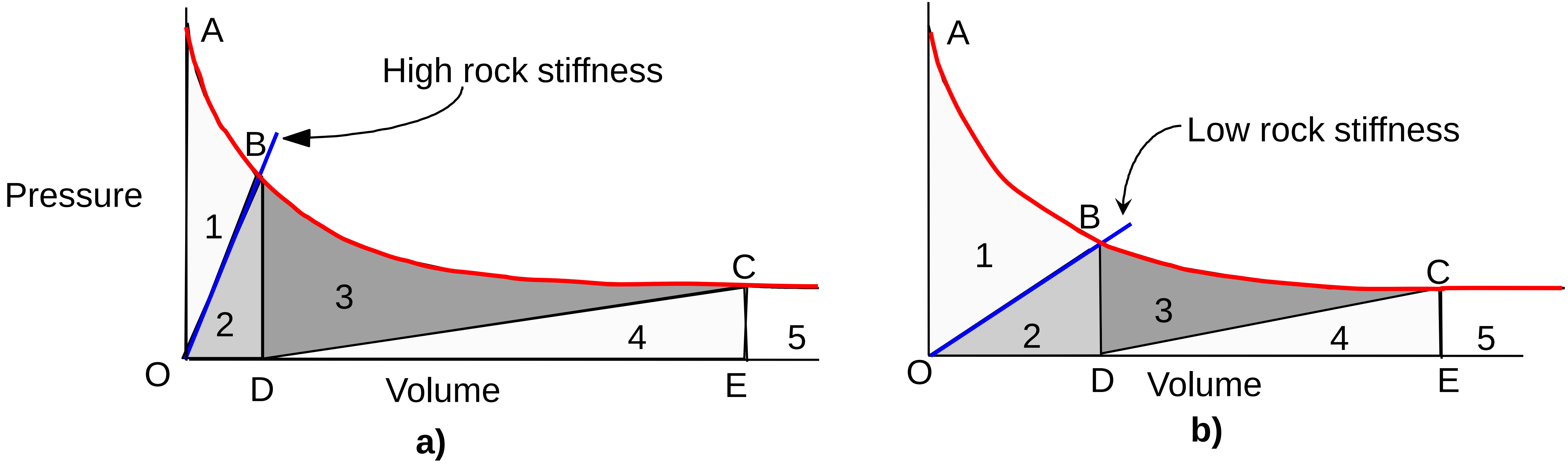
Effect of Rock Stiffness

Effect of 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
- Bench Height
  - Influences burden stiffness
- Delay Time & Accuracy
  - Influences interaction between detonating holes
- Staggered/Square pattern
  - Determines distribution of energy in rock mass

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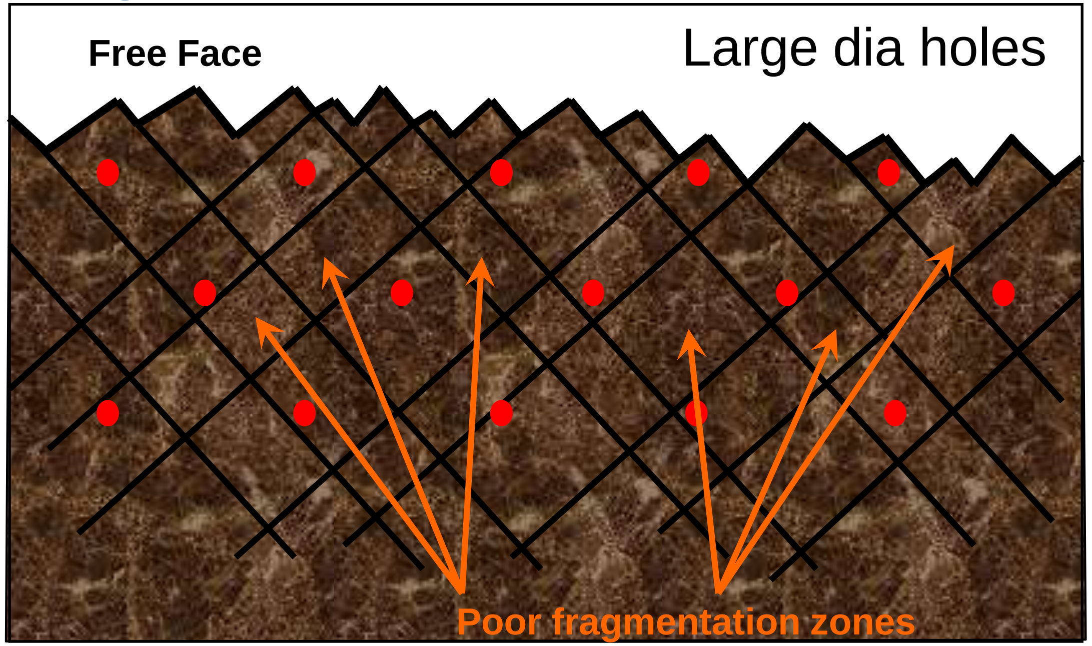
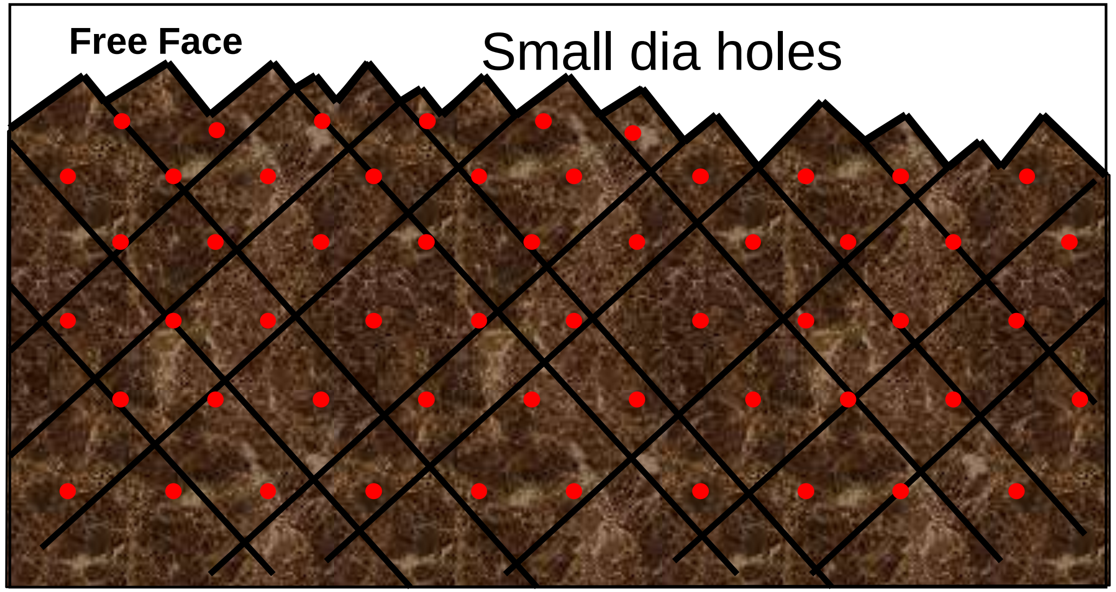
Hole Diameter & Burden/Spacing





Blast Design Factors

- Hole Diameter
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  - Influences energy distribution and burden stiffness
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- **Bench Height**
  - **Influences burden stiffness**
- Delay Time & Accuracy
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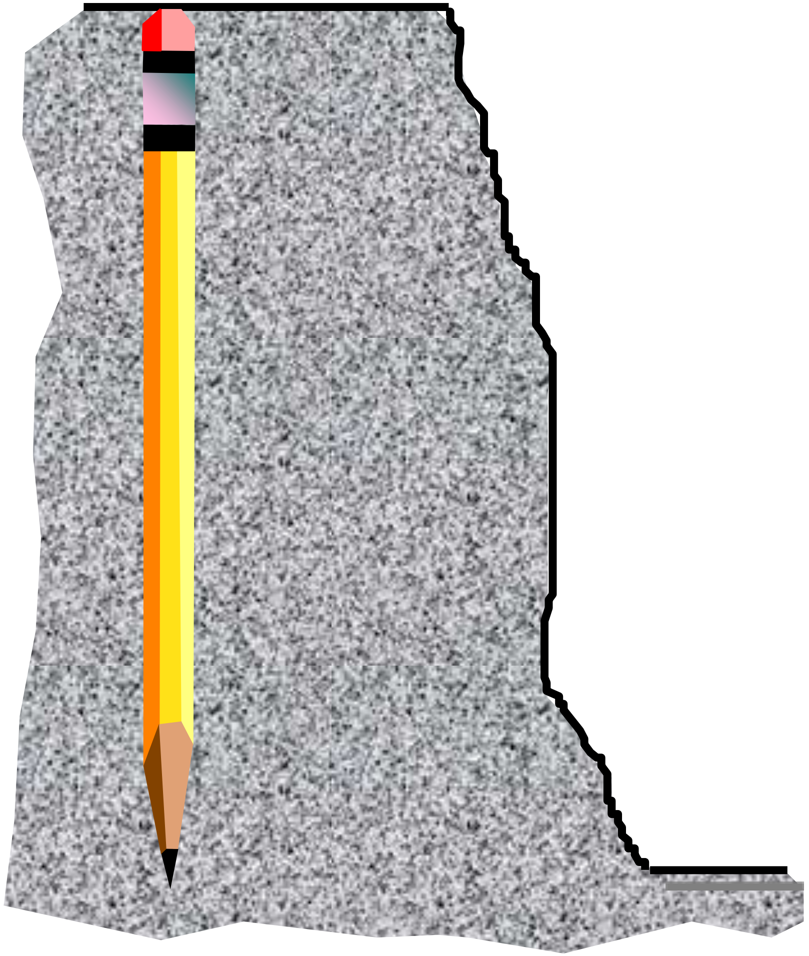
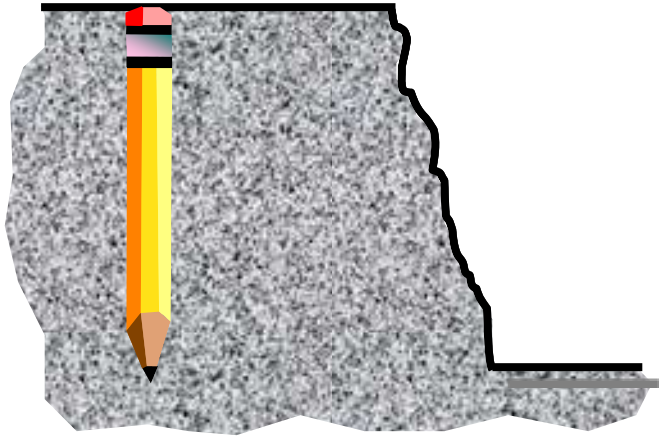
Burden Stiffness





Stiffness = Height/Burden

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

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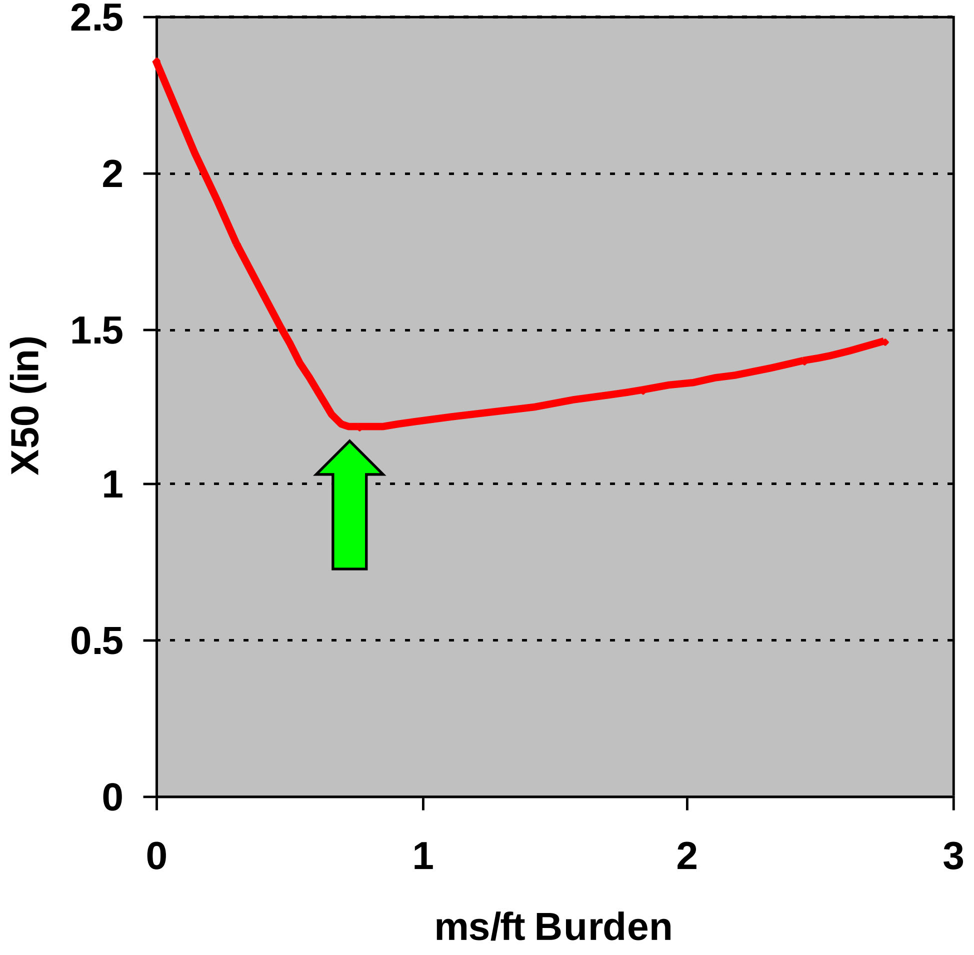
Interhole Delay Time & Fragmentation

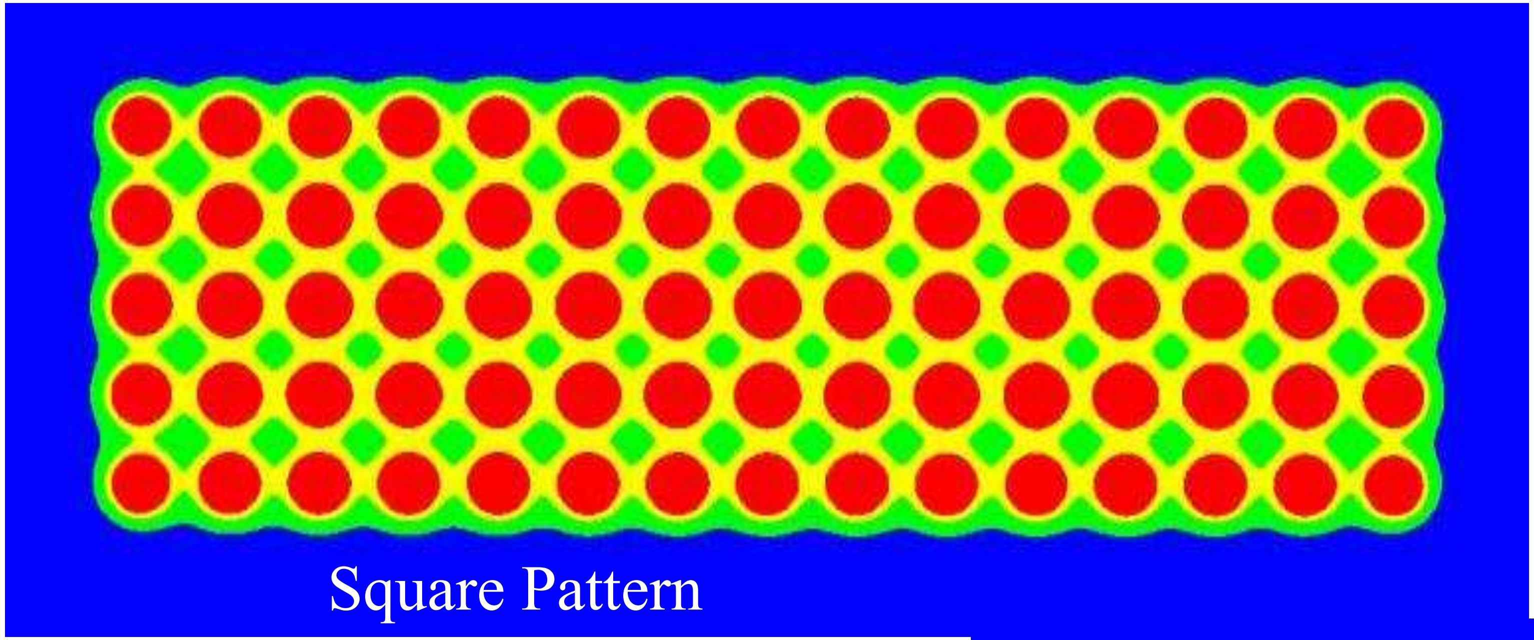


(after Cunningham, 2005)

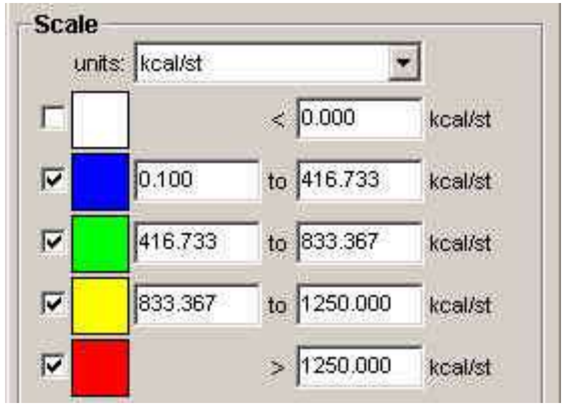
Blast Design Factors

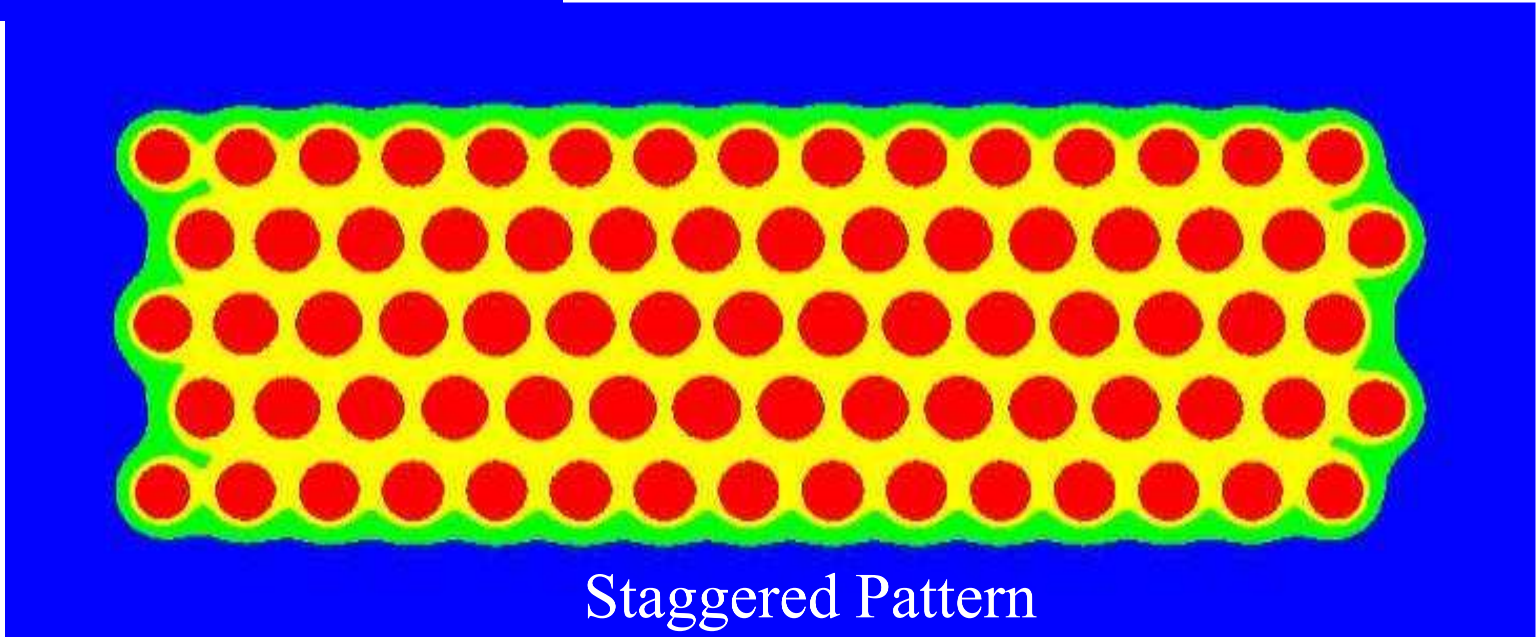
- Hole Diameter
  - Influences energy distribution and burden stiffness
- Burden/Spacing
  - Influences energy distribution and burden stiffness
  - Relationship with joint spacing affects oversize
- Bench Height
  - Influences burden stiffness
- Delay Time & Accuracy
  - Influences interaction between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

Explosive Energy Distribution



Square Pattern





Staggered Pattern

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

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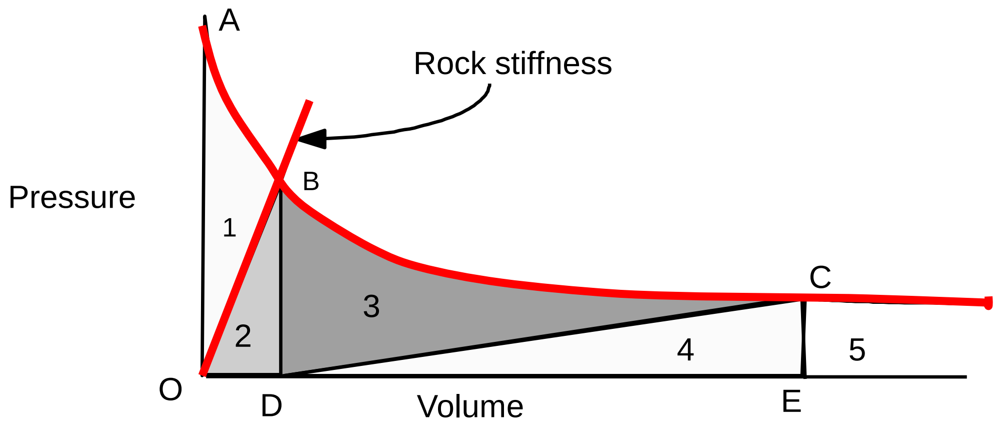
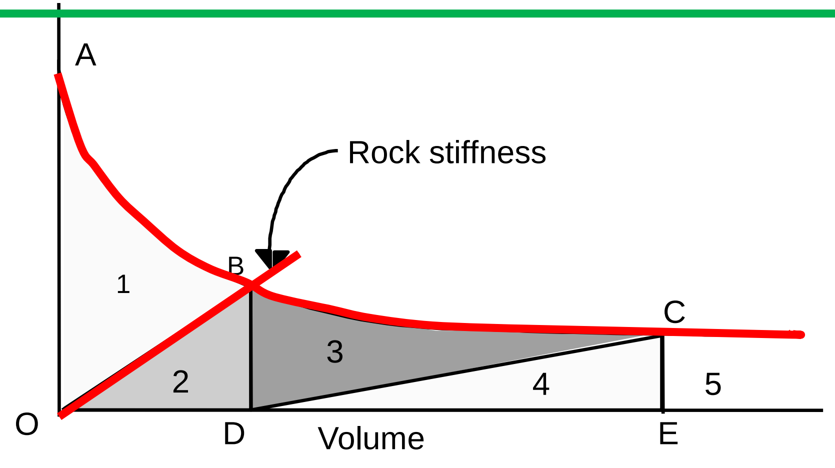
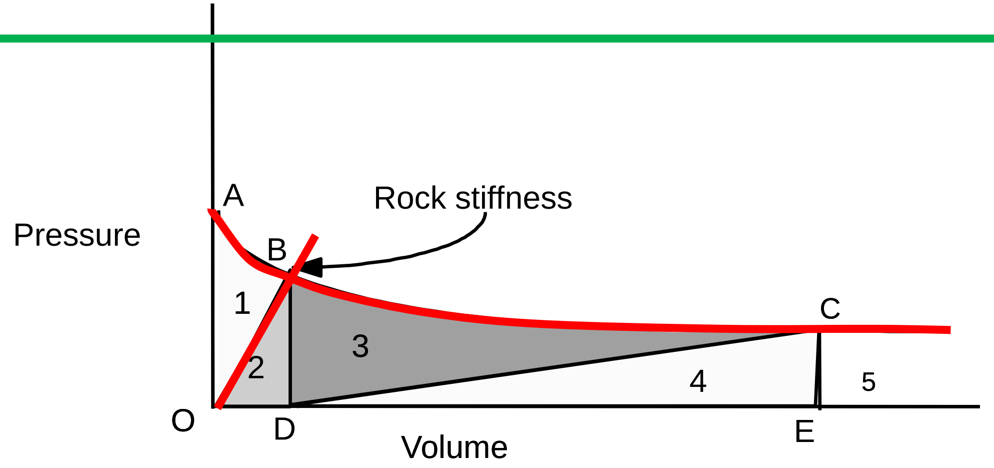
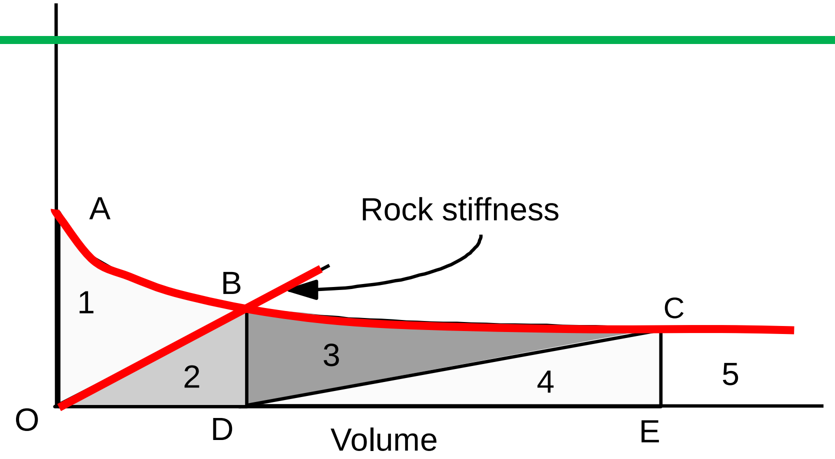
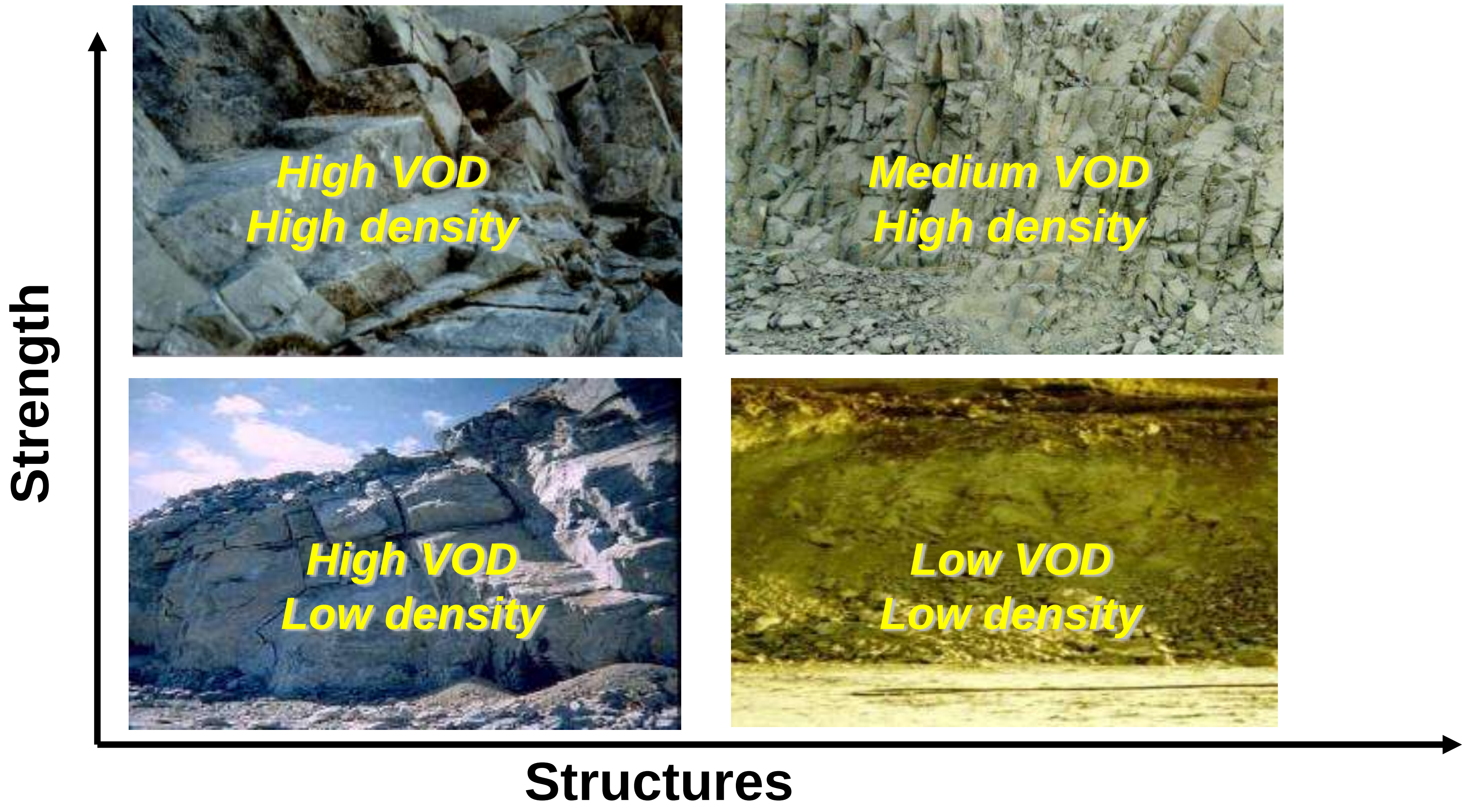
Explosive Selection

	Hard and Brittle Rock	Soft and Plastic Rock
High VOD	 a)	 b)
Low VOD	 c)	 d)

Explosive Selection to Meet Rock Structure and Strength Properties



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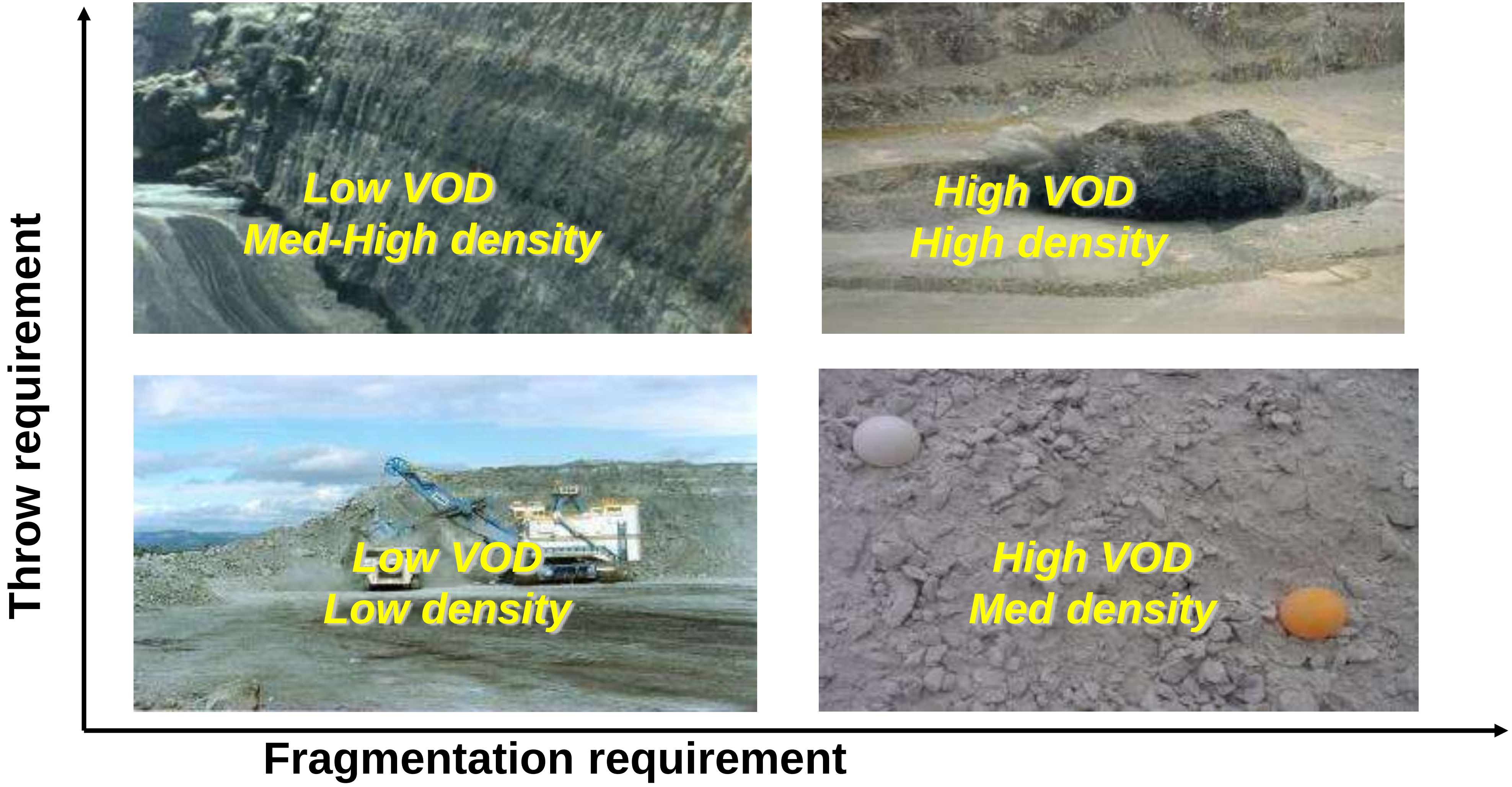
Explosive Selection to Meet Blast Objectives



In Summary Fragmentation Results. . .

Have a significant impact on quarry economics

Therefore, Fragmentation Optimization …

- **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**

‘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)?

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