302 – Blast and Drill
A Single Value Chain Process

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Improving Processes. Instilling Expertise.

DYNO
Dyno Nobel

SANDVIK

The lowest cost crushing is ????

Where did this approach come from?

- **Since 2003 Dyno Nobel and Sandvik have been working in a cooperative alliance.**

- **The alliance has provided both companies with a better understanding of the effect that activities and costs from individual unit operations in the quarry process, particularly those that each of us participates in, have up and down the total process stream.**

- **Joint case studies have begun to identify opportunities where aggregate producers further minimize cost and maximize profits.**

QUARRY ACADEMY

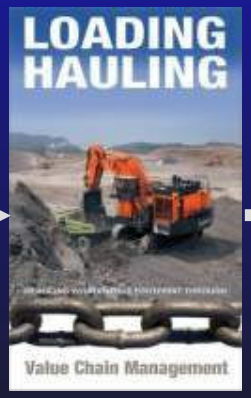
Unit Operations as Process

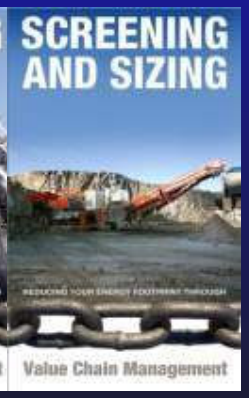
"Optimal Zone"

+ Optimum

- Total Cost -

$ $





Chemical Crushing

Transport

Mechanical Crushing

Drill and Blast is so much more than a necessary Evil!

- **Most economical method to take rock apart.**
- **Significant contributor to *reducing costs* down stream in the aggregate production value chain.**
  - ✓ **Doing things right today and better tomorrow.**
  - ✓ **Use as a chemical crusher to feed the mechanical crush, shape, size process.**

QUARRY ACADEMY

Size Reduction In the Quarry Process

At the end of the day, the quarry process has to crush the rock to a final end product specification.

- **Where and how is this best done?**

  (Value Transformation)

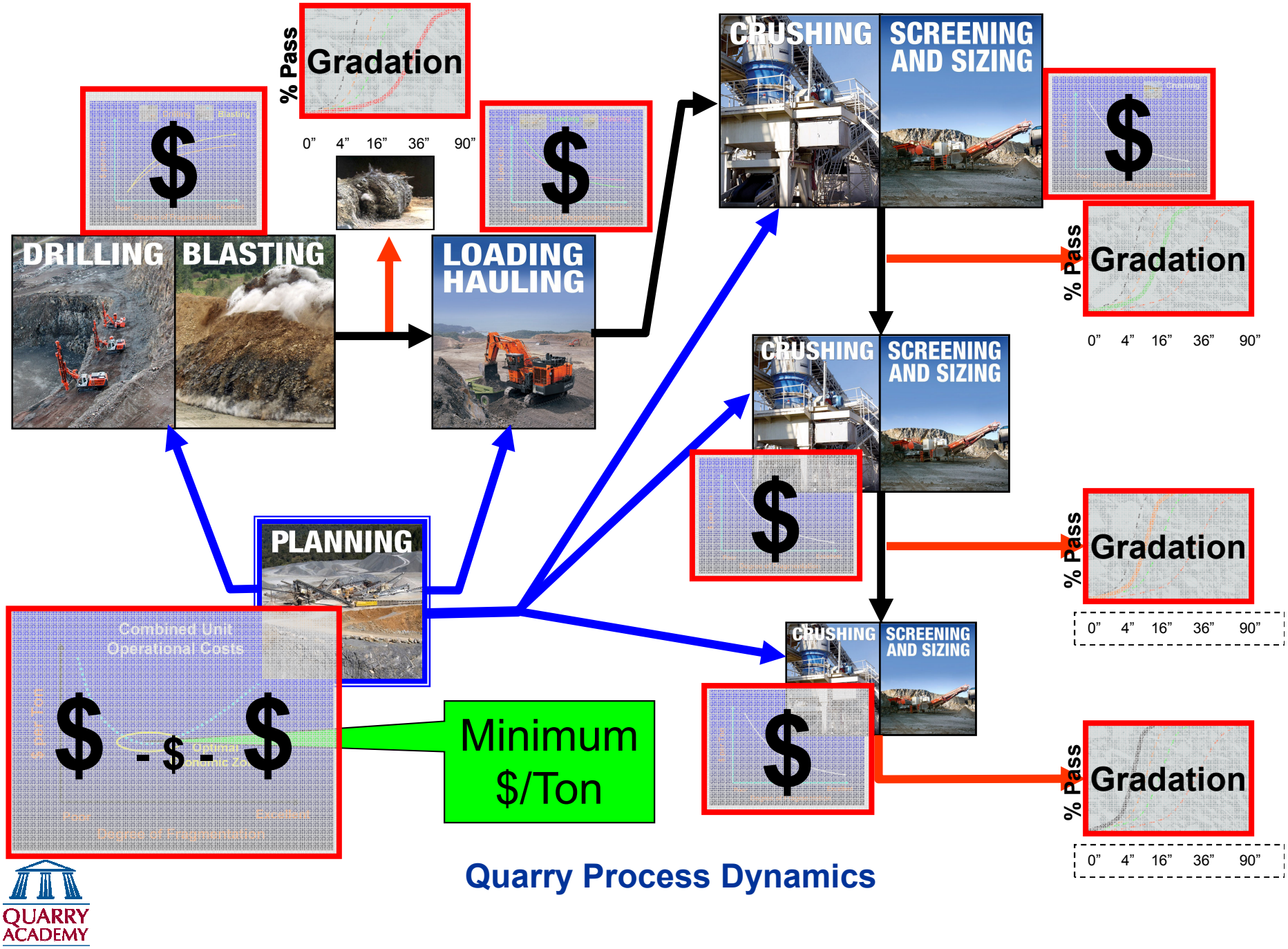
- **What offers the greatest operational flexibility?**

  (Capitol Investment Intensity)

- **In the plant, is there any benefit in allowing a prior crusher stage to achieve less than it's size reduction ratio capacity before passing it's output to the next stage of crushing and screening?**

  (Lean/Waste Reduction)

QUARRY ACADEMY


% Pass
Gradation
0” 4” 16” 36” 90”
$
DRILLING
BLASTING
LOADING HAULING
CRUSHING
SCREENING AND SIZING
PLANNING
Combined Unit Operational Costs
$ - $ - $
Minimum $/Ton
Quarry Process Dynamics
QUARRY ACADEMY

As Chemical Crusher, Drill and Blast targets expand one step further.

- **Normal Drill and Blast**
  - ✓ **Zero Harm**
  - ✓ **Full Regulatory Compliance**
  - ✓ **Controlled boundaries of blast / excavation**
  - ✓ **Uniform Breakage**
  - ✓ **Easy to dig, load, haul, dump and feed.**
- **Chemical Crusher**
  - ✓ **Control / Influence particle size distribution.**

QUARRY ACADEMY

Basic Drill and Blast Principles Still Apply

- **When explosives are detonated they release the chemical energy stored within them.**

- **All that energy will go somewhere:**

  - ✓ **into breaking and fragmenting the rock**
  - ✓ **into moving and heaving the rock**
  - ✓ **into ground vibration**
  - ✓ **into air overpressure and heat**

QUARRY ACADEMY

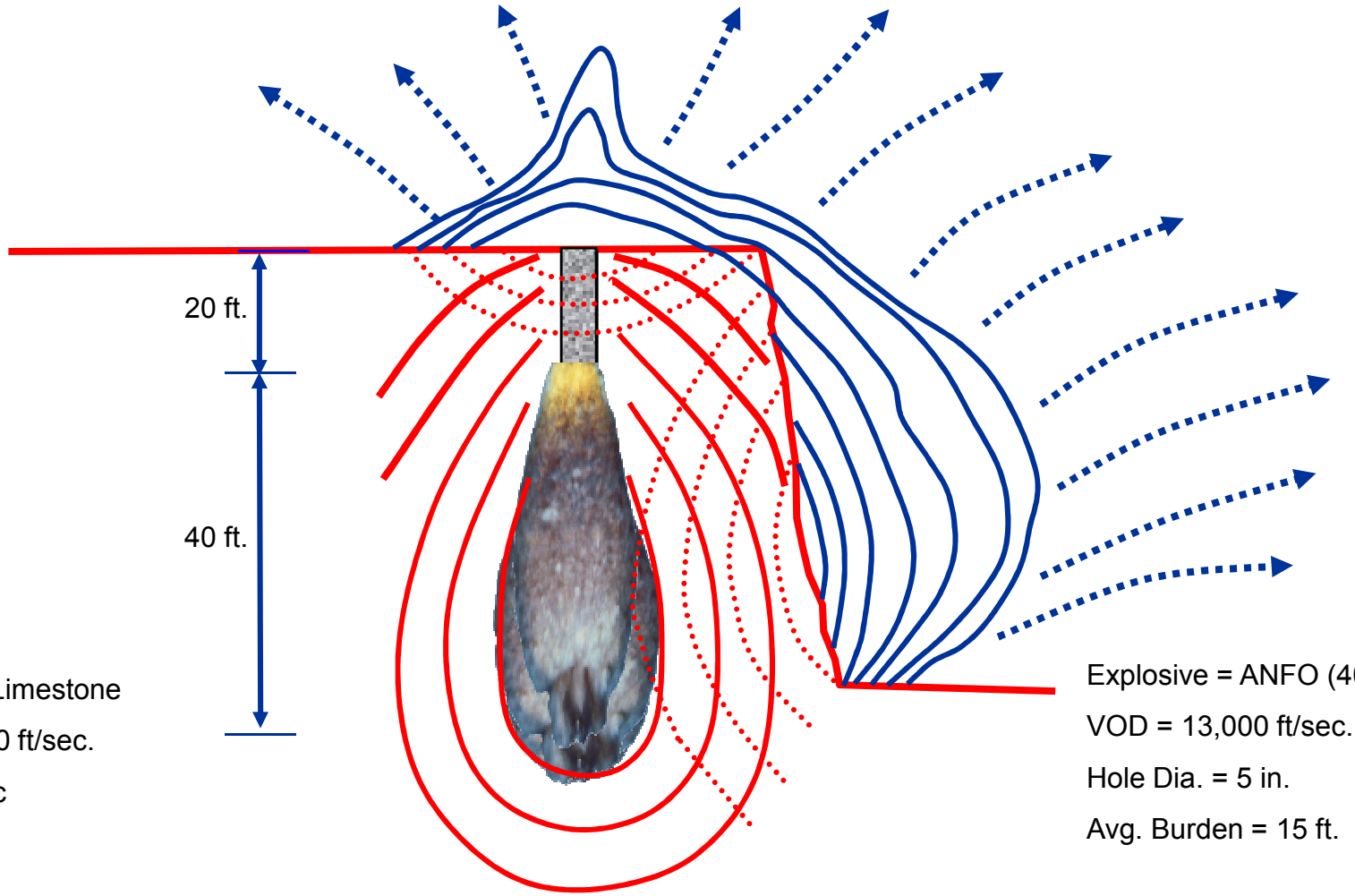
Basic Drill and Blast Principles Still Apply.

- **Without the drill hole, explosives would not be a practical tool for the quarry industry.**
- **In a correctly designed blast, an accurately placed drill hole puts the right quantity of explosive energy in the right place!**
- **In a correctly designed blast, an accurate and precise explosive initiation system applies the right quantity of explosive energy at the right time!**

QUARRY ACADEMY

Blast Dynamics

Action – Reaction Energy Release



Material = Limestone

Vp = 15,000 ft/sec.

P = 2.3 g/cc

Explosive = ANFO (40 ft.)

VOD = 13,000 ft/sec.

Hole Dia. = 5 in.

Avg. Burden = 15 ft.

QUARRY ACADEMY

Blast Dynamics
Stress / Pressure Dissipation

H_d = Hole Diameter

UCS = Unconfined compressive Strength of rock

Step 1= Pulverized Zone

Blast hole diameter expanded

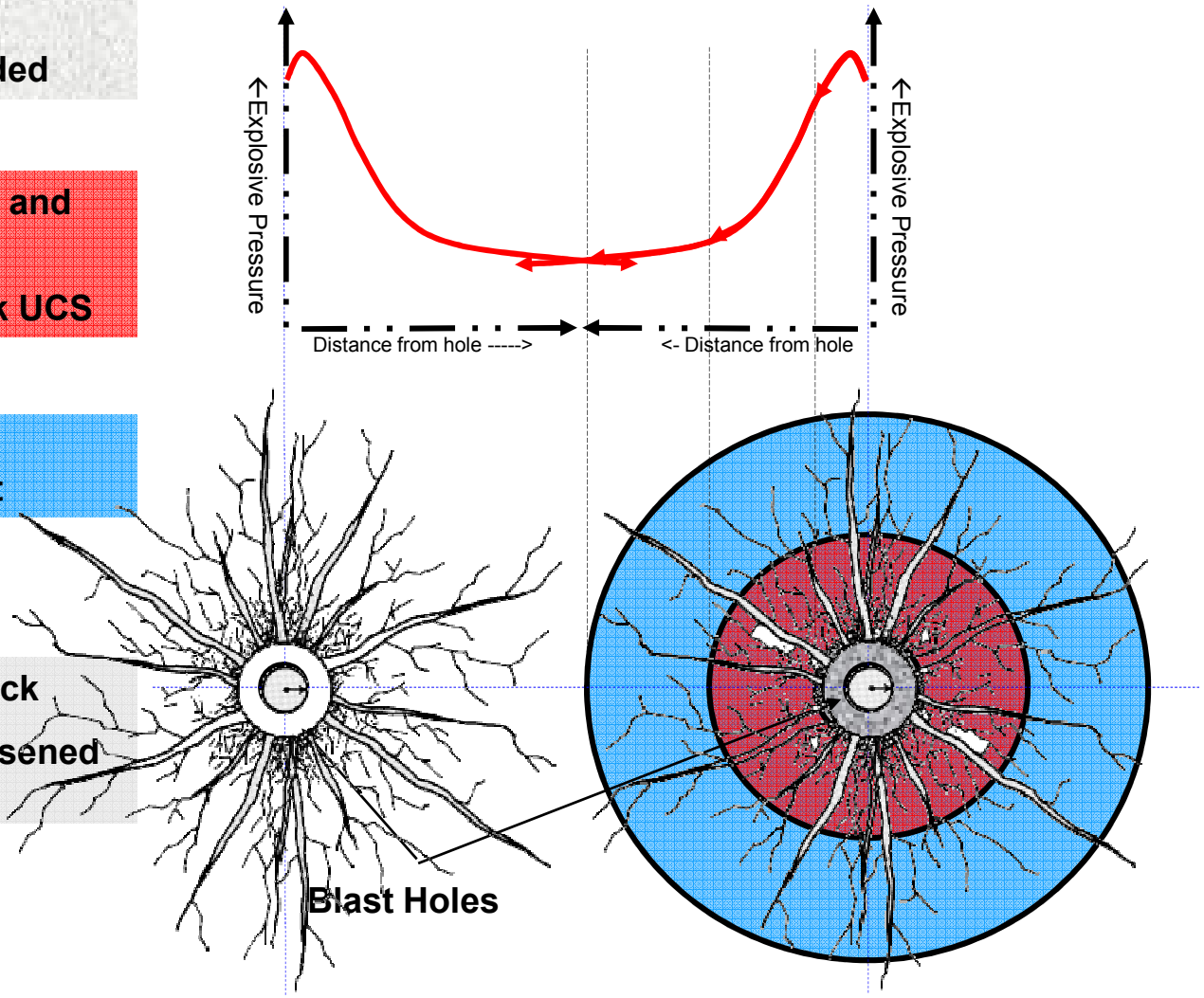
Step 2 = Intense fracturing and cleaving of minerals

Blast Hole Pressure > Rock UCS

Step 3 = Minimum stress pressure in rock from blast

Step 4 = Damage limit to rock

Pre-existing blocks are loosened and moved



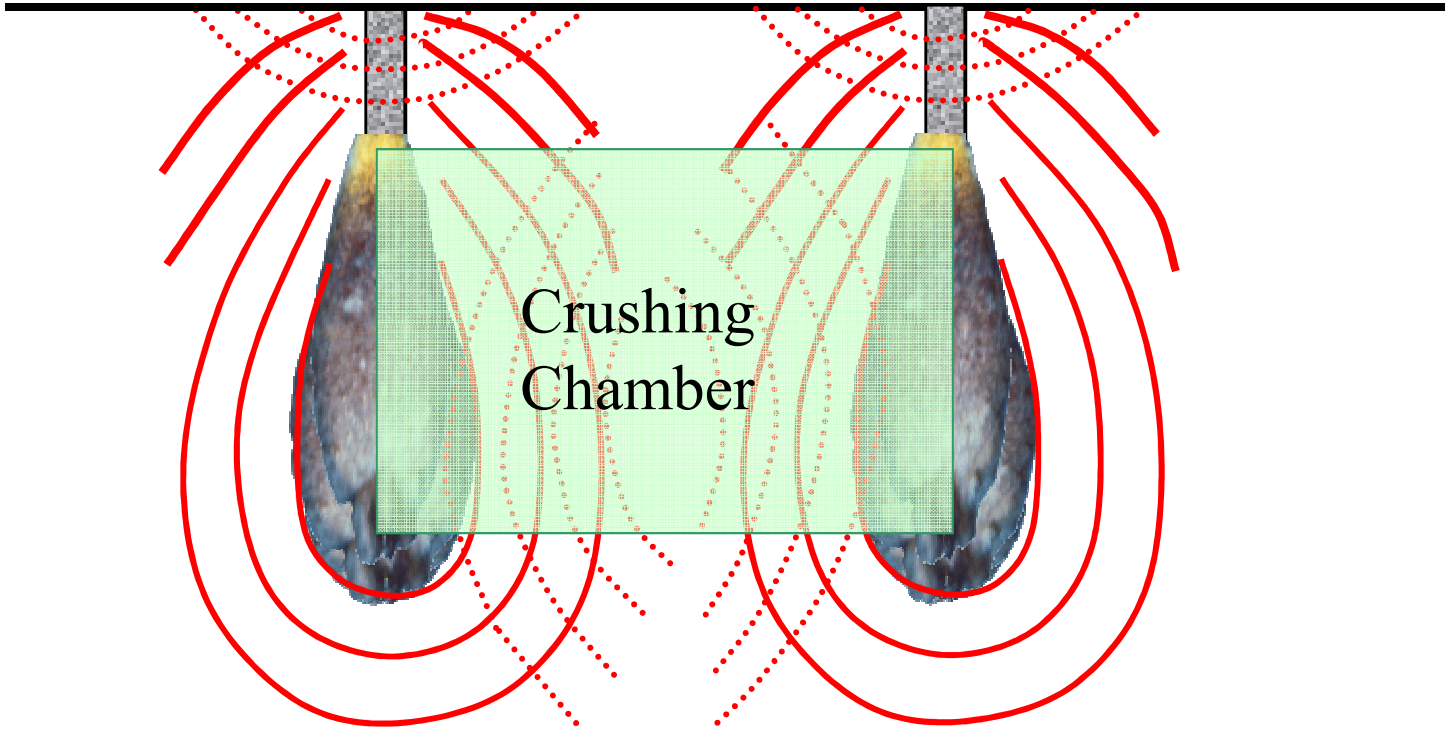
QUARRY ACADEMY

Chemical Crusher

- ✓ Capable of crushing in excess of 1,100 tons/hr of rock reserves.
- ✓ Portable and is built at the rock bench.
- ✓ Disposable and fully consumed on use.
- ✓ Could be assembled in 15.5 hrs or less. Daily if necessary.
- ✓ Except for the diesel and/or electricity to build it, it is internally powered.
- ✓ Has design flexibility to meet changing rock conditions and to produce different rock size gradations.
- ✓ Major drawback is: that, without proper controls, it can have noise, dust and vibration issues.

QUARRY ACADEMY

Chemical Crusher (conceptually)



QUARRY ACADEMY

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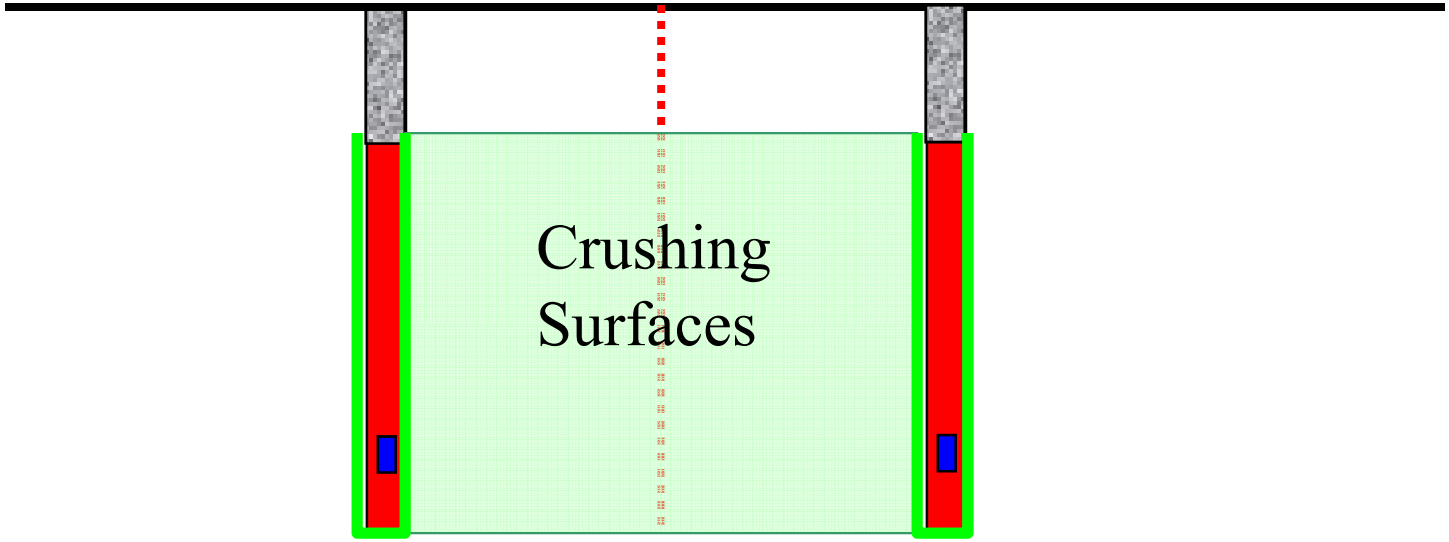

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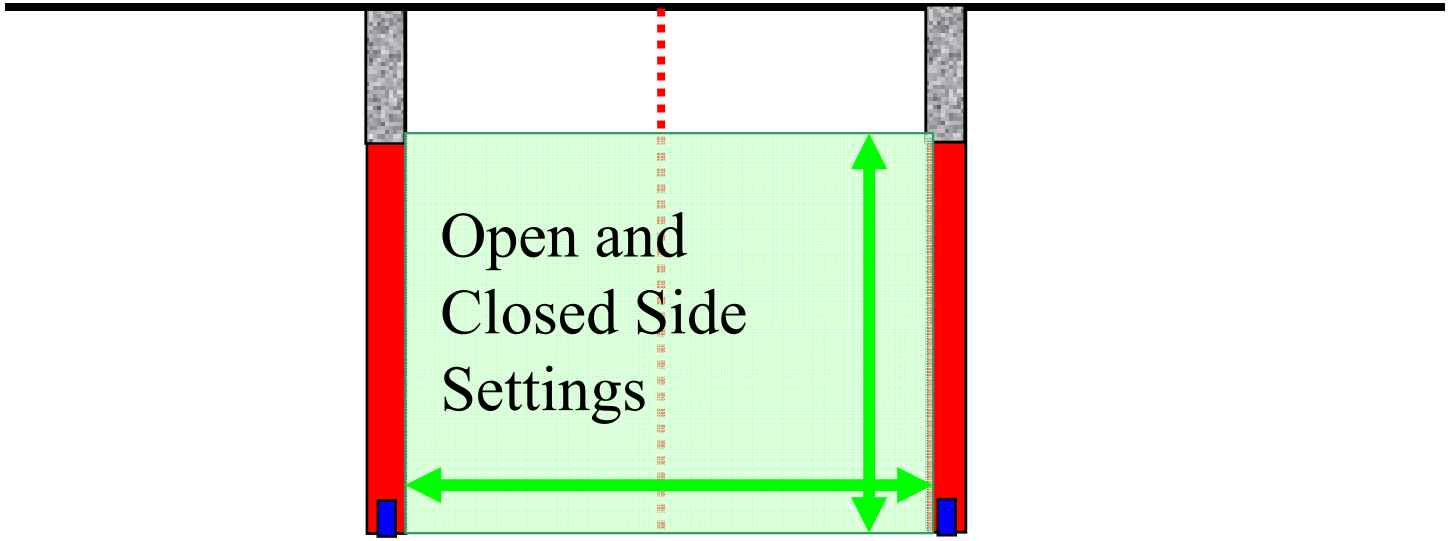
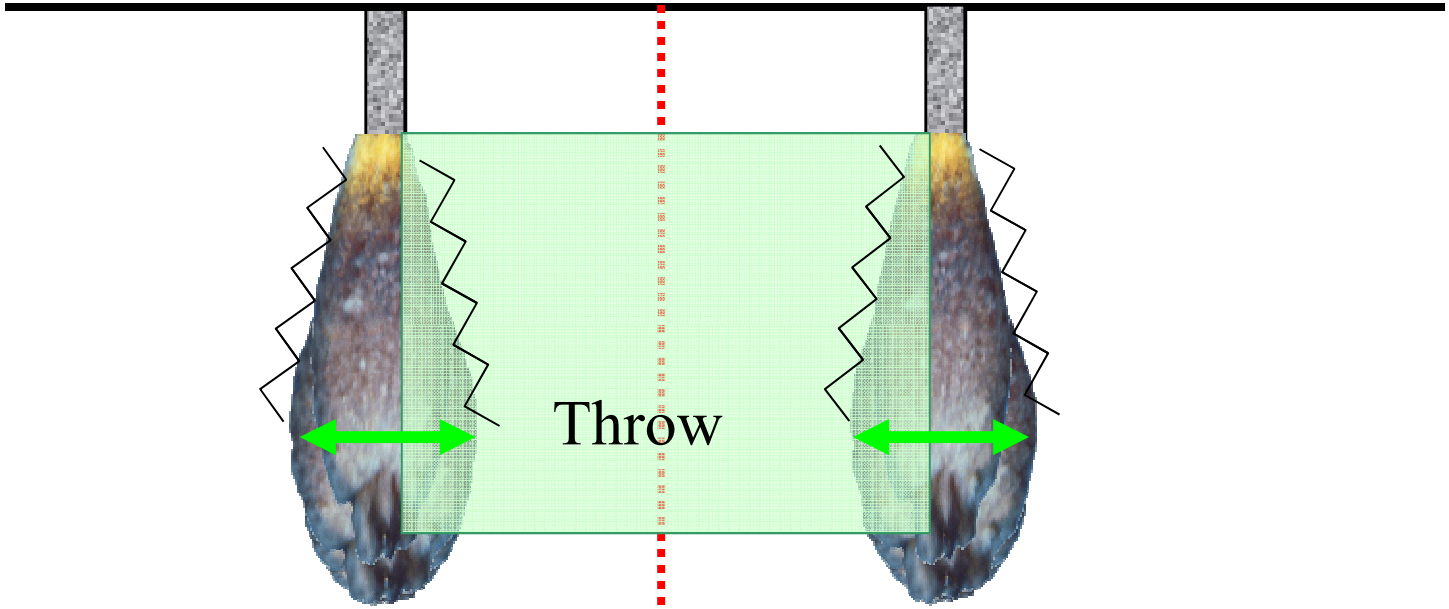


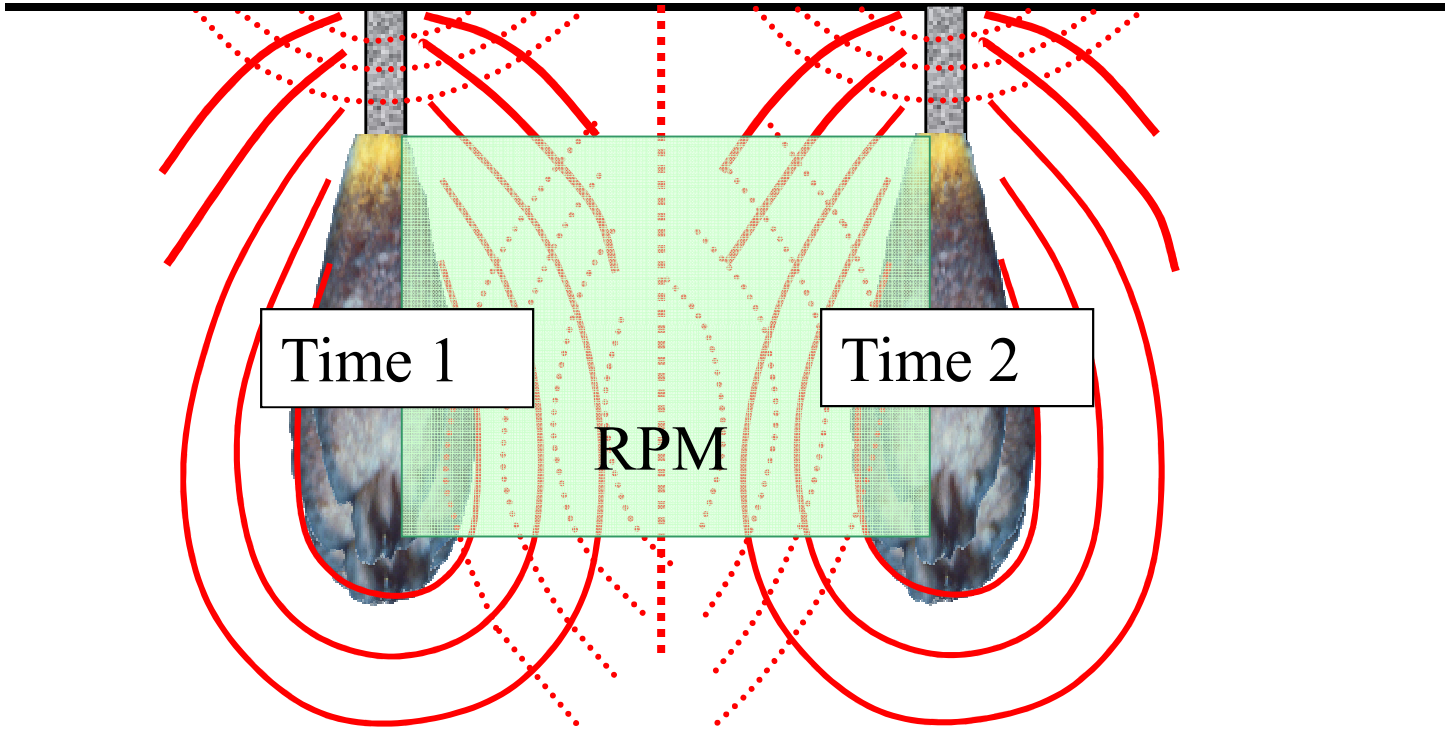
QUARRY ACADEMY

Chemical Crusher (conceptually)



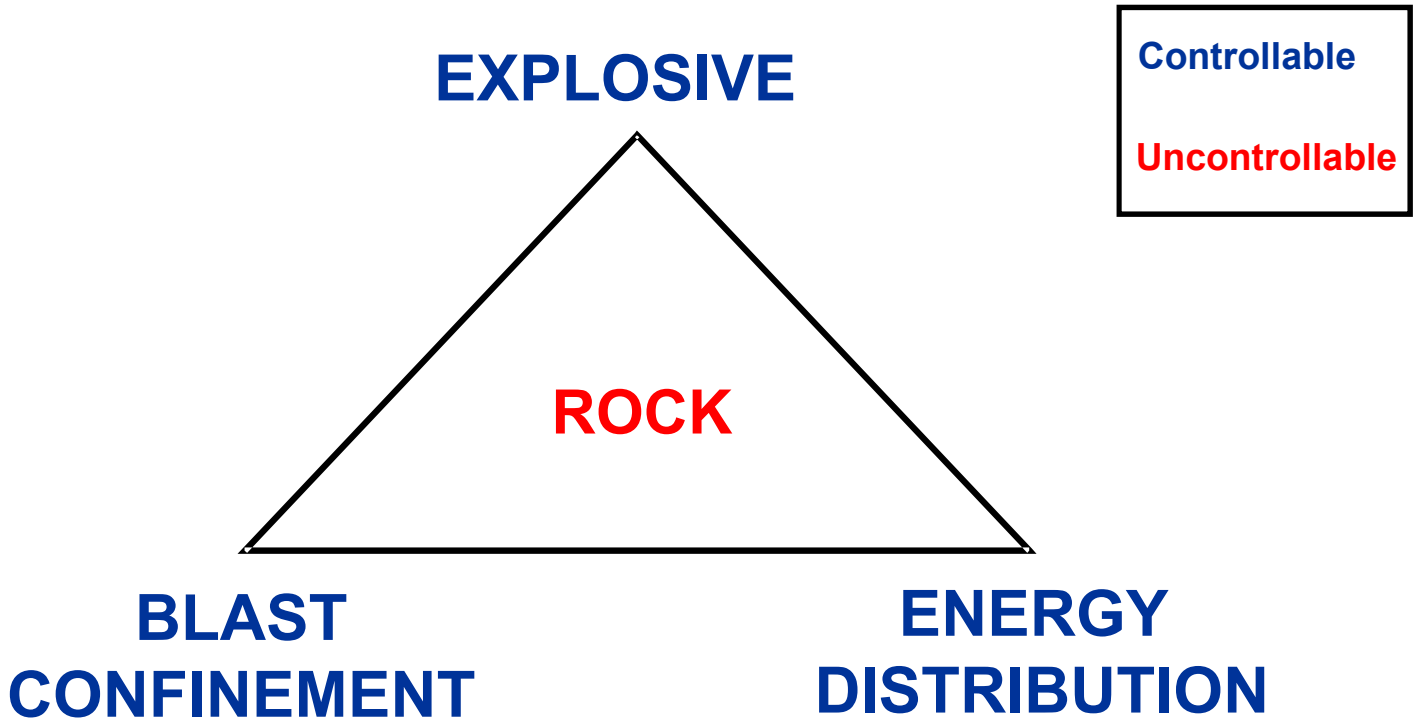
QUARRY ACADEMY

Chemical Crusher (conceptually)



QUARRY ACADEMY

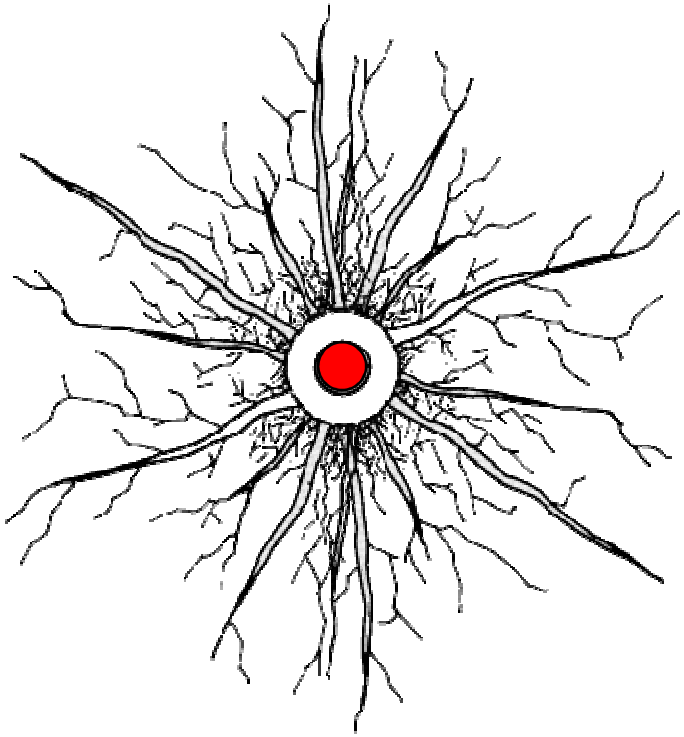
Chemical Crusher - Key Design Factors



QUARRY ACADEMY

Explosive Type
A controllable factor in building the Chemical Crusher

- **Select the best explosive or explosives for the rock.**
  - ✓ **Density (g/cc)**
  - ✓ **Velocity of Detonation (ft/sec)**
  - ✓ **Energy (kcal/lb)**
  - ✓ **Water Resistance**
  - ✓ **Critical Diameter**
  - ✓ **Physical Form**
    - ✓ **Package**
    - ✓ **Bulk**
      - ✓ **Dry Blend / Free Flowing**
      - ✓ **Wet Blend / Augerable**
      - ✓ **Pumpable Blend**



QUARRY ACADEMY

Blast Confinement
A controllable factor in building the Chemical Crusher

- **Design to confine the explosive energy so that it can do effective work.**
  - ✓ **Amount of material surrounding the explosive in the drill hole**
    - ✓ **Material between the drill hole and any static or dynamic free space.**
  - ✓ **Distance of the drill hole from an open face.**
    - ✓ **Face burden**
  - ✓ **Distance of drill holes relative to one another.**
    - ✓ **Burden**
    - ✓ **Spacing**
  - ✓ **Type and amount of stemming / non explosive decking**
  - ✓ **Initiation sequence and time between and within individual holes.**

QUARRY ACADEMY

Energy Distribution

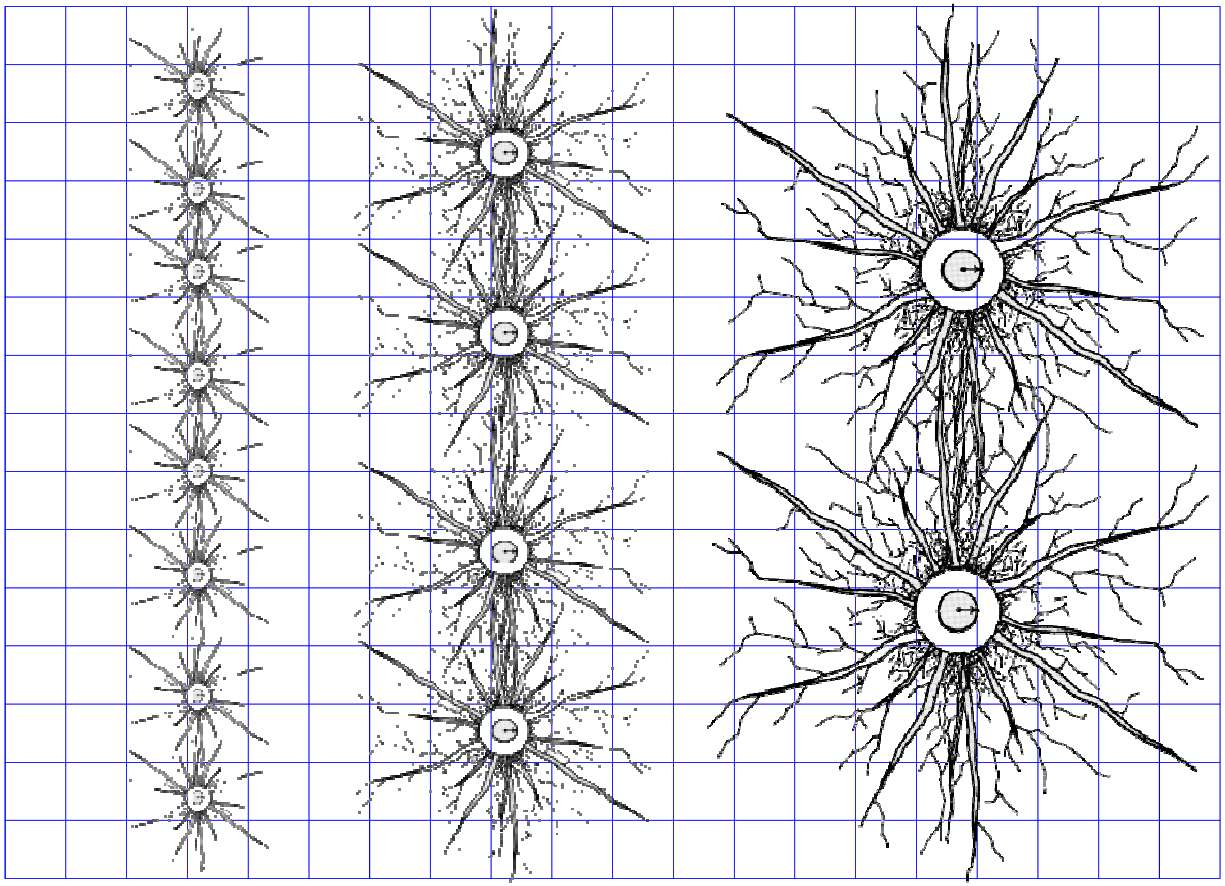
A controllable factor in building the Chemical Crusher

- **How the explosive energy is distributed throughout the rock mass – vertically and horizontally to do work.**
  - ✓ **Diameter of the drill hole.**
    - ✓ **Limits the diameter of explosive.**
  - ✓ **Diameter of the explosive.**
    - ✓ **Package explosive can limit the effective diameter of the blast hole.**
  - ✓ **Depth of the drill hole.**
    - ✓ **Amount loaded with explosive.**
    - ✓ **Explosive deck(s) and their location throughout the rock mass**
  - ✓ **Orientation of drill holes**
    - ✓ **Relative to one another – staggered, in-line**

QUARRY ACADEMY

Effect of Hole Diameter on Fragmentation Control (Small to Large)

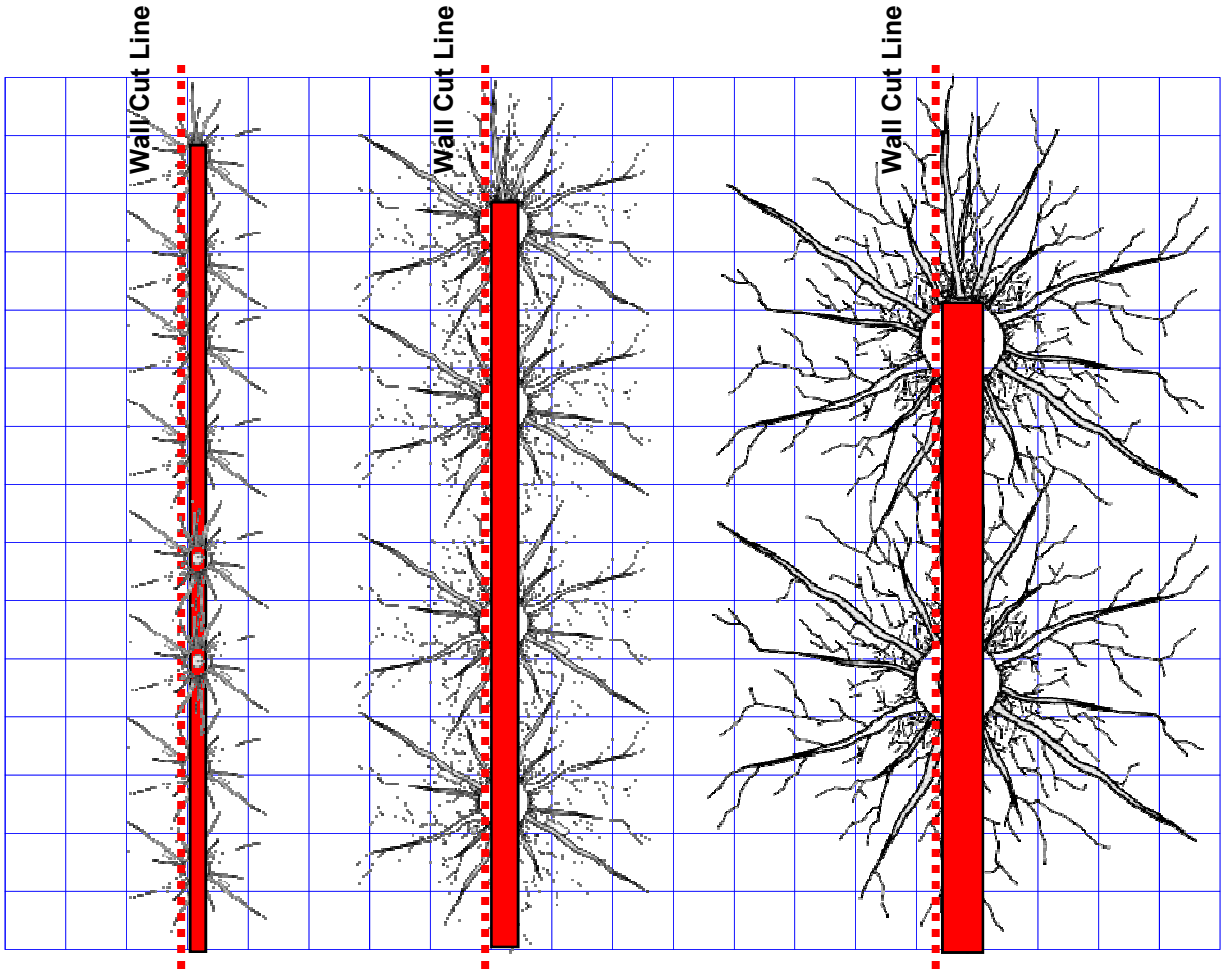
As hole size increases, the area of influence around each hole *and* the geometry of the fragmentation changes.



QUARRY ACADEMY

Effect of Hole Diameter on Fragmentation Control (Small to Large)

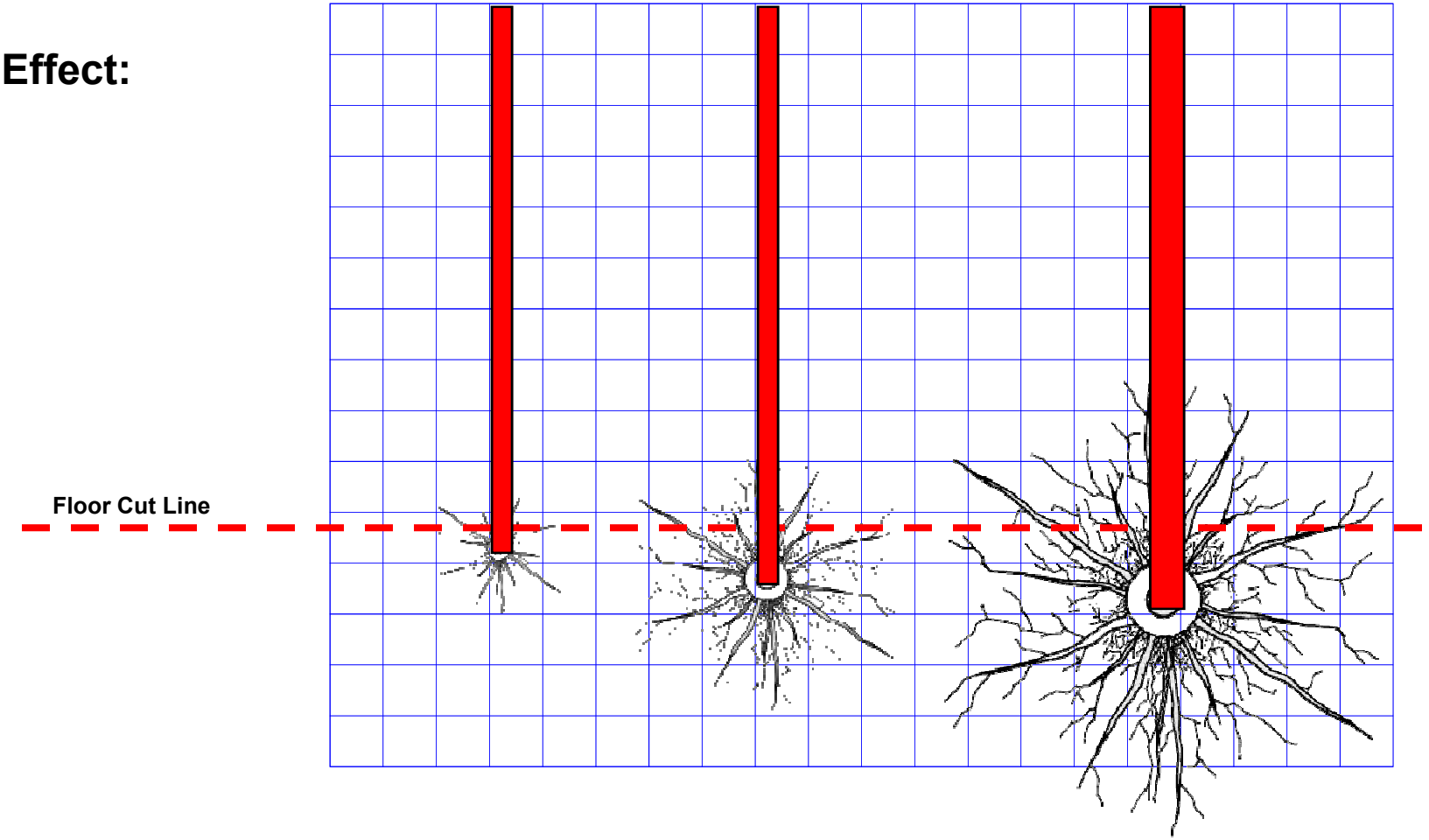
Wall Effect:



QUARRY ACADEMY

Effect of Hole Diameter on Fragmentation Control (Small to Large)

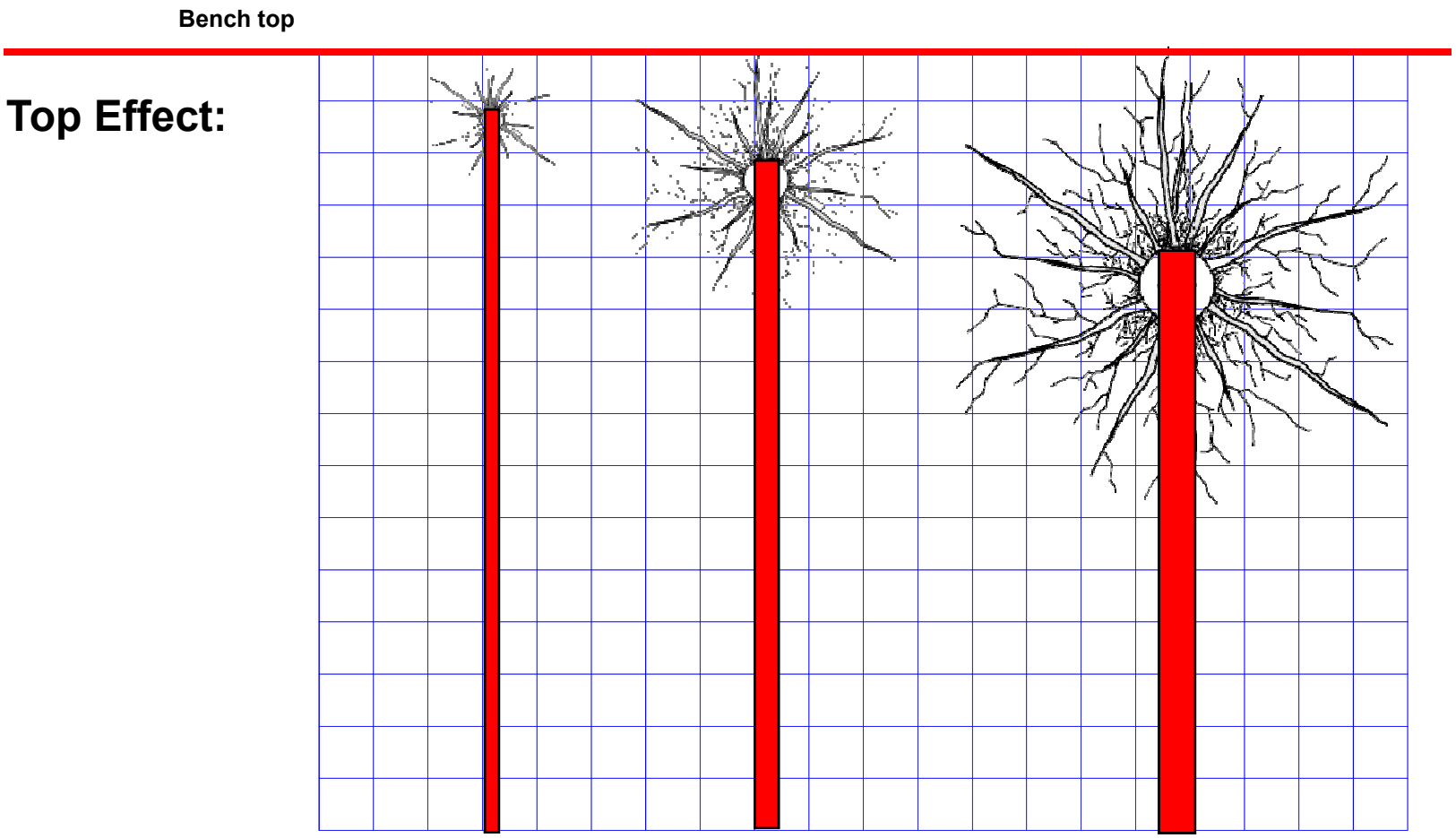
Floor Effect:



QUARRY ACADEMY

Effect of Hole Diameter on Fragmentation Control (Small to Large)

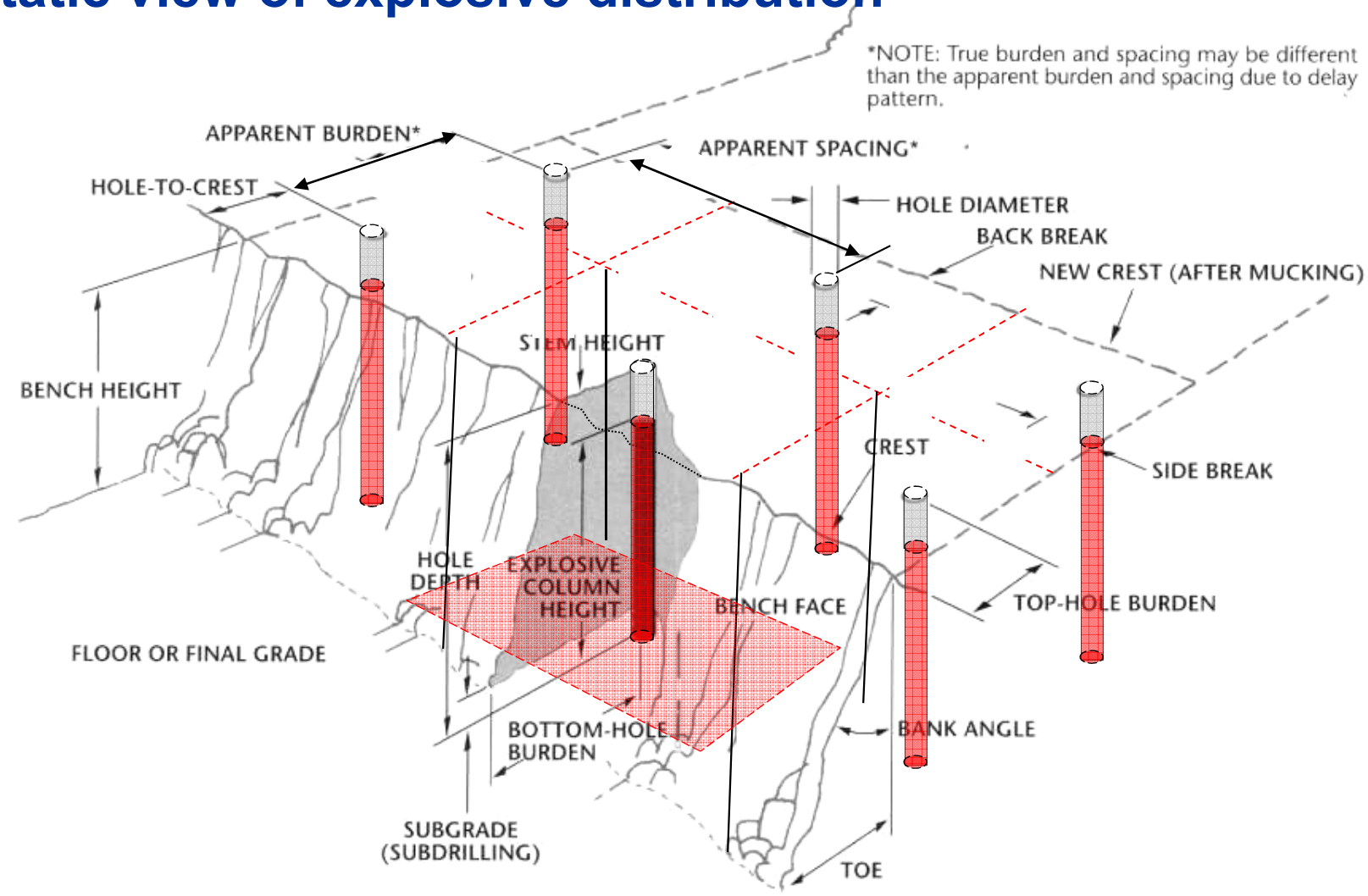
Bench Top Effect:



QUARRY ACADEMY

Building the Chemical Crusher

Static view of explosive distribution

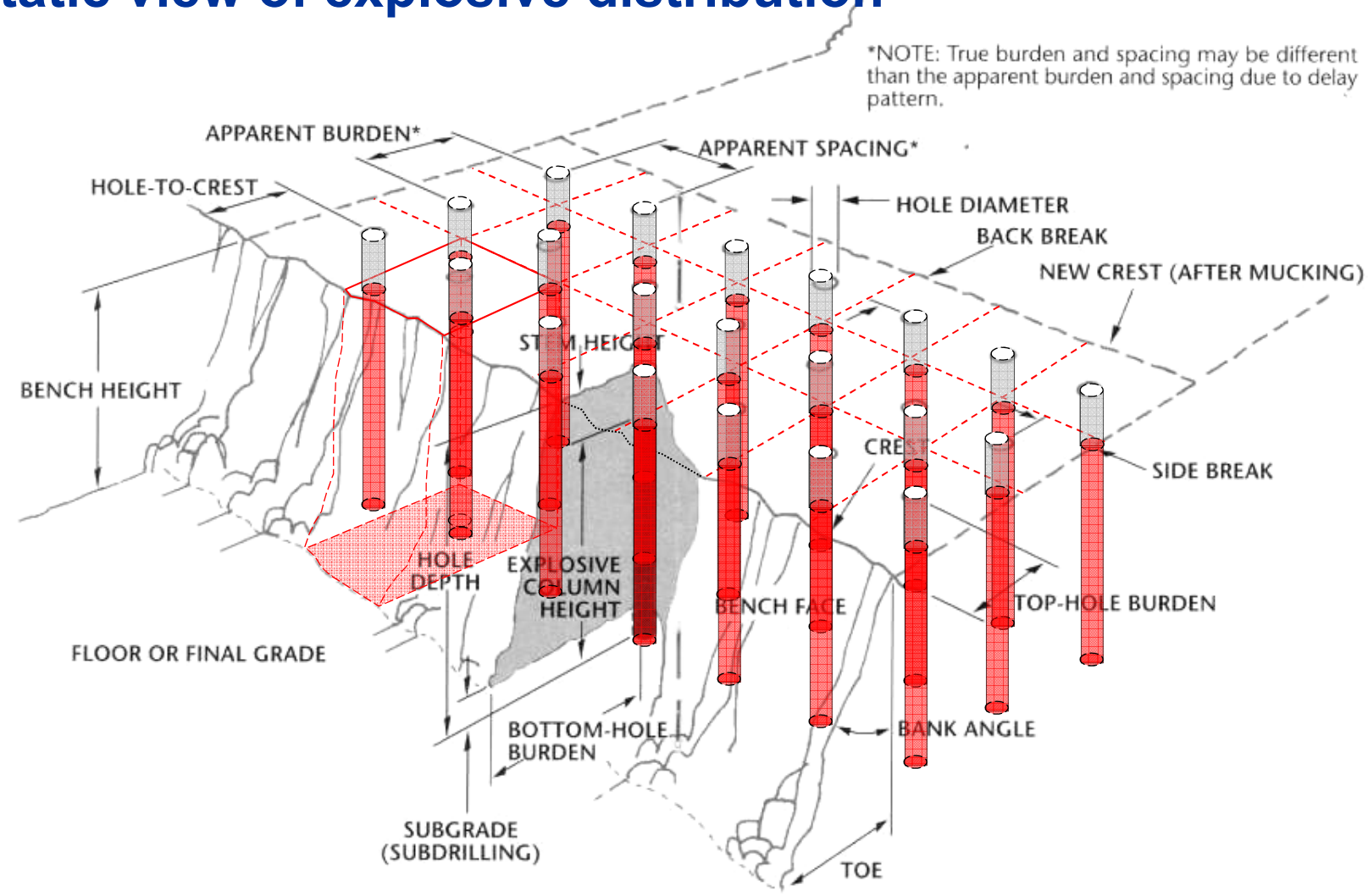


QUARRY ACADEMY

Larger Diameter Holes

Building the Chemical Crusher

Static view of explosive distribution



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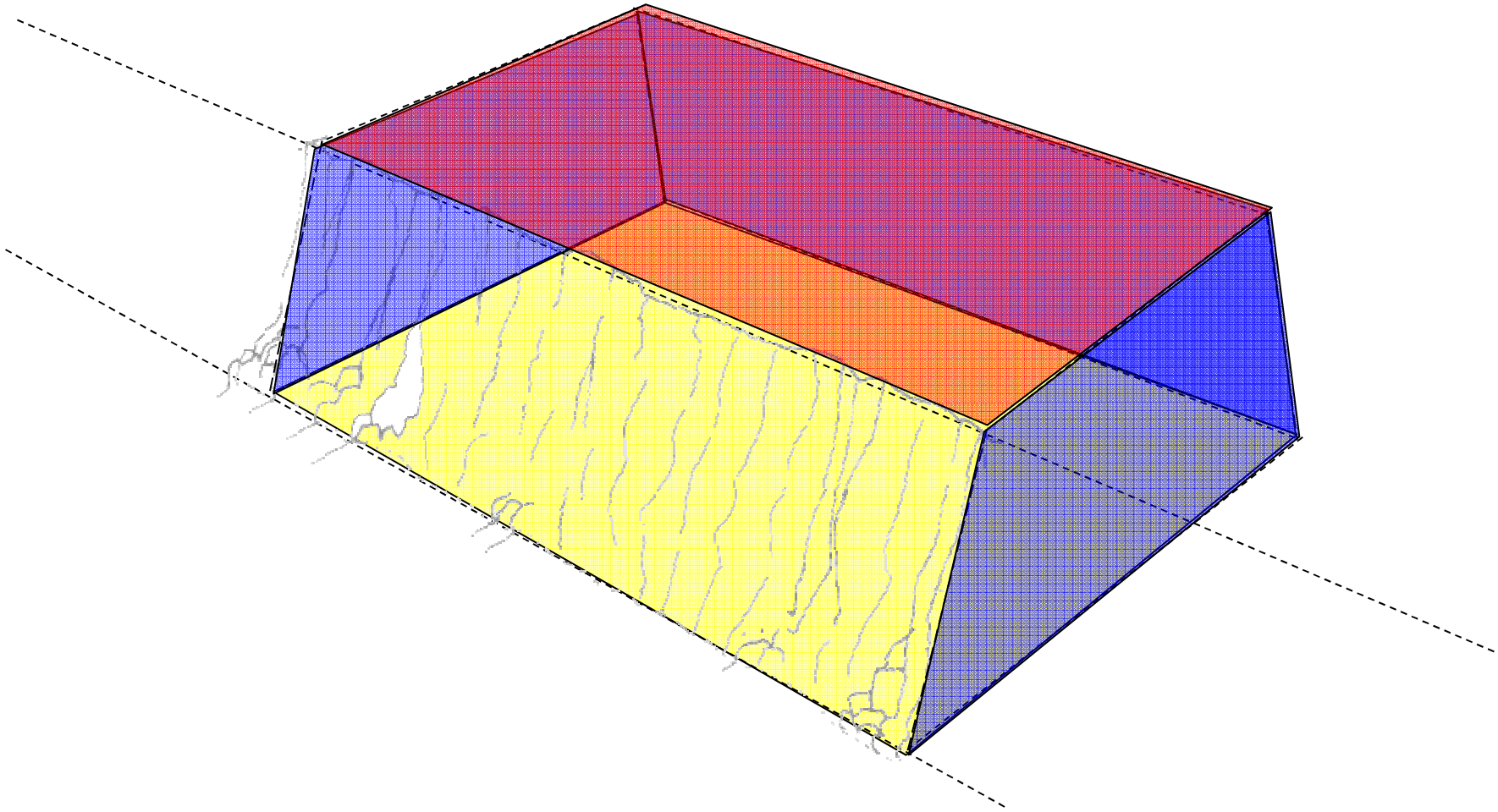
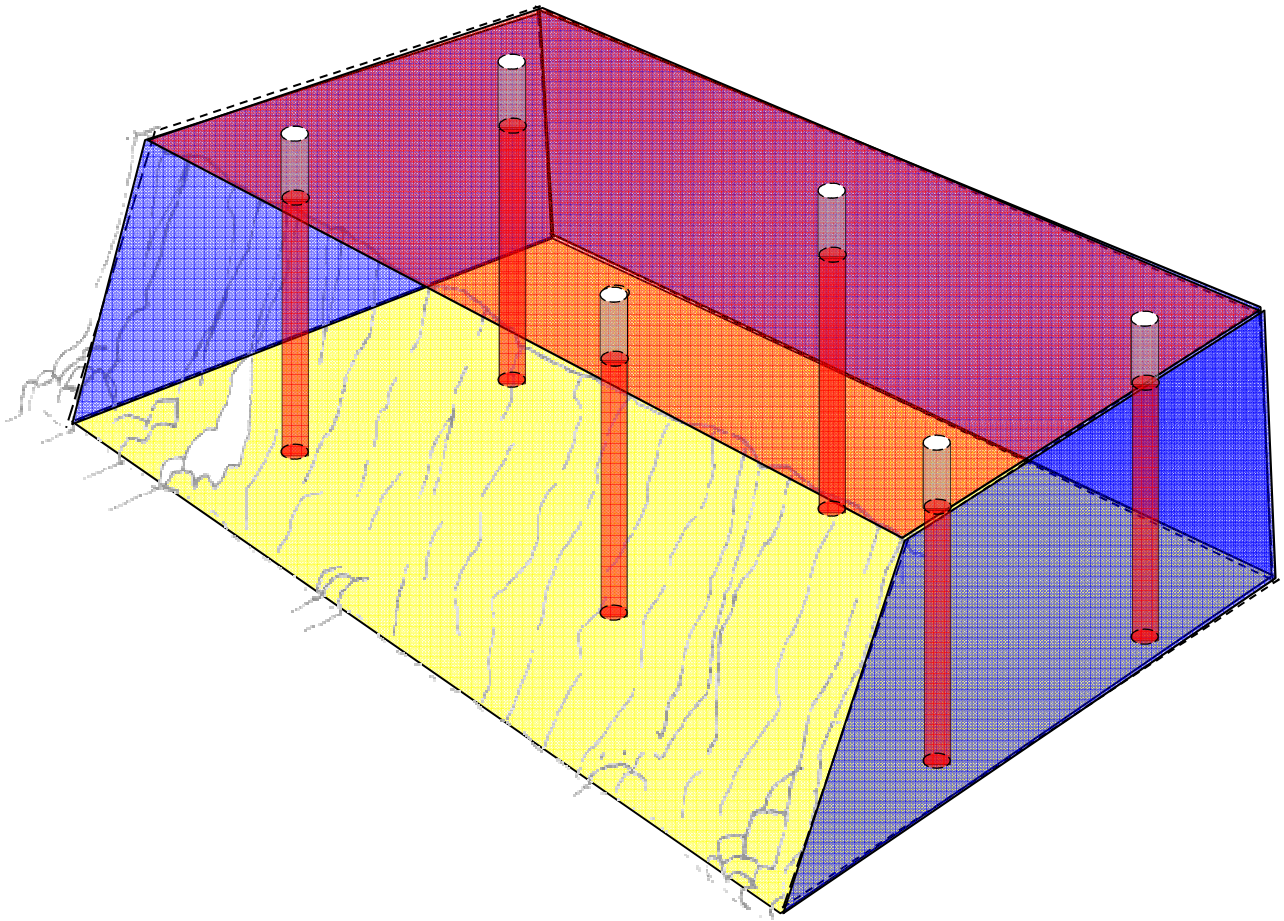
Smaller Diameter Holes

Target Work Zone for Chemical Crusher



QUARRY ACADEMY

Larger diameter holes in Target Work Zone



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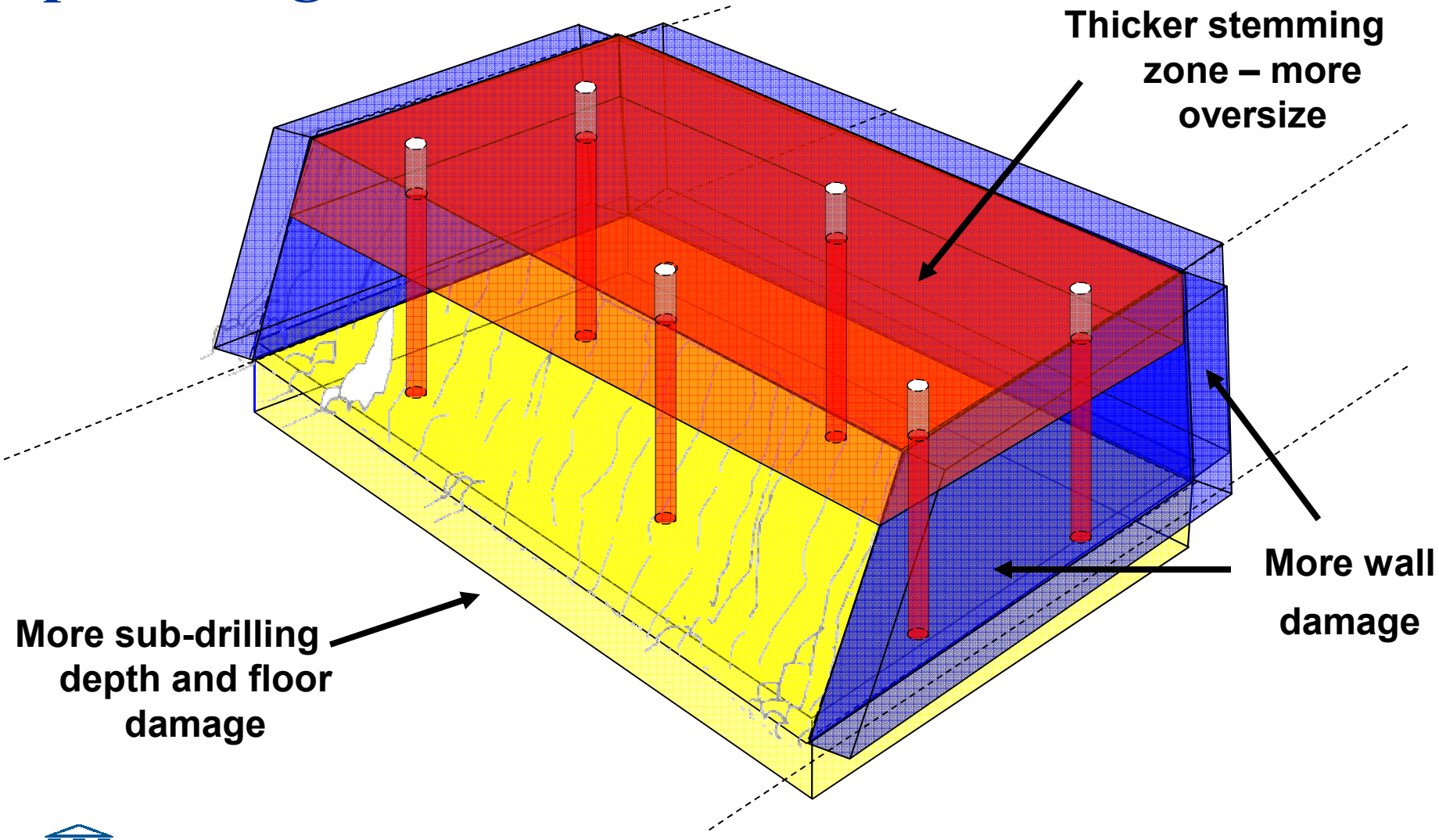
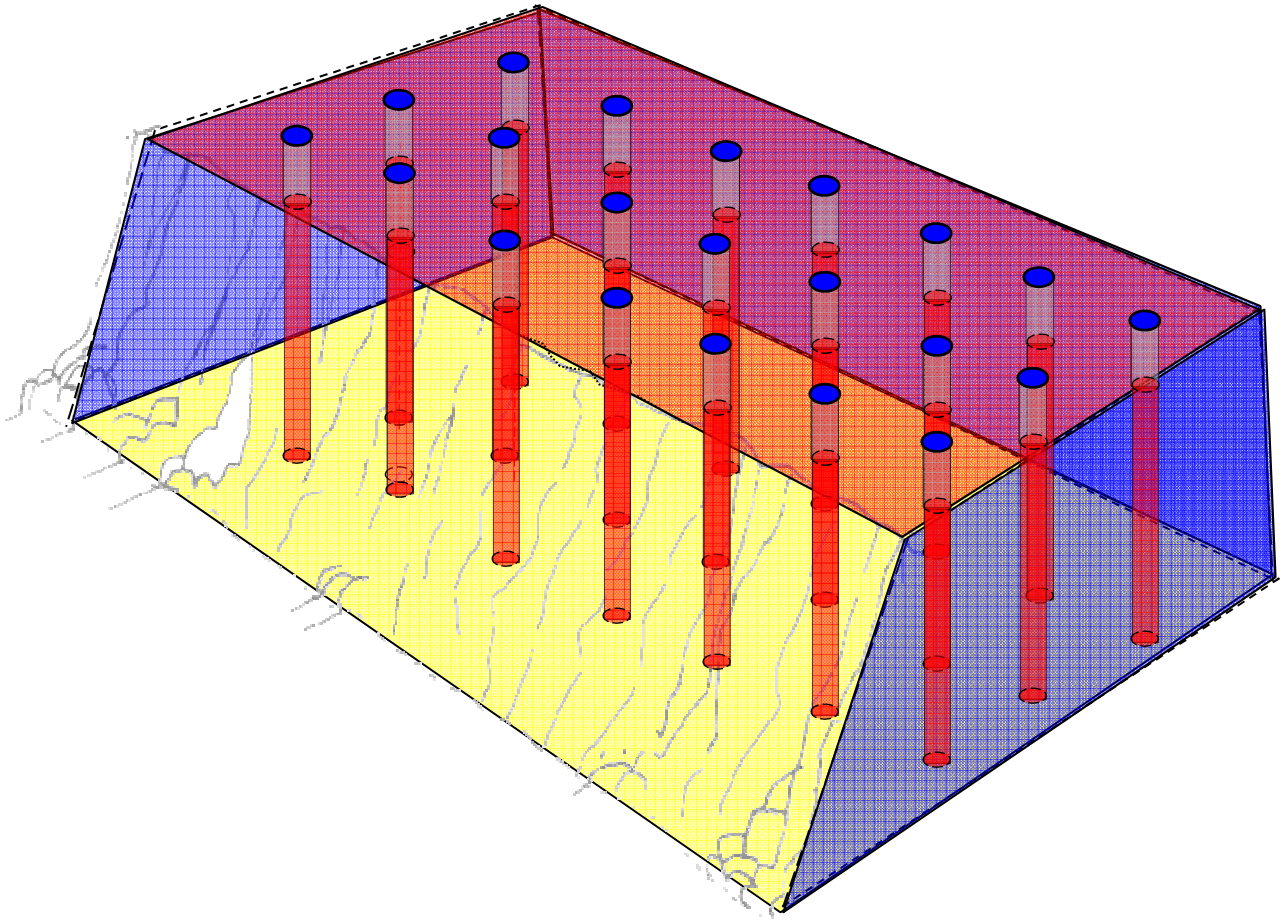
Larger diameter holes allow for smaller overall percentage of crushed rock



QUARRY ACADEMY

Small diameter holes in Target Work Zone



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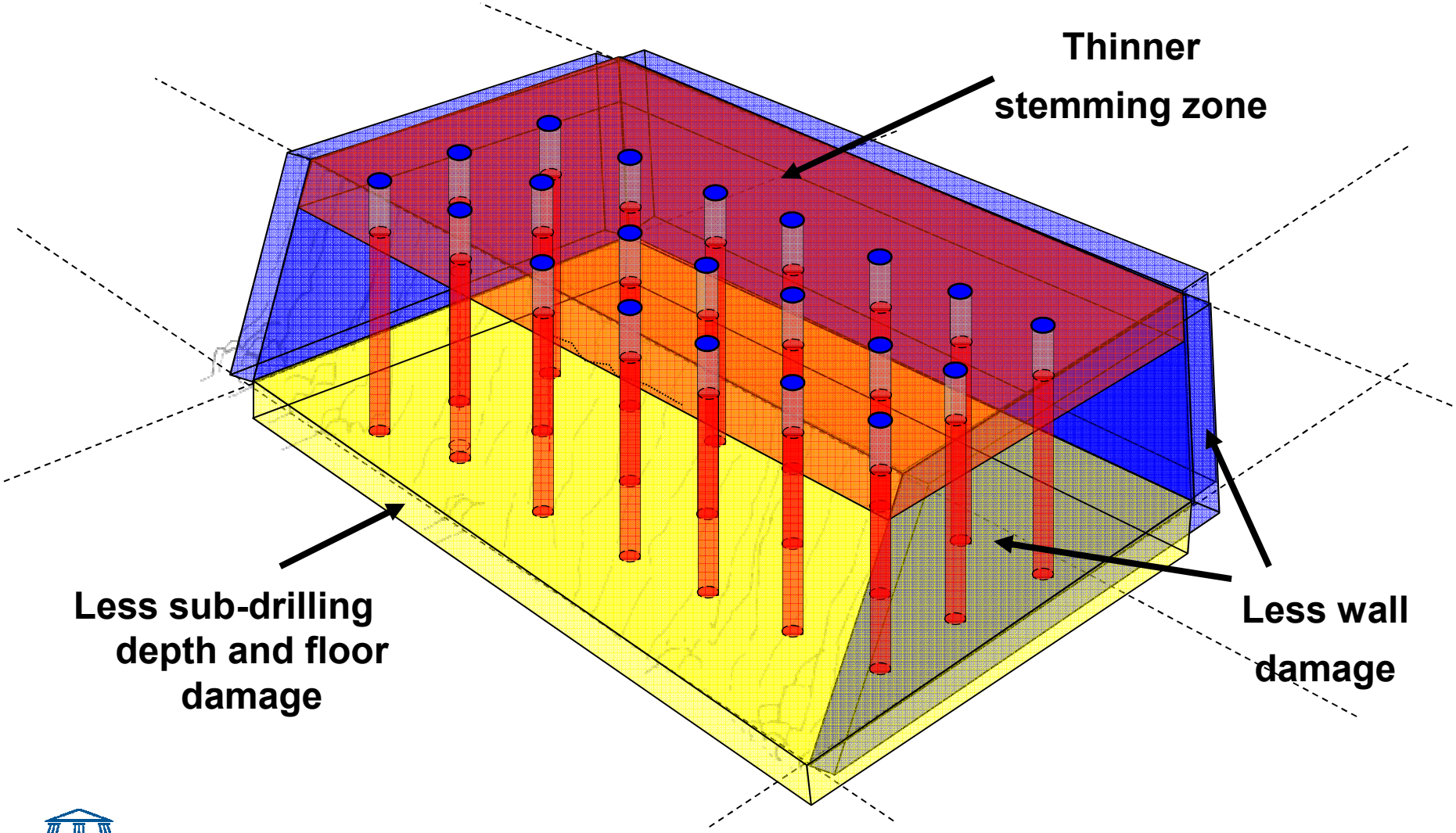
Smaller diameter holes allow for higher overall percentage of crushed rock



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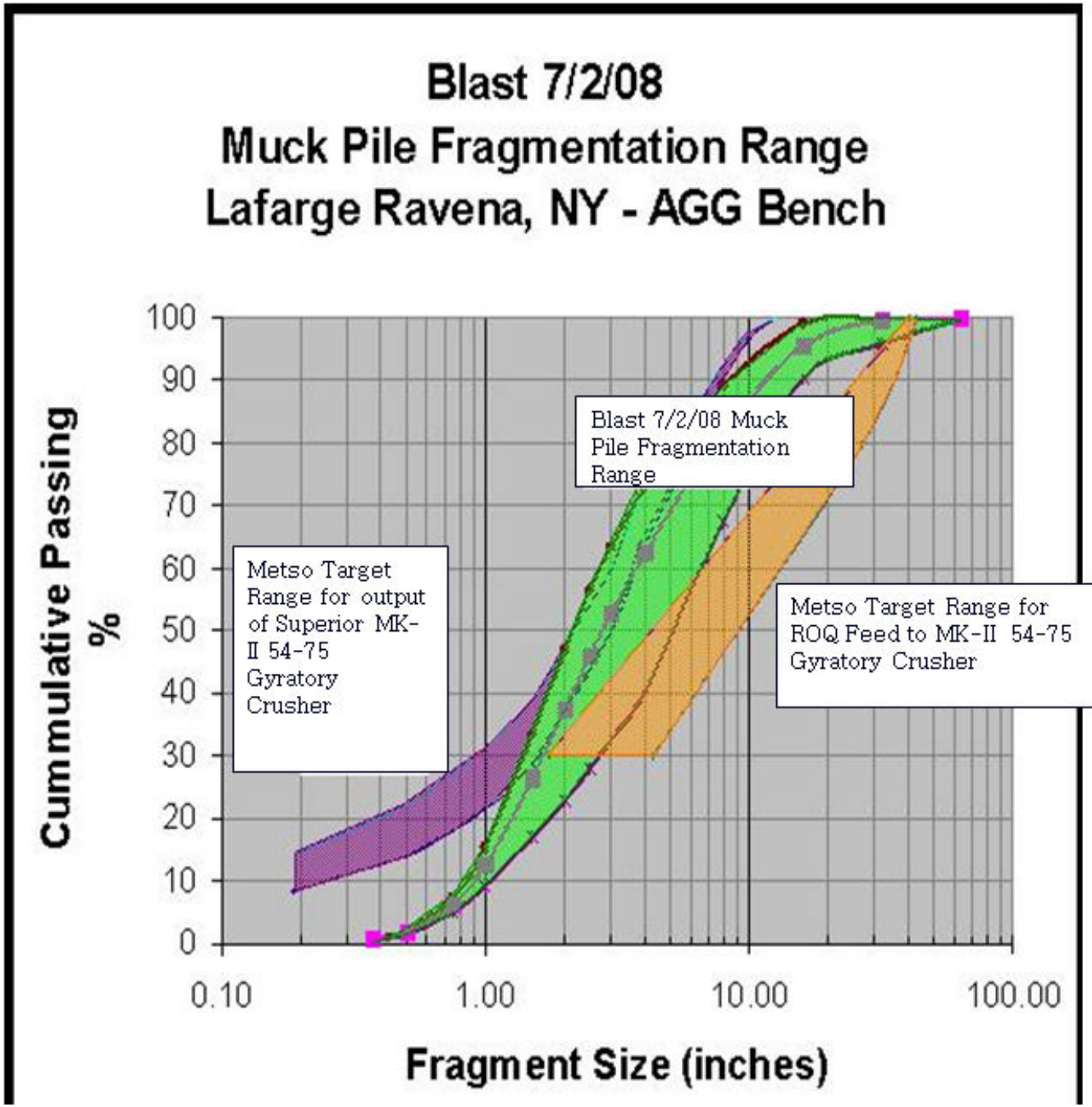

QUARRY ACADEMY

Operations Process Improvement
Leveraging Drill & Blast

“Blast to -1 inch Product” *

* From Drill to Pre-wash Product.

QUARRY ACADEMY

Operations Process Improvement
Project Outcomes

- Impressive cost savings and increases in plant tonnage throughput within the “Blast to 1 inch minus” process of the Holt Summit Value Map were realized over the validation phase of the project.
- Drilling and Blasting cost increased by 28%.
- Waste was reduced by 19%.

QUARRY ACADEMY

Operations Process Improvement
Project Outcomes

- **The standard cost model for the "Blast to 1 inch minus" process of the Holt Summit value map showed that over the total process:**
  - ✓ **There was a 10% to 27% increase in crusher plant capacity**
    - ✓ **From baseline of 373 TPH to an average of 475 TPH = +102 TPH shift in capacity.**
  - ✓ **There was a 7% to 31% reduction in net total cost per ton with scalping**
  - ✓ **Even when scalping was not utilized an 8.8% reduction in the net cost per ton was achieved.**

QUARRY ACADEMY

Summary

- Drill and Blast can be used to produce fragmentation that will enable the mechanical crush/screen process to be more efficient and cost effective.
- The optimized distribution of explosive energy as a function of drill hole diameter, accurate location, explosive product, and timing is the key to leveraging the chemical crushing result.
- Case work to date indicates that implementation of drill and blast programs that leverage chemical crushing of stone, yield process stream cost savings that are better measured in dollars per ton than in cents per ton.

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