301 – Blast and Drill
A Single Value Chain Process

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QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

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Drill & Blast
Taking The Rock Apart

Wanted List

- Easy to dig and load (shape and throw)
- Control or influence particle size distribution
- Fast easy economical accurate drilling
- Efficient uniform breakage
- Consistent excavation to elevation design grades and boundaries
- Full regulatory compliance
- “0” harm

Activity Target:
Right Energy
Right Place
Right Time

Fragmentation

Loadability

Control/Safety

Not Wanted List

- No fly rock
- No noise
- No vibration
- No oversize
- No undersize
- No ragged loose walls
- No over or under excavation by blasting
- No missfires or unused blasting agents
- No Floor Humps

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Drilling & Blasting – A Latent* Opportunity

- **The market environment in the nation and global theater of operations has shifted to a degree and extent that we find ourselves working in a *new paradigm.***
- **For many mine and quarry operations especially, *traditional* belt tightening is *not enough* to meet financial and operational objectives.**
- **The effect that activities and costs of individual unit operations have up and down the *total process stream* must be considered so that on combination minimum cost and *maximum profits* are realized.**
- **Drilling & Blasting can be a significant contributor to *reducing costs* down stream in the aggregate producer's value chain. Planning and maintaining control of the entire drill and blast process is imperative. *Consistency and reproducibility* are key drivers for performance.**

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Latent = *Present or potential but not evident or active

What is really going on here?

If I want more $$ savings $$ at the end of the process chain, what should I be looking at to get it?

What will I have to do differently to get the desired result?

"Optimal Zone"
PLANNING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
Unit Operations as Process
+
Optimum
Total Cost
-
-
$
$
DRILLING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
BLASTING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
LOADING HAULING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
CRUSHING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
SCREENING AND SIZING
REDUCING YOUR ENERGY FOOTPRINT THROUGH
Value Chain Management
Chemical Crushing
Transport
Mechanical Crushing

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?
- What offers the greatest operational flexibility?
- 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?

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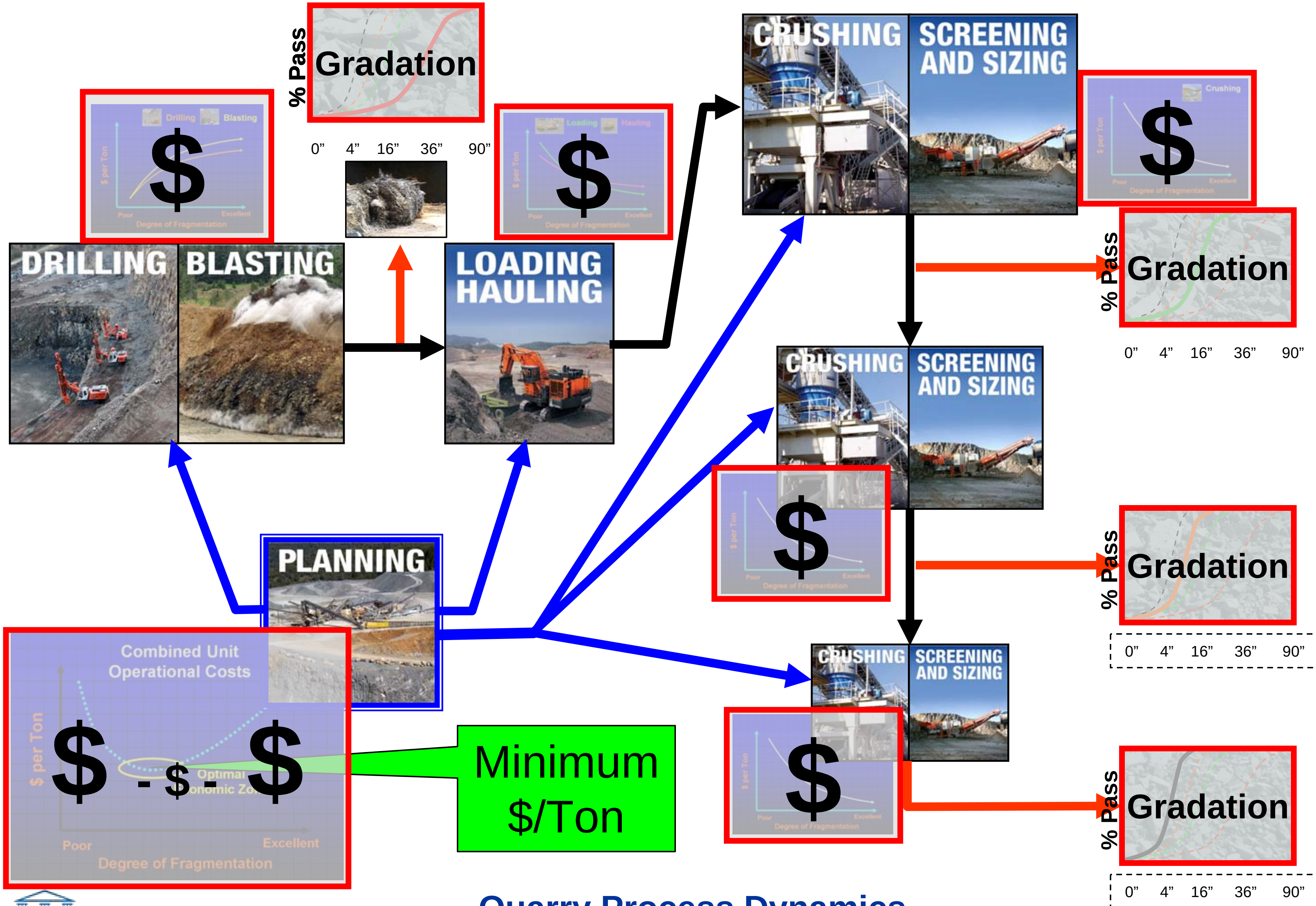

Quarry Process Dynamics

Drill and Blast
Necessary Evil or God Send?

- **When explosives are detonated they release the chemical energy stored within them.**
- ***<u>All</u>* that energy will go somewhere:**
  - ✓ **into fragmenting the rock**
  - ✓ **into moving and heaving the rock**
  - ✓ **into ground vibration**
  - ✓ **into air overpressure and heat**
- **Without the drill hole, explosives would not be a practical tool for the quarry industry.**
- **In a *<u>correctly designed blast</u>*, the drill hole puts the right quantity of explosive energy in the right place!**

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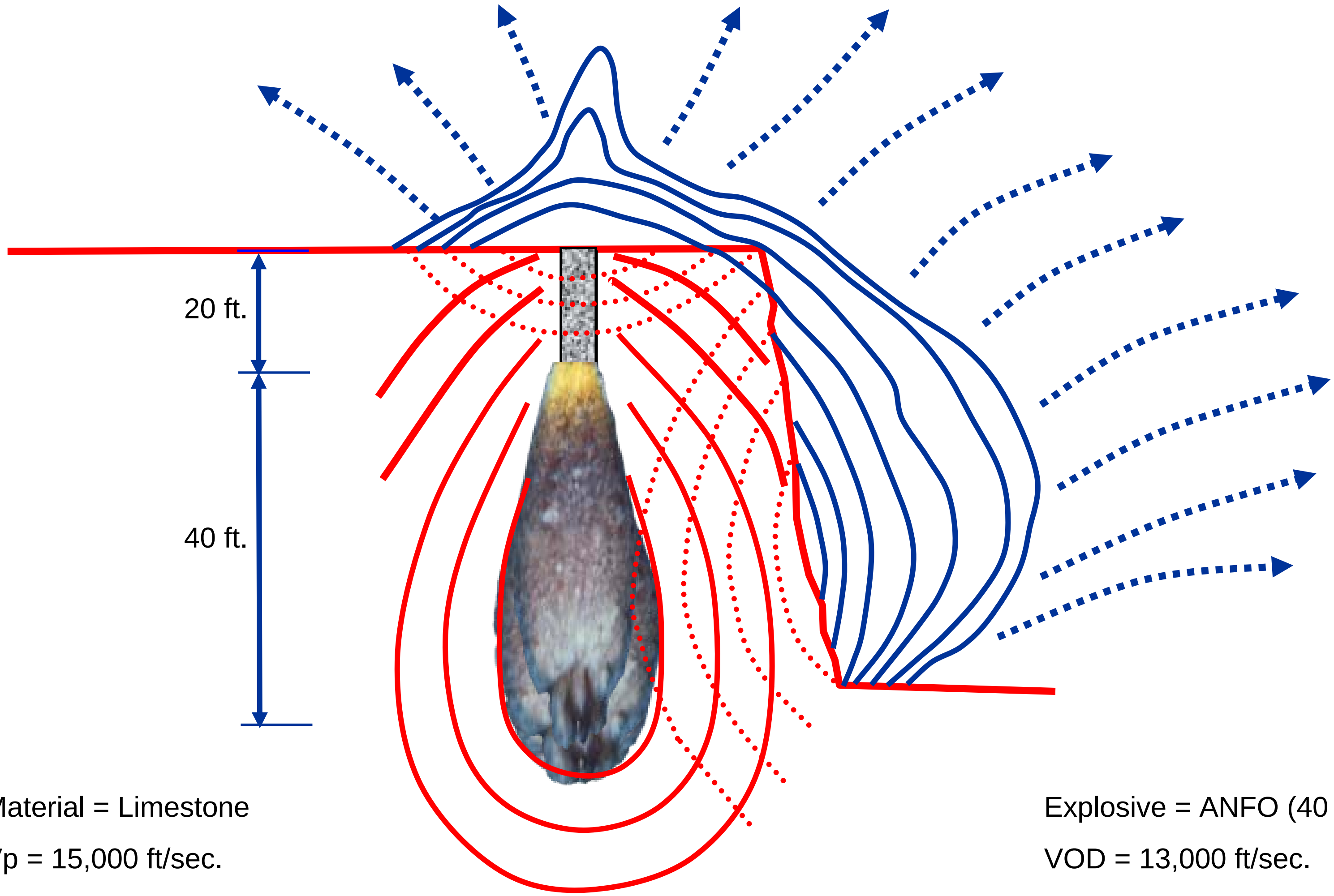
Blast Dynamics

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.

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Blast Dynamics
Stress / Pressure Dissipation

H_d = Hole Diameter

UCS = Unconfined compressive Strength of rock

Step 1= Pulverized Zone

Blast hole diameter expanded

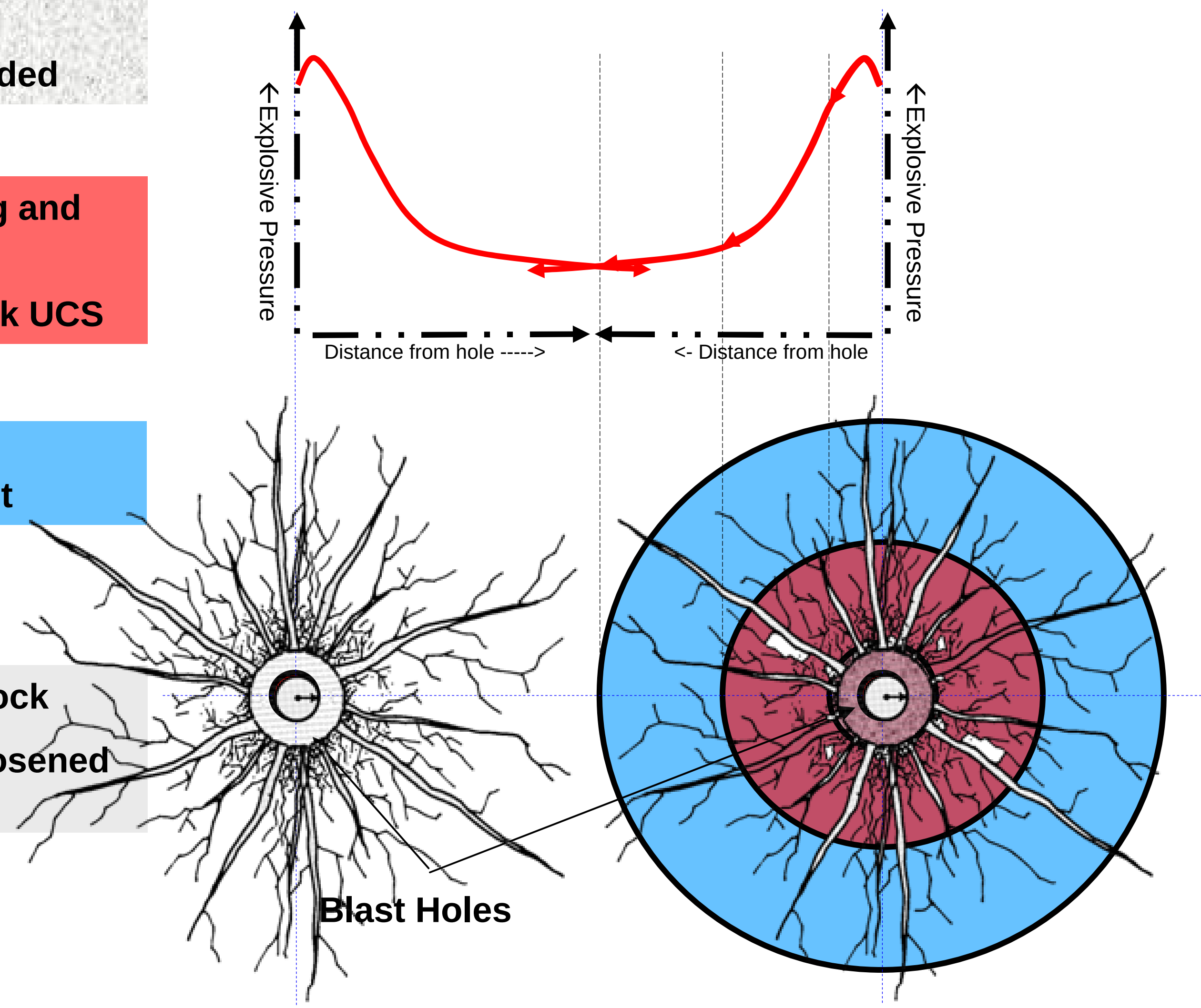
Step 2 = Intense fracturing and cleaving of minerals

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



Imagine

- **Having a crusher**
  - ✓ **Capable of crushing in excess of 1,100 tons/hr of rock reserves.**
  - ✓ **That was portable and could be 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, is internally powered.**
  - ✓ **Has design flexibility to meet changing rock conditions and to produce different rock size gradations.**
  - ✓ **And whose only drawback is that without controls it can have noise, dust and vibration issues.**

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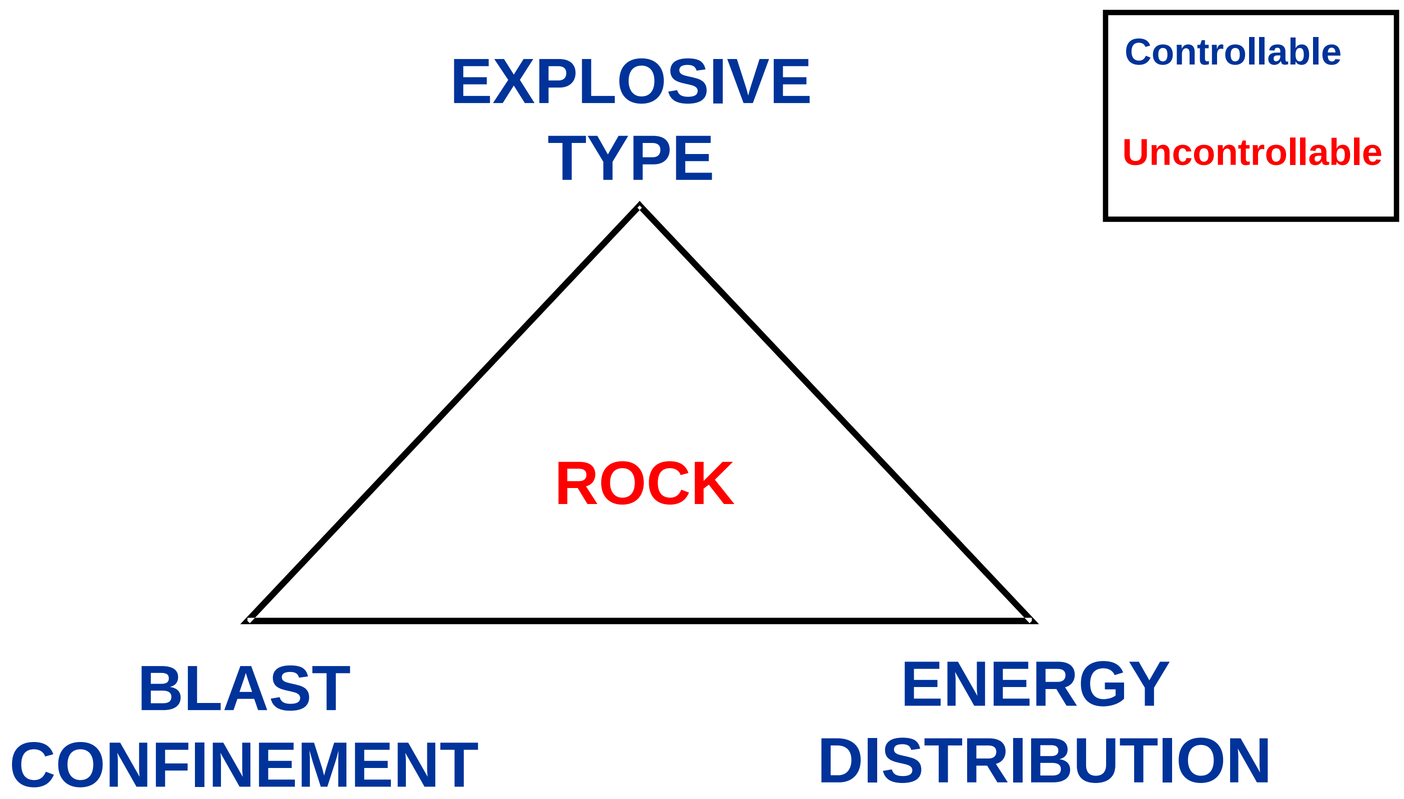
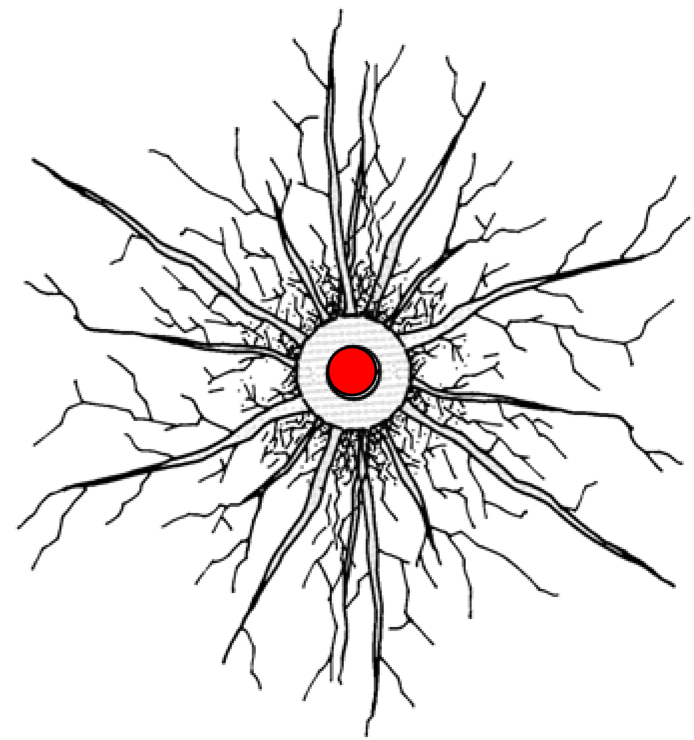
Chemical Crusher - Key Design Factors



Explosive Type

A controllable factor in the 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**
  - ✓ **Form**
    - **Package**
    - **Bulk**
      - **Dry Blend / Free Flowing**
      - **Wet Blend / Augerable**
      - **Pumpable Blend**



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Blast Confinement
A controllable factor in the building the Chemical Crusher

- **Design to confine the explosive energy so that it can do 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 individual holes.**

Optimizing Explosive Energy Confinement

- **Explosive Energy must be confined long enough after detonation to establish fractures and displace the rock mass.**
  - ✓ **Design timing to provide adequate relief without loss of confinement.**
- **Control paths of least resistance for explosive energy**
  - ✓ **Load according to geology and face conditions**
  - ✓ **Use adequate and proper stemming materials**
- **Use multiple primers to insure explosive column performance.**
- **Accurately layout and drill the blast pattern**
- **Remember:**
  - ✓ **over confinement = excessive ground vibration**
  - ✓ **under confinement = excessive air blast**

Energy Distribution

A controllable factor in the 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**

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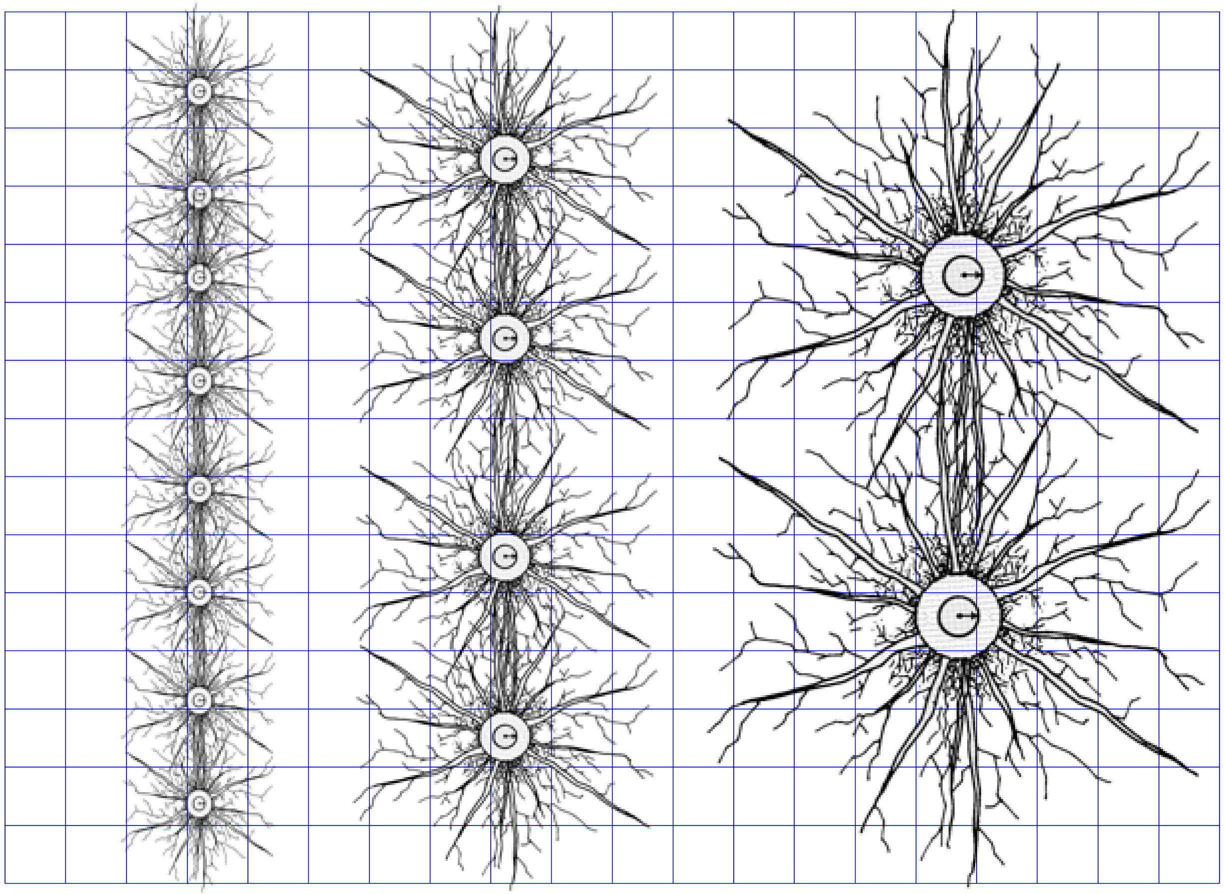
Optimizing Explosive Energy Distribution

- **Important to maintain as even a distribution of energy from top to bottom of the bench as possible.**
- **Increased distribution reduces overall rock fragment size.**
- **Decreased distribution increases overall rock fragment size.**
- **Even distribution achieves more uniform fragmentation.**
- **Widely spaced jointed rock masses require reduced patterns.**

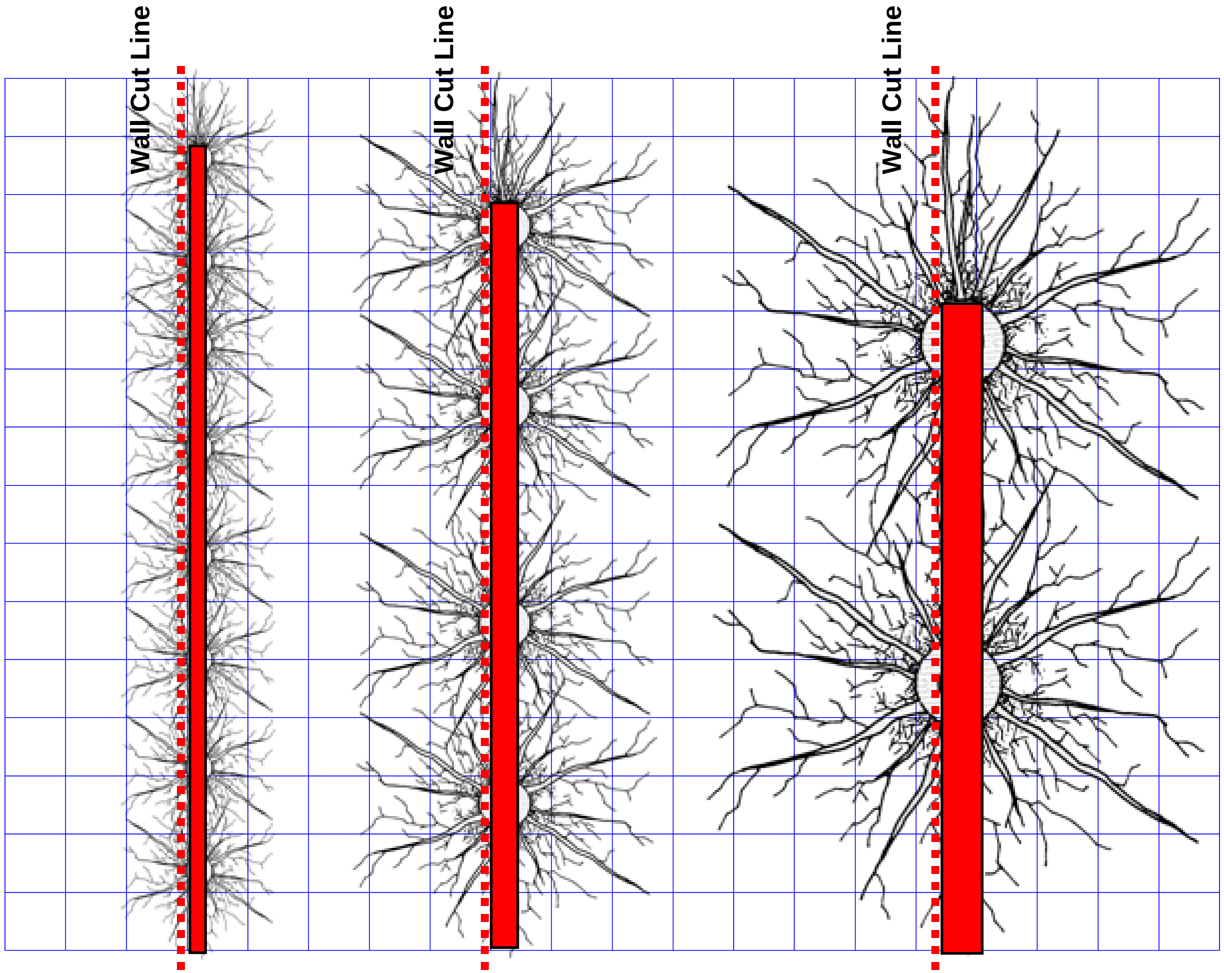
Effect of Hole Diameter on Fragmentation
Small to Large

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



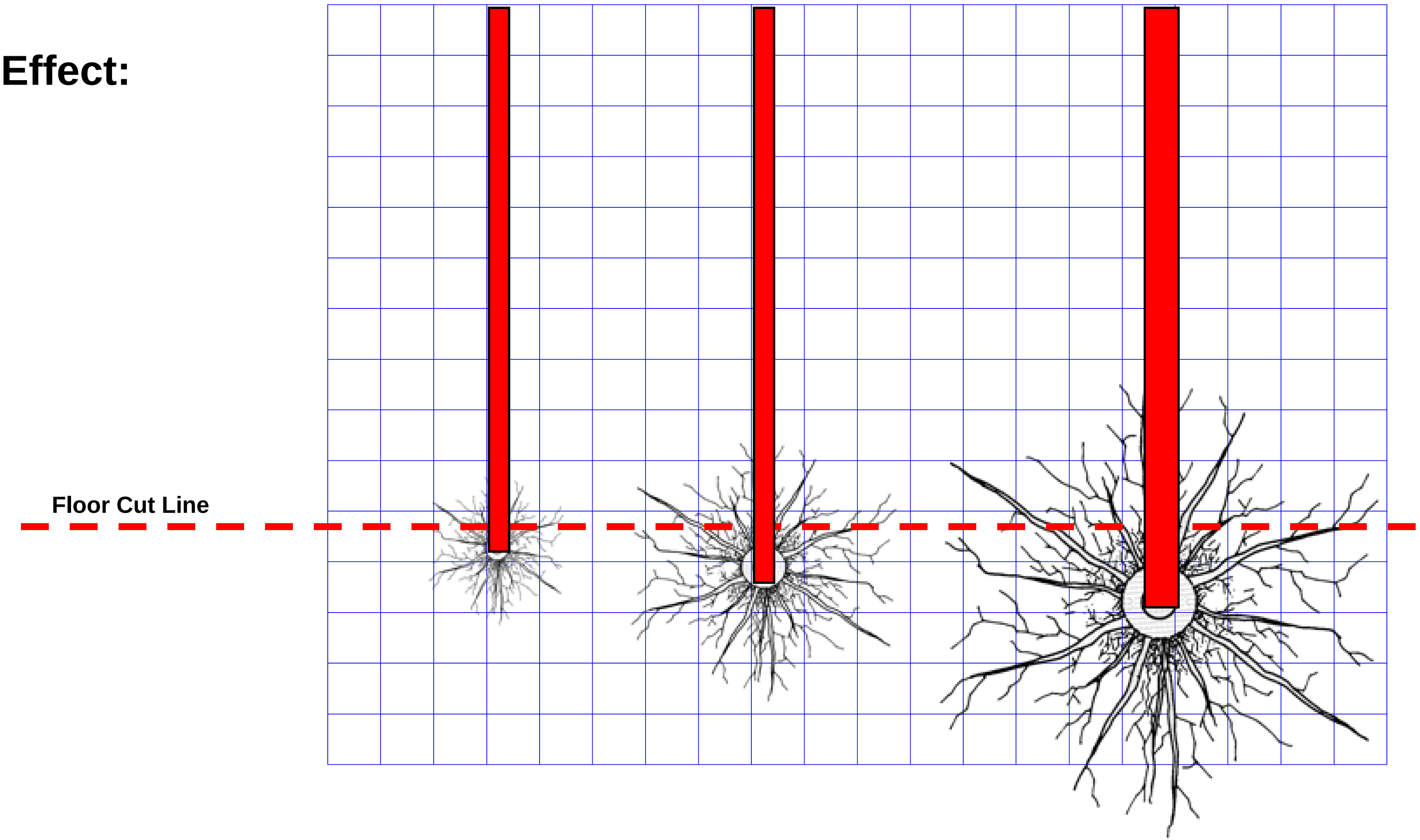
Effect of Hole Diameter on Fragmentation
Small to Large

Wall Effect:



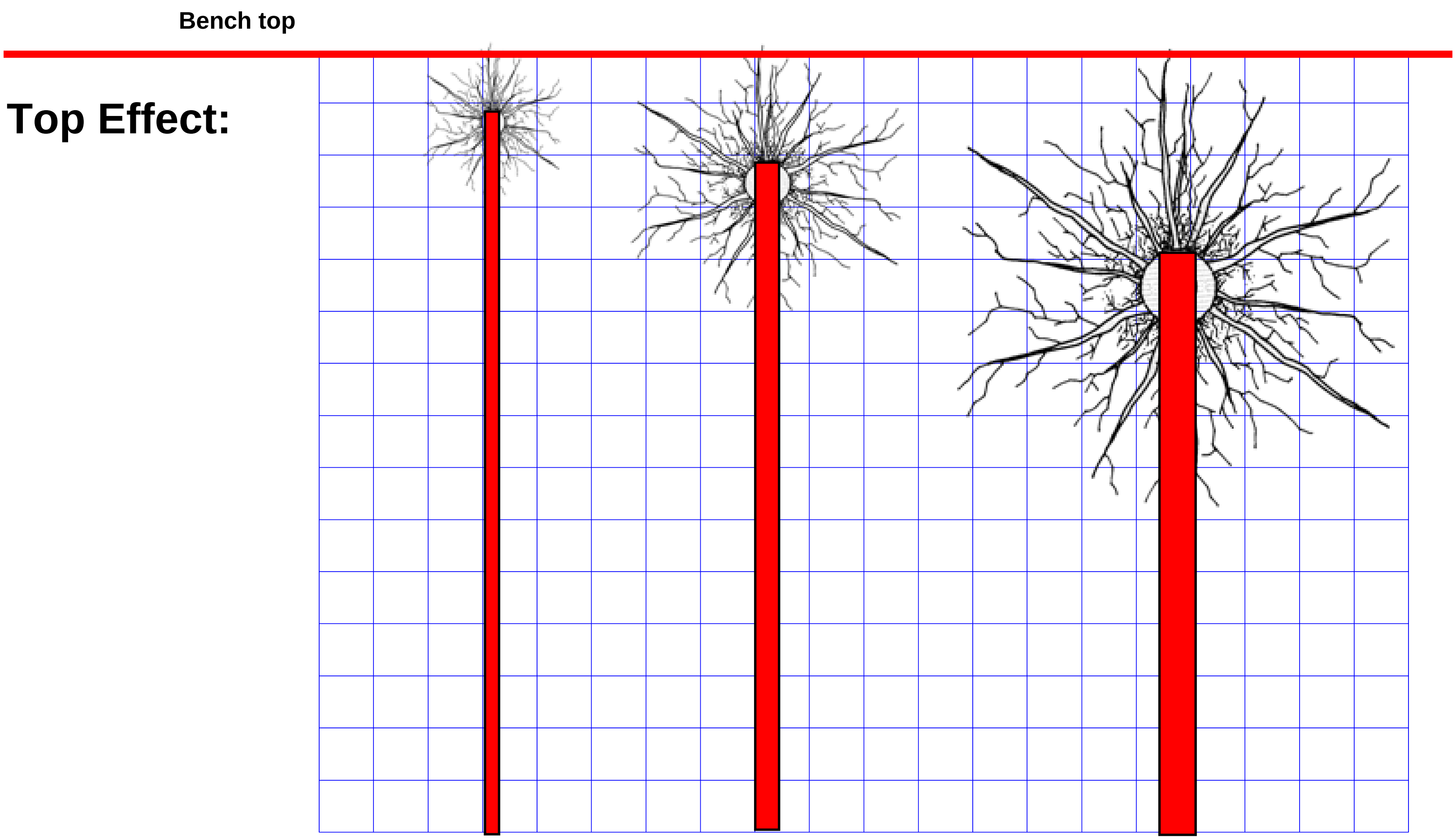
Effect of Hole Diameter on Fragmentation
Small to Large

Floor Effect:

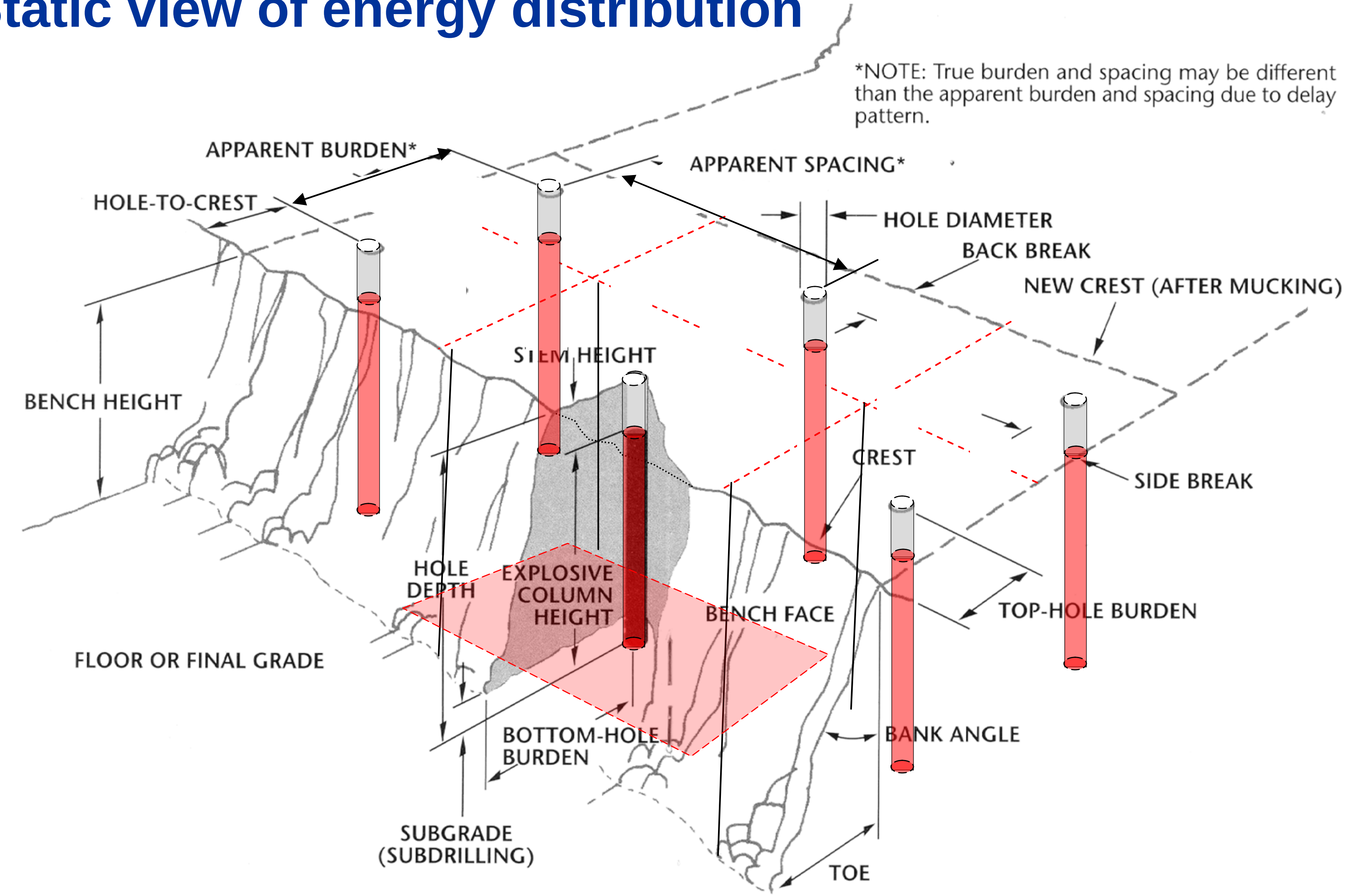


Effect of Hole Diameter on Fragmentation
Small to Large

Bench Top Effect:



Building the Chemical Crusher
Static view of energy distribution



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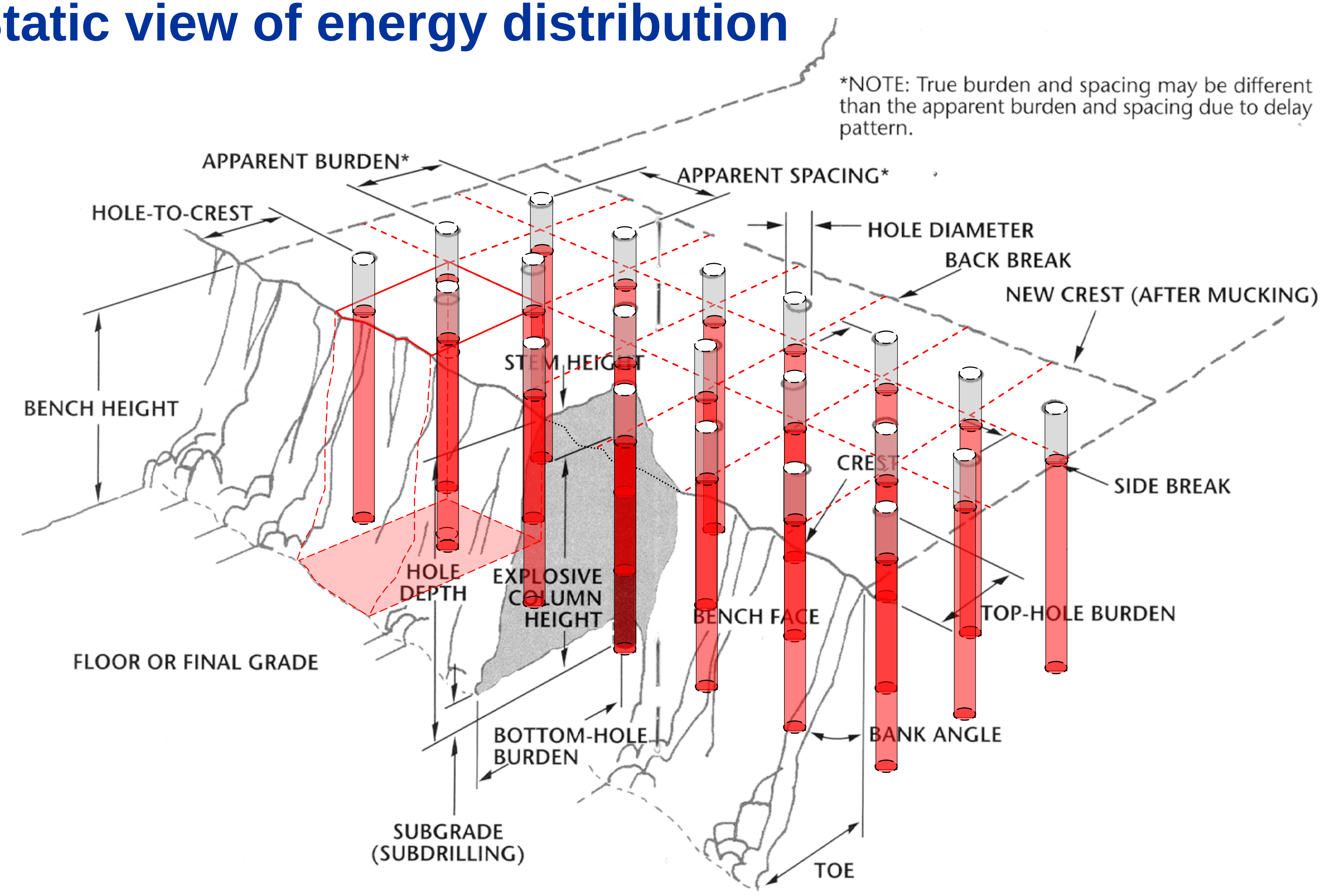
Larger Diameter Holes

Building the Chemical Crusher
Static view of energy distribution



Smaller Diameter Holes

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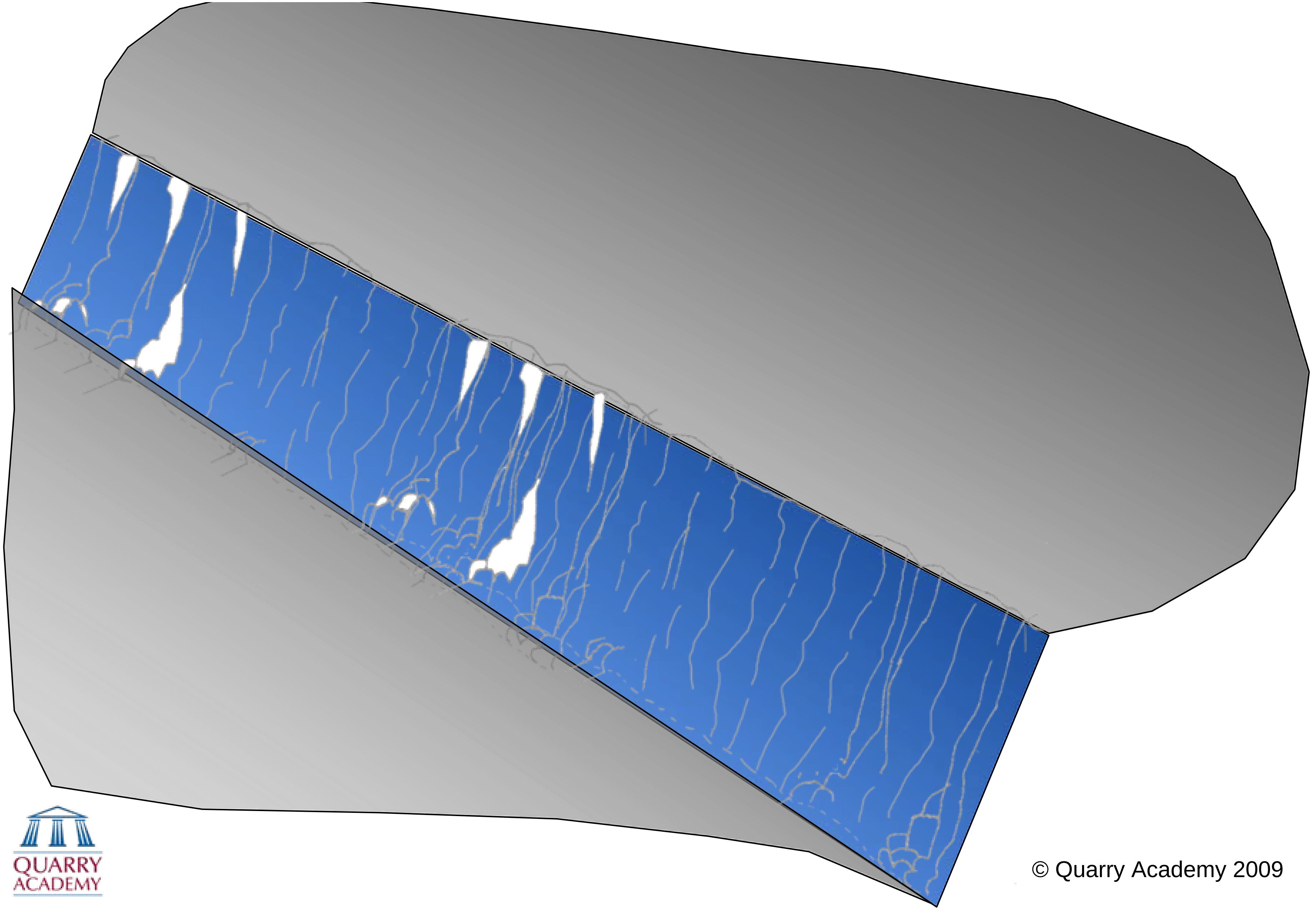
Target Work Zone for Chemical Crusher



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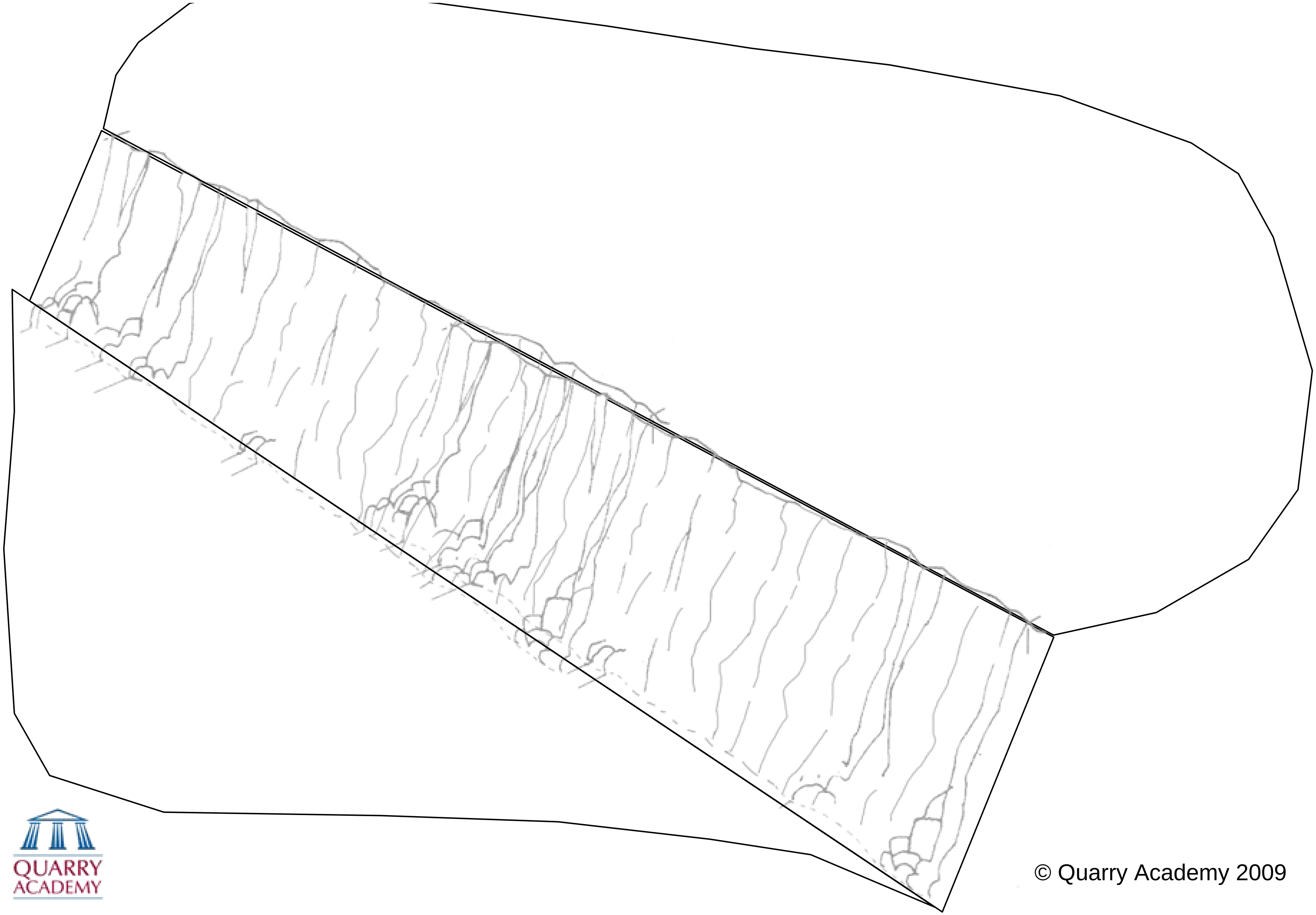
Target Work Zone for Chemical Crusher



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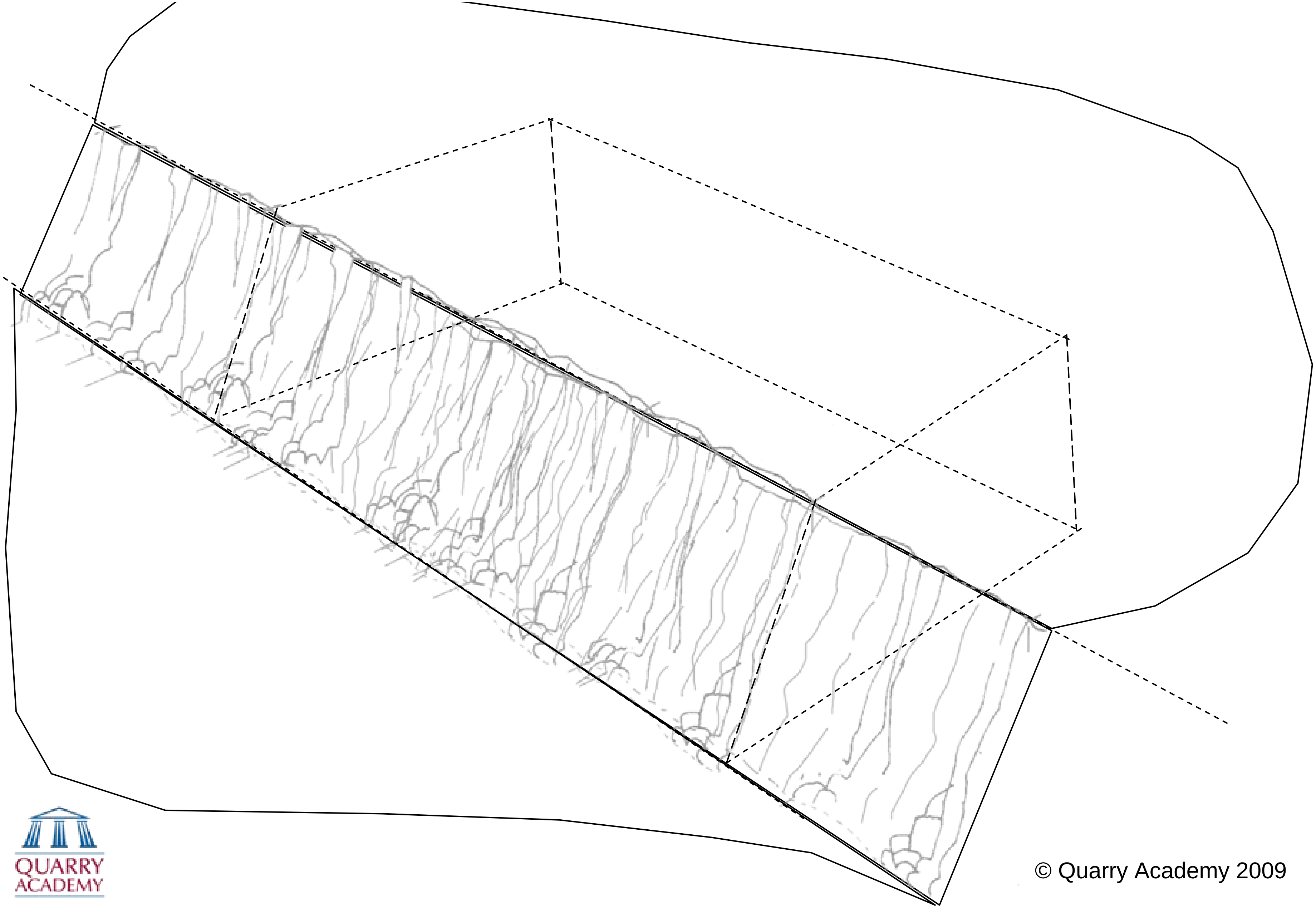

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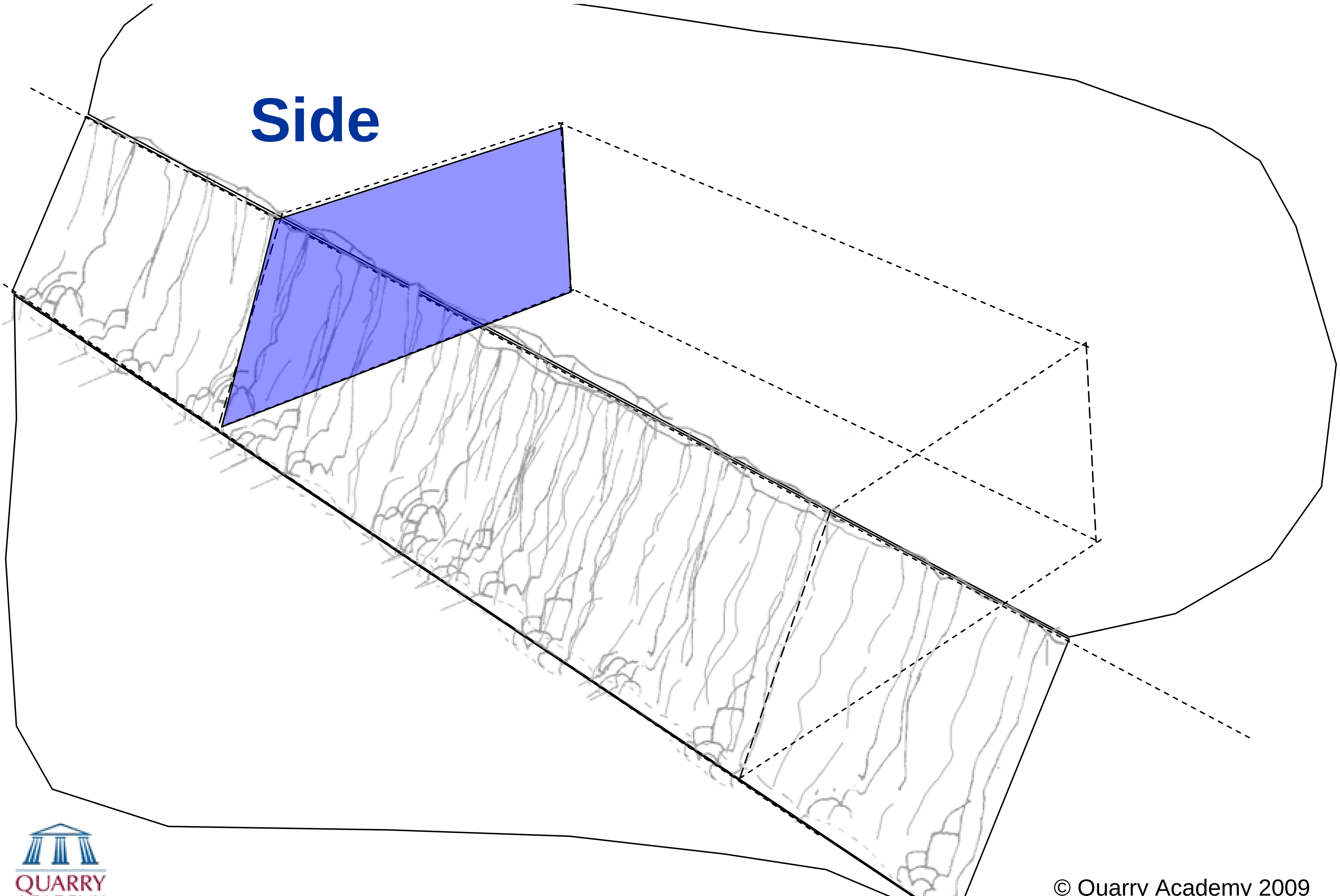
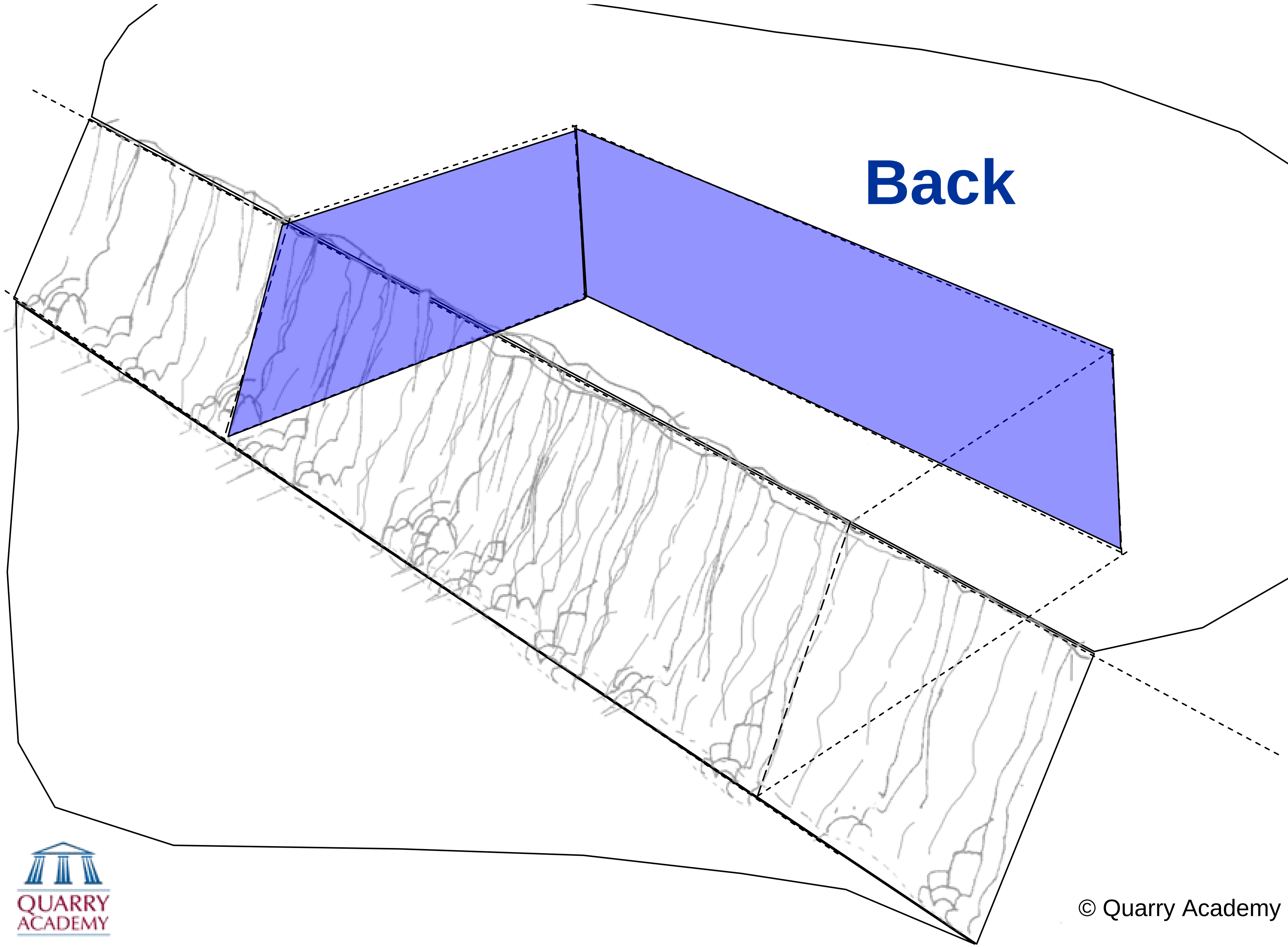


Target Work Zone for Chemical Crusher



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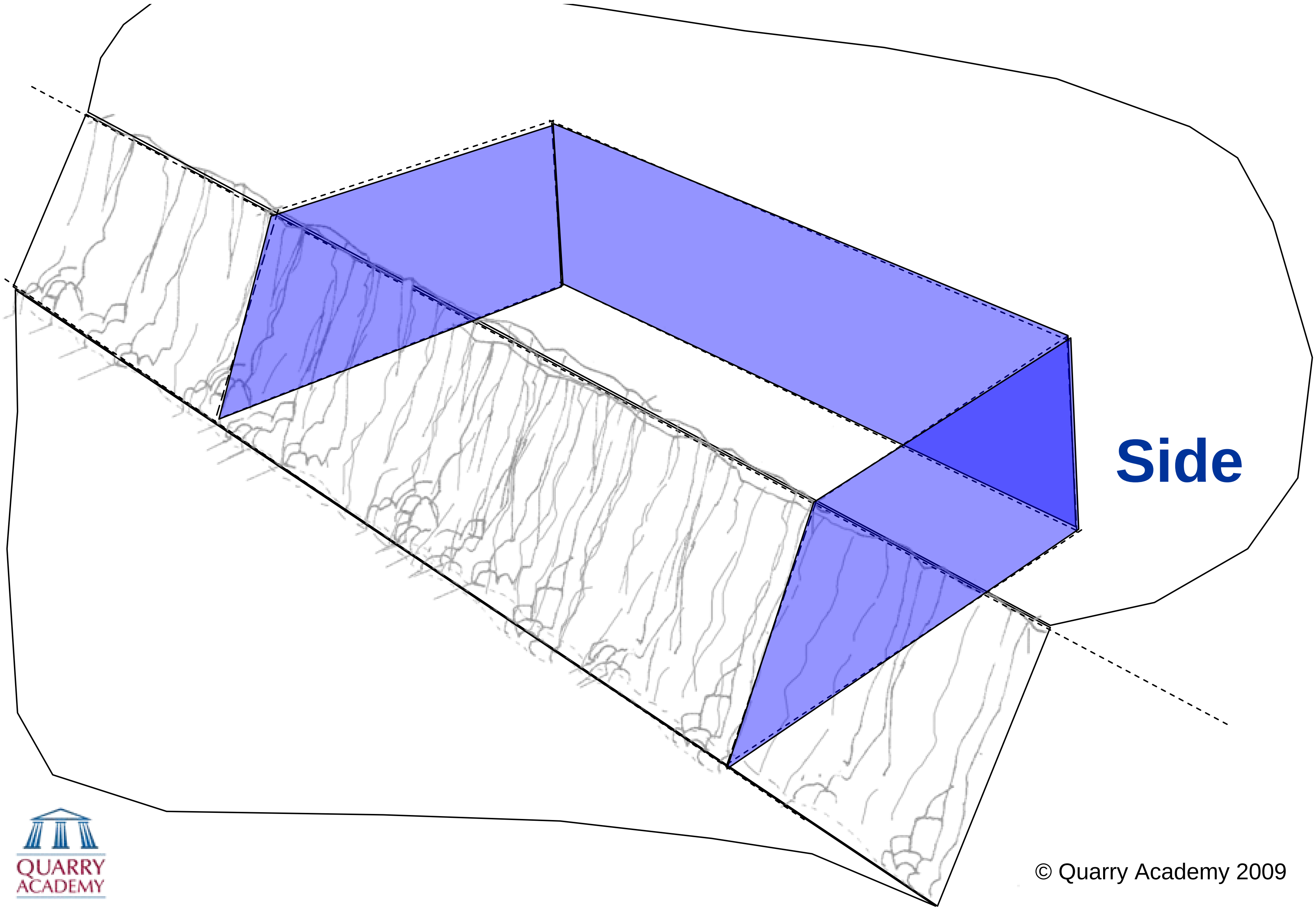
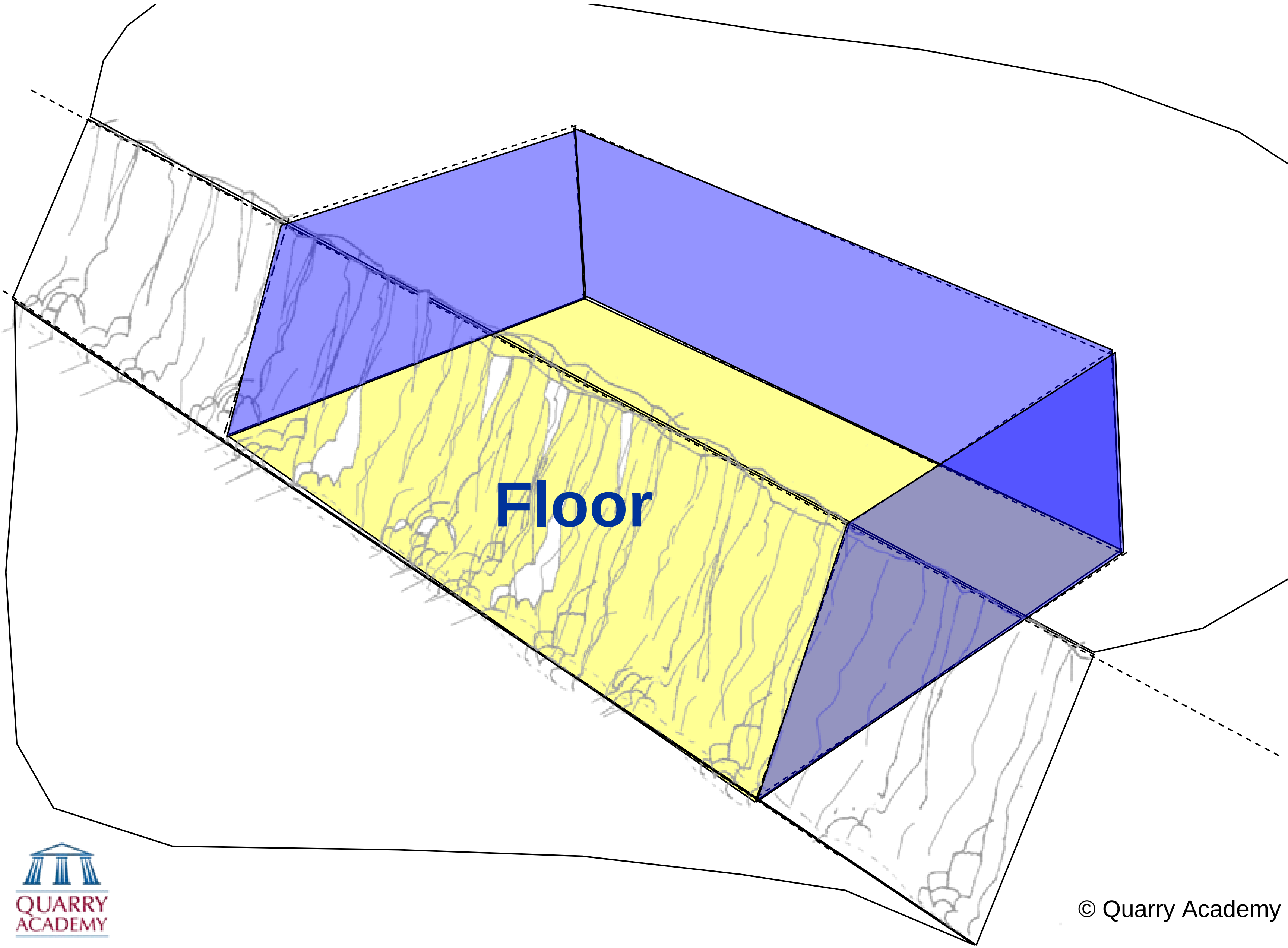


Target Work Zone for Chemical Crusher



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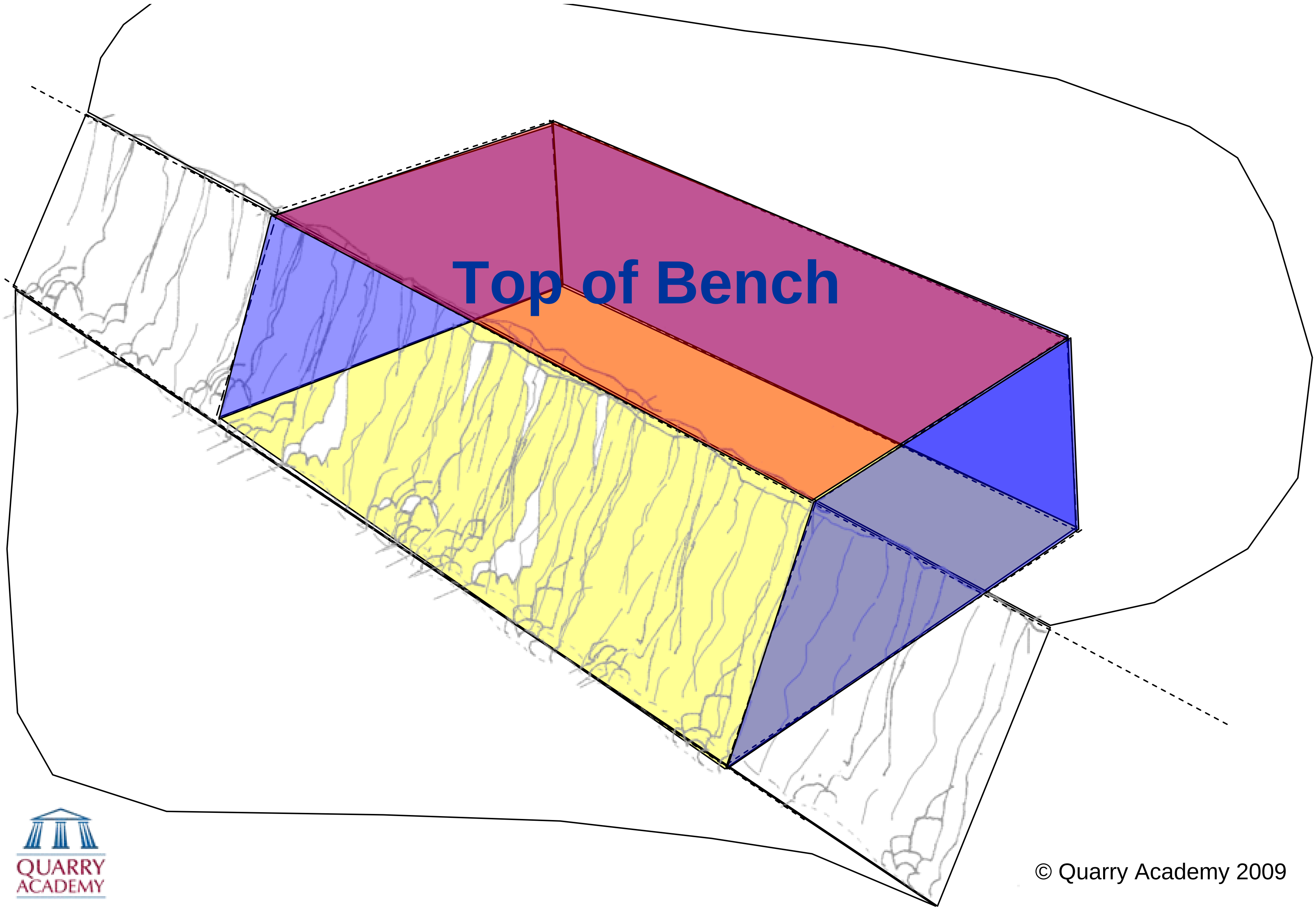
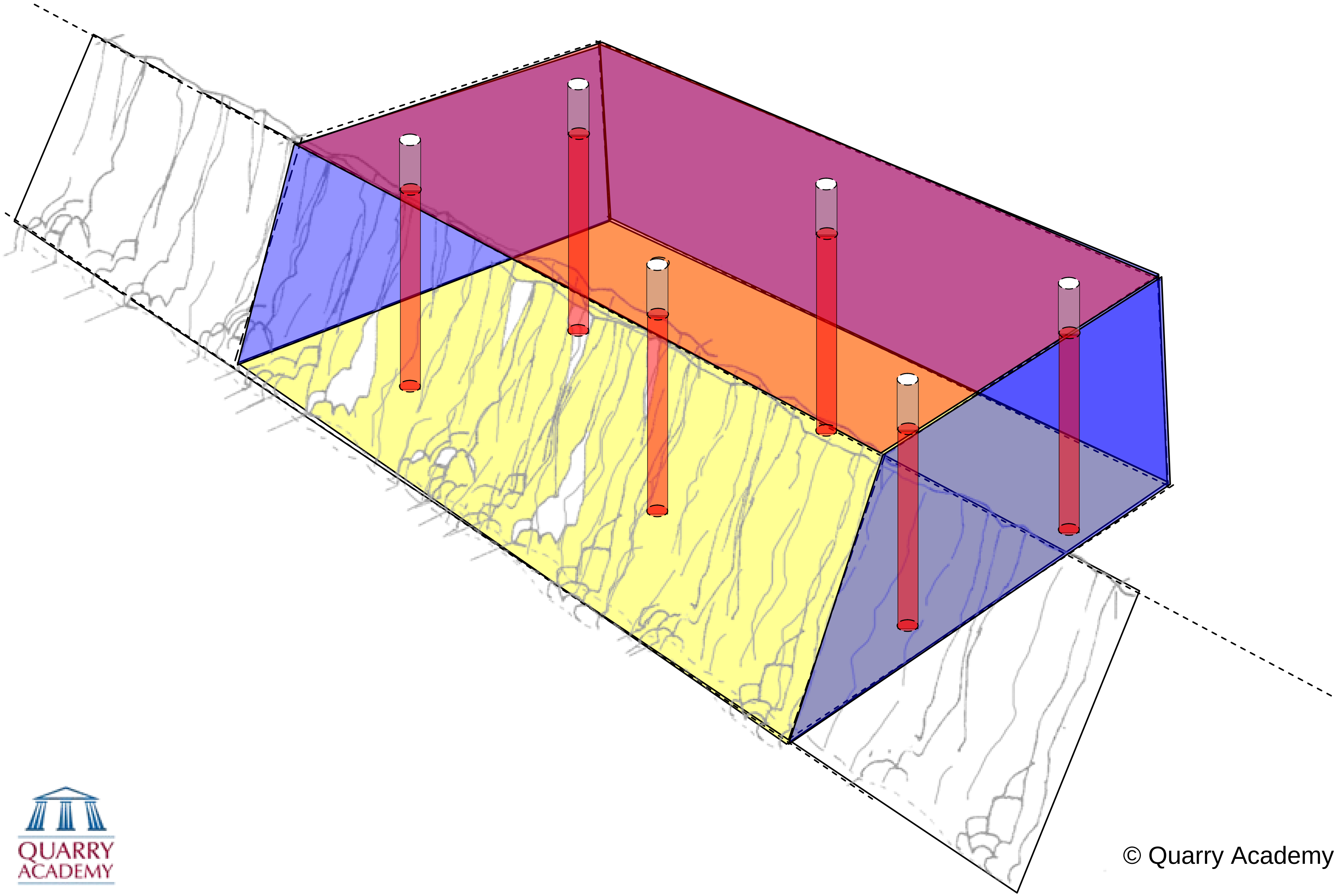
Target Work Zone for Chemical Crusher

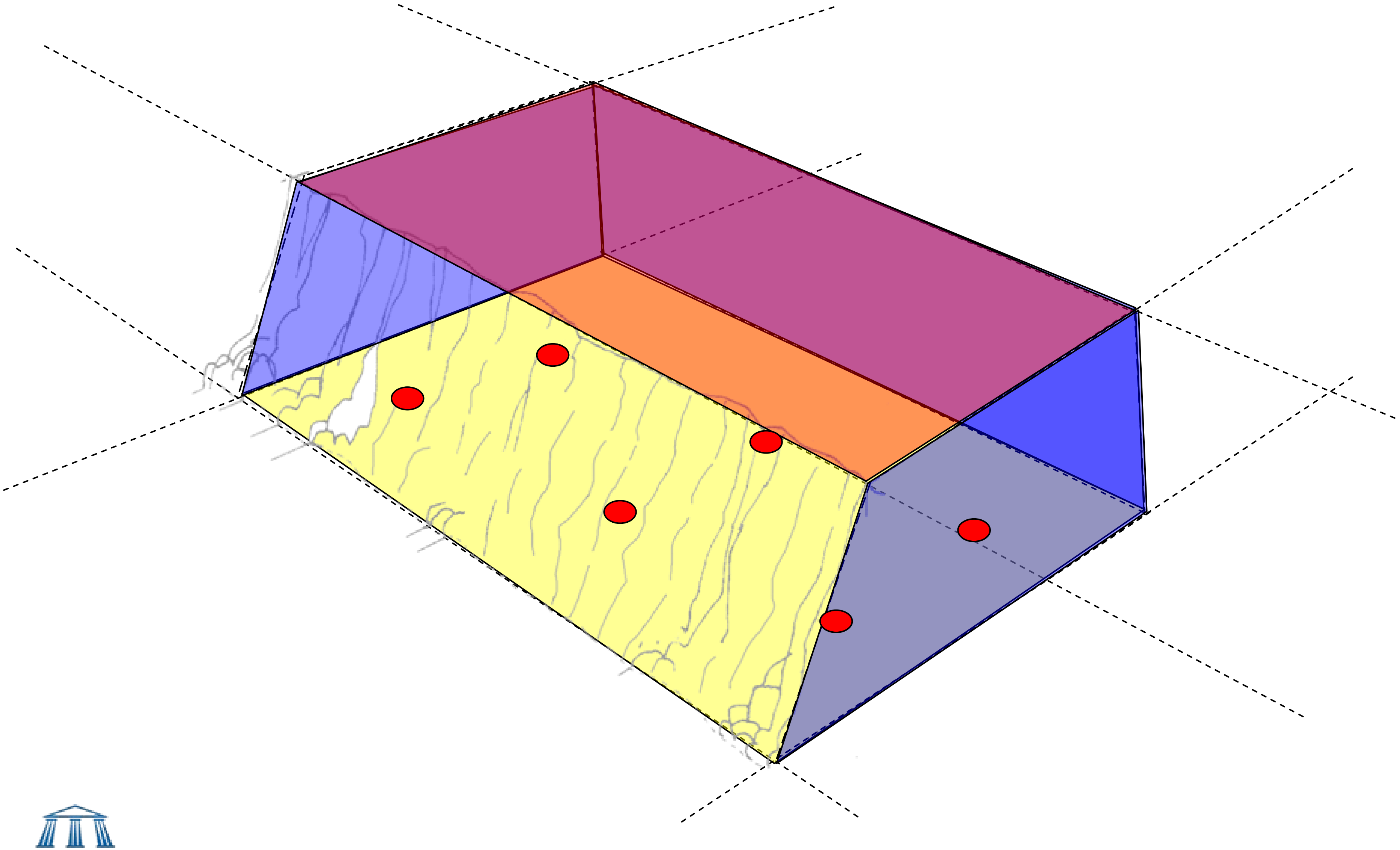


Energy Distribution in Target Work Zone

Larger diameter holes



Target Work Zone for Chemical Crusher
Larger diameter holes



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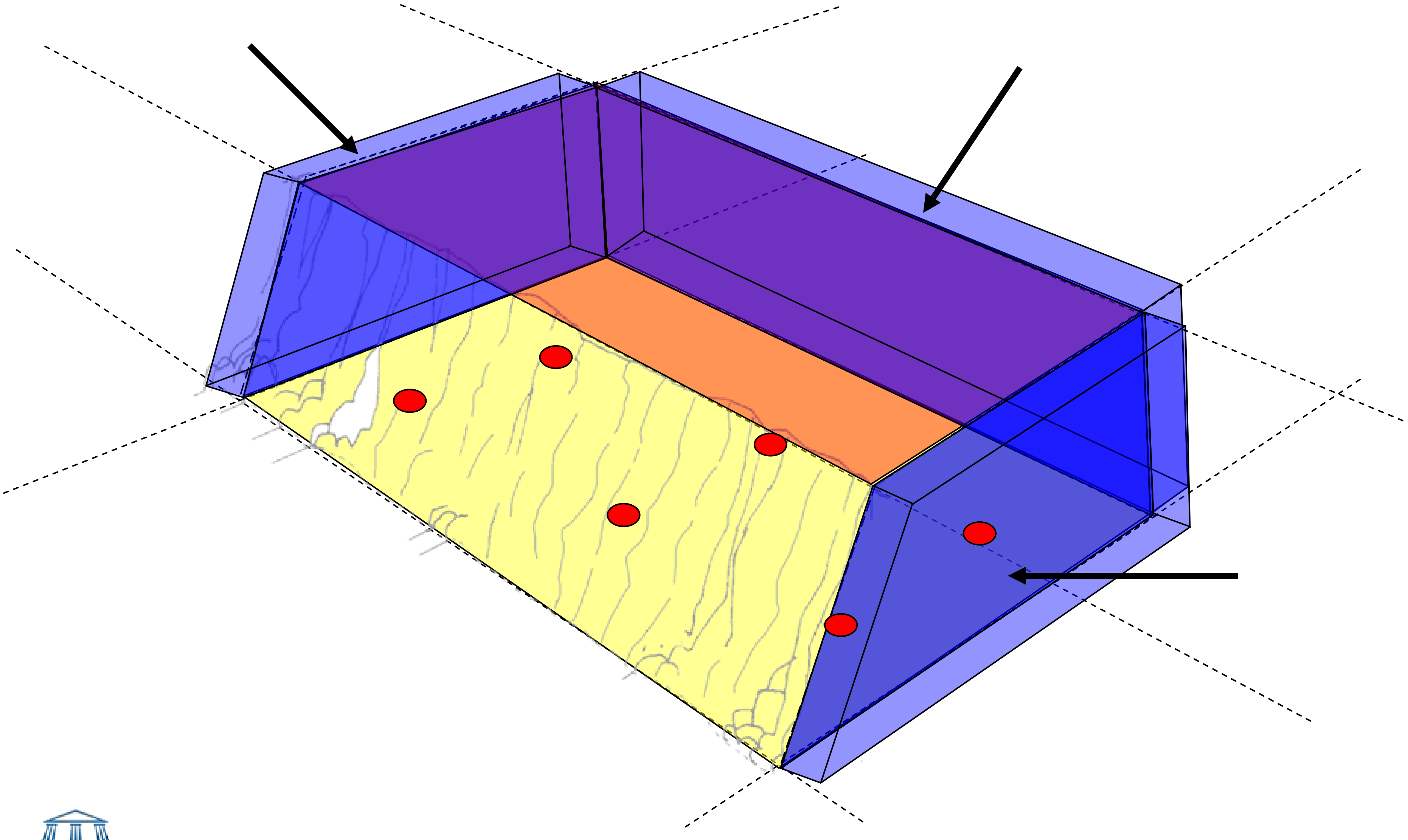
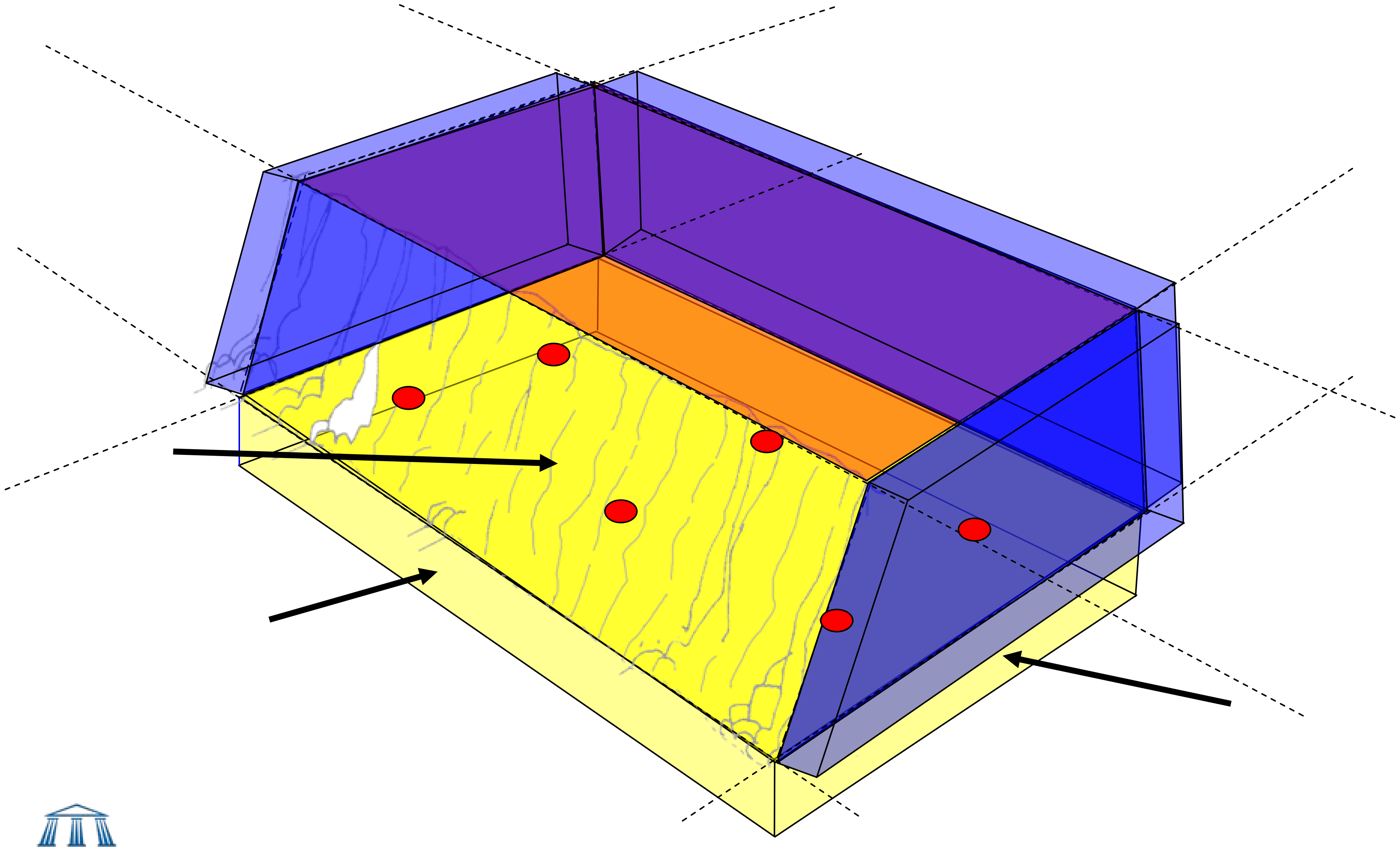
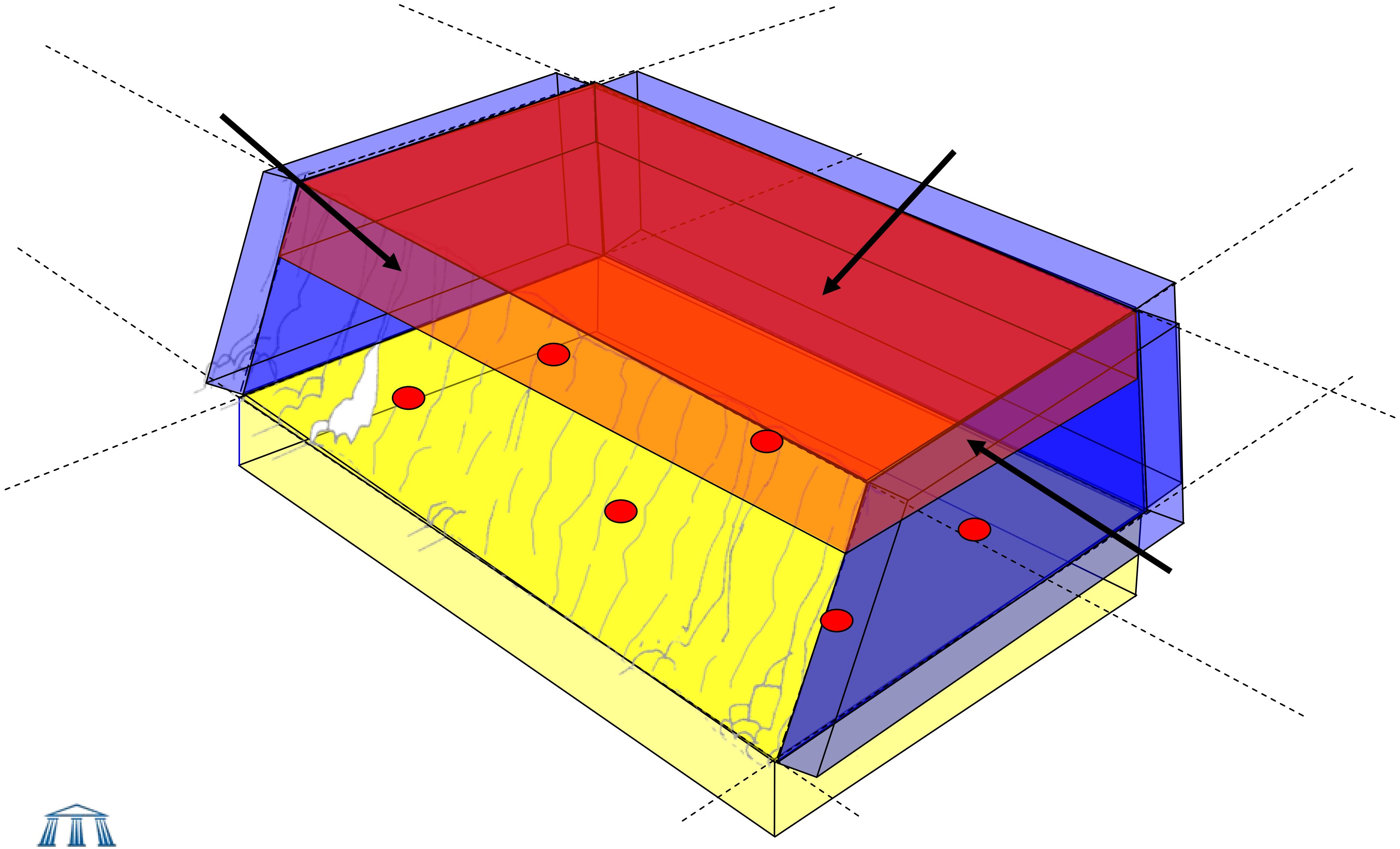
Wall Zone



Sub-Drilling Zone

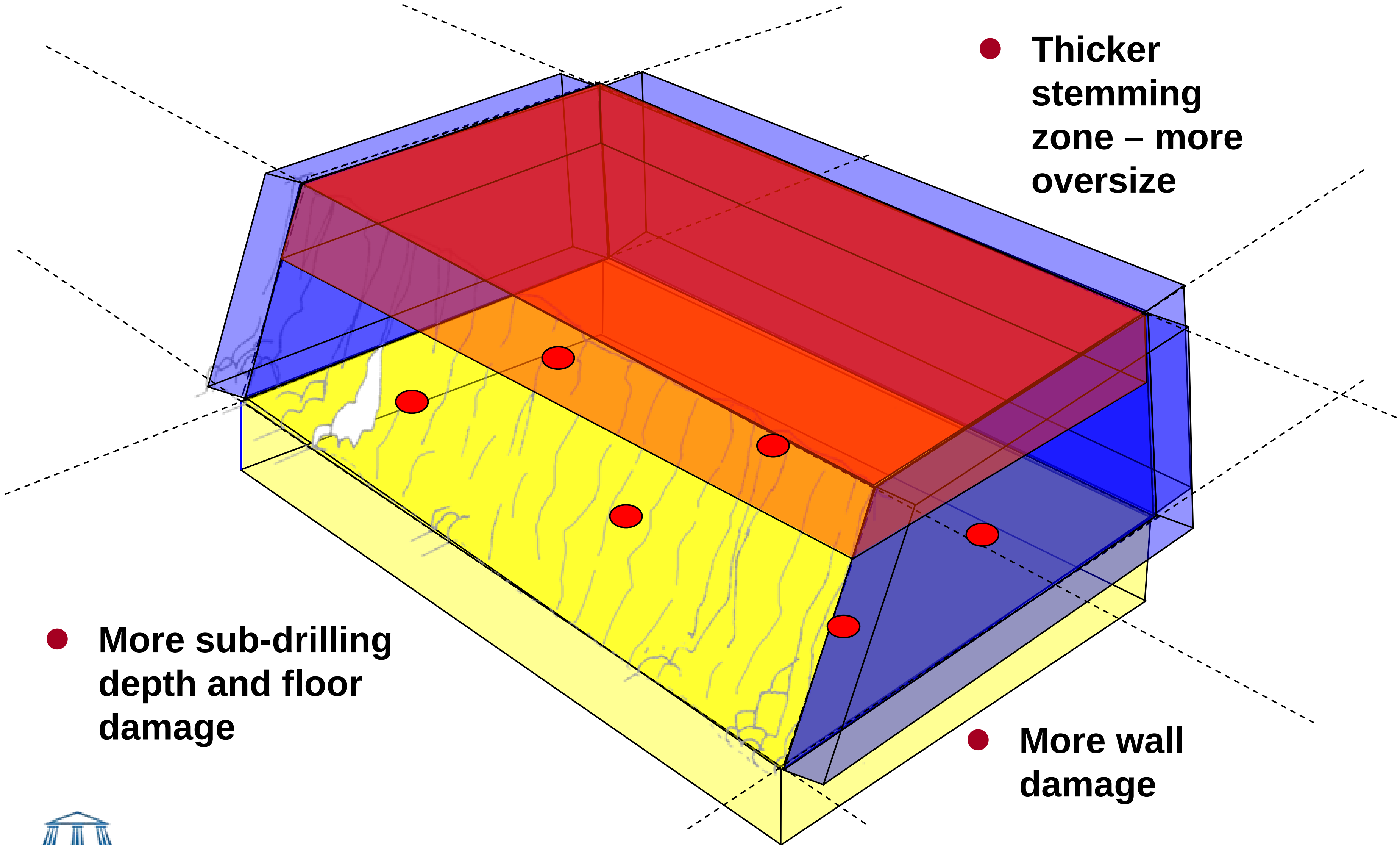


Stemming Zone



Energy Distribution

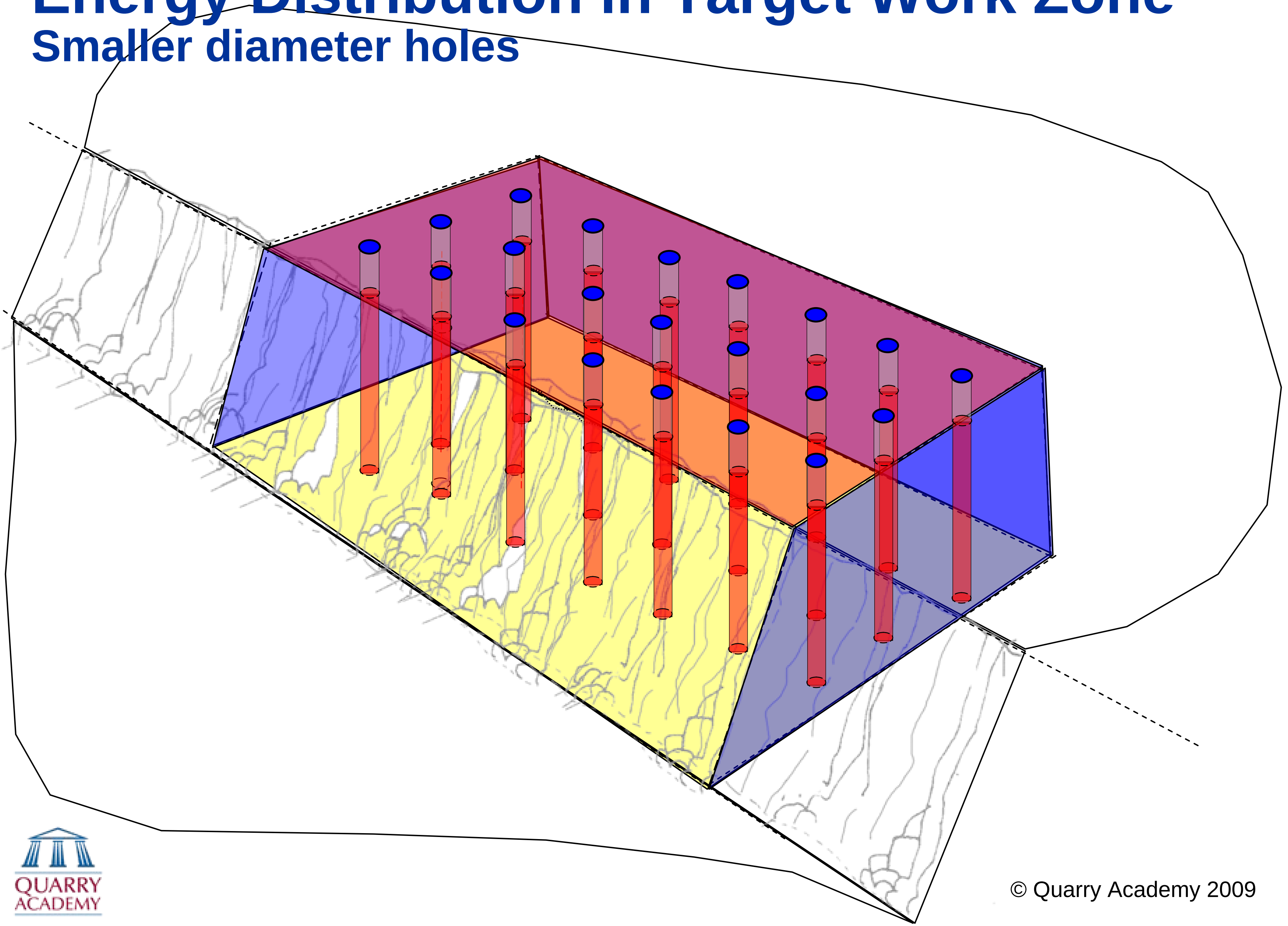
Larger diameter holes reduce % crushed rock



- **Thicker stemming zone – more oversize**
- **More sub-drilling depth and floor damage**
- **More wall damage**

Energy Distribution in Target Work Zone

Smaller diameter holes



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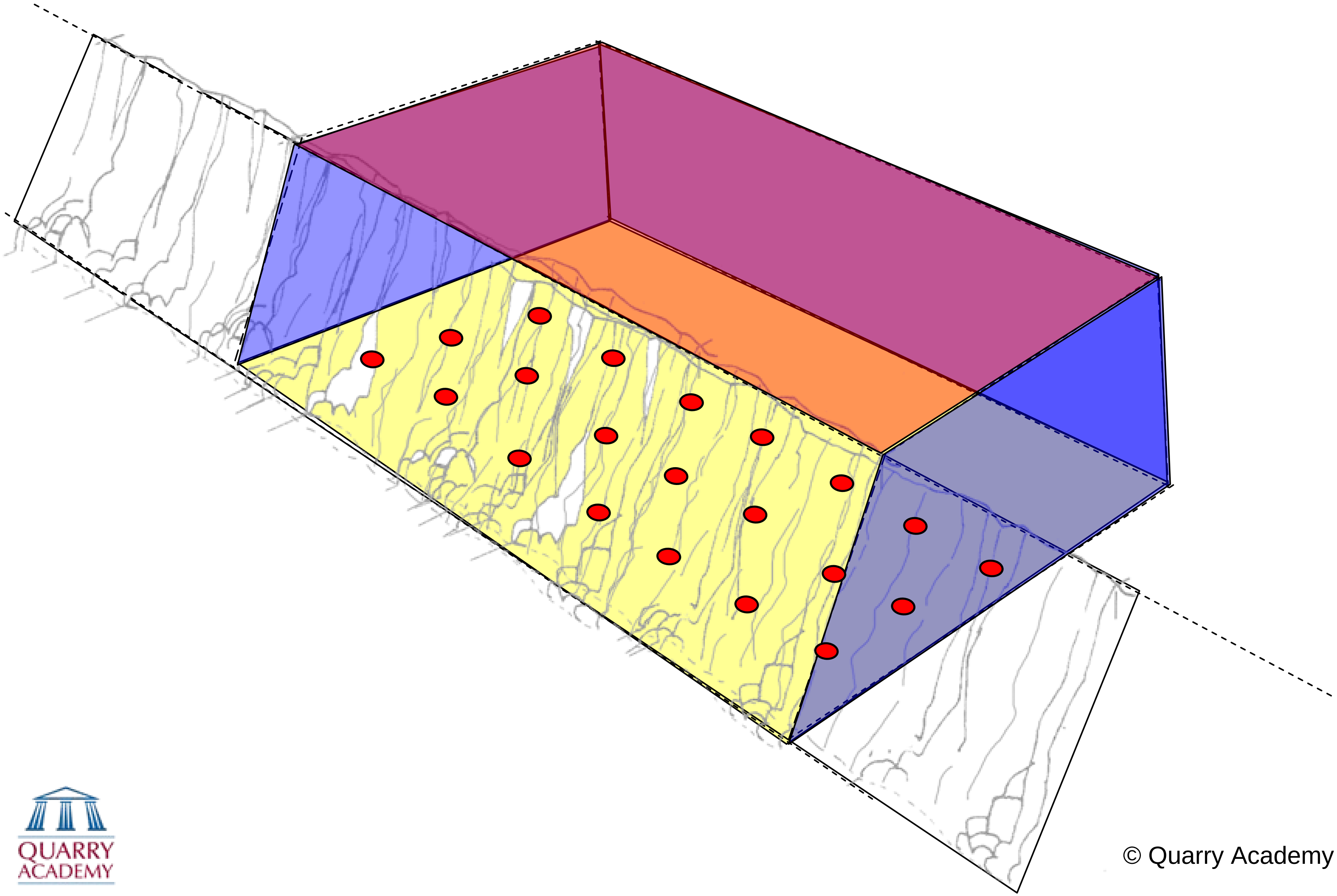
Target Work Zone for Chemical Crusher

Smaller diameter holes



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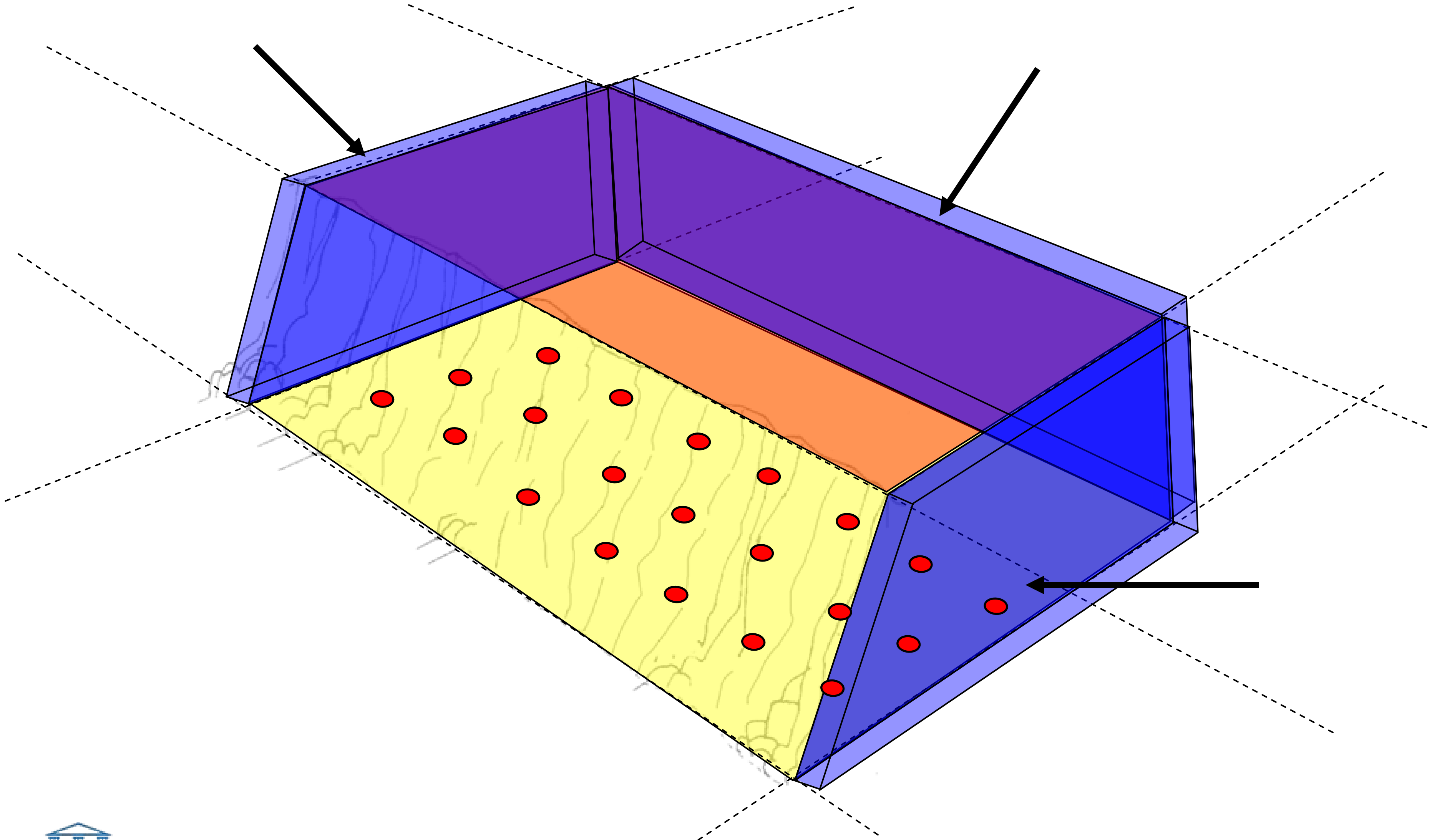
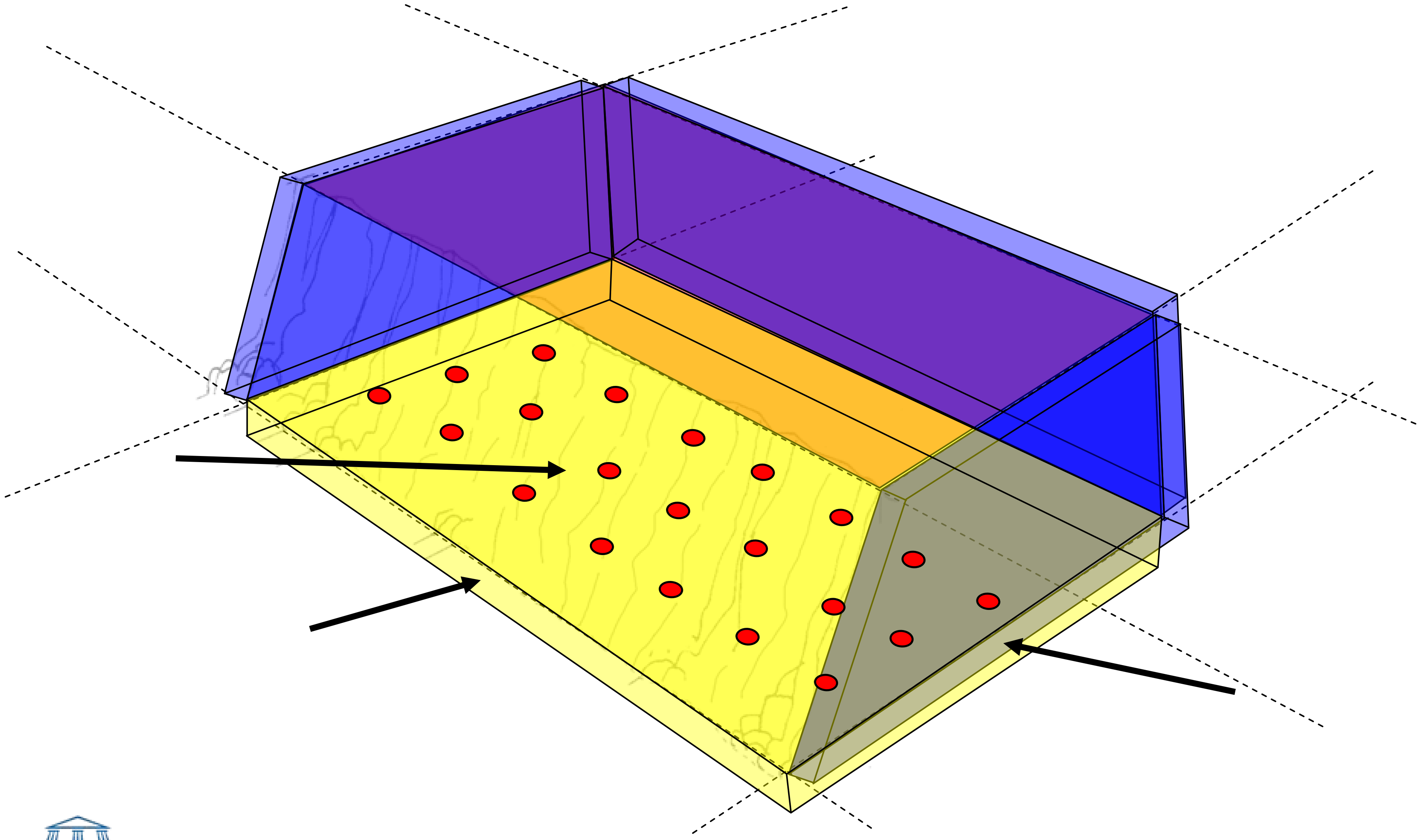
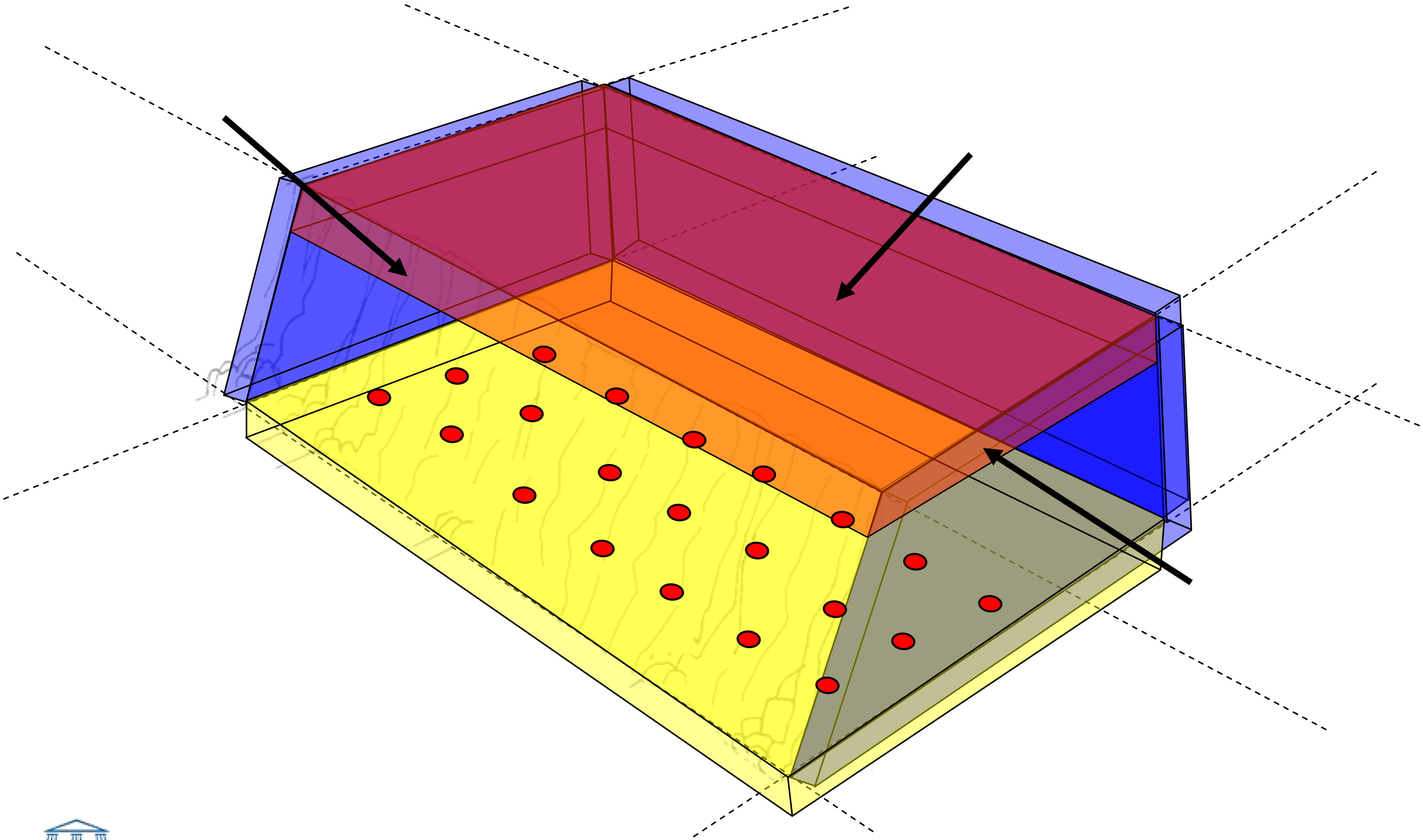
Wall Zone



Sub-Drilling Zone

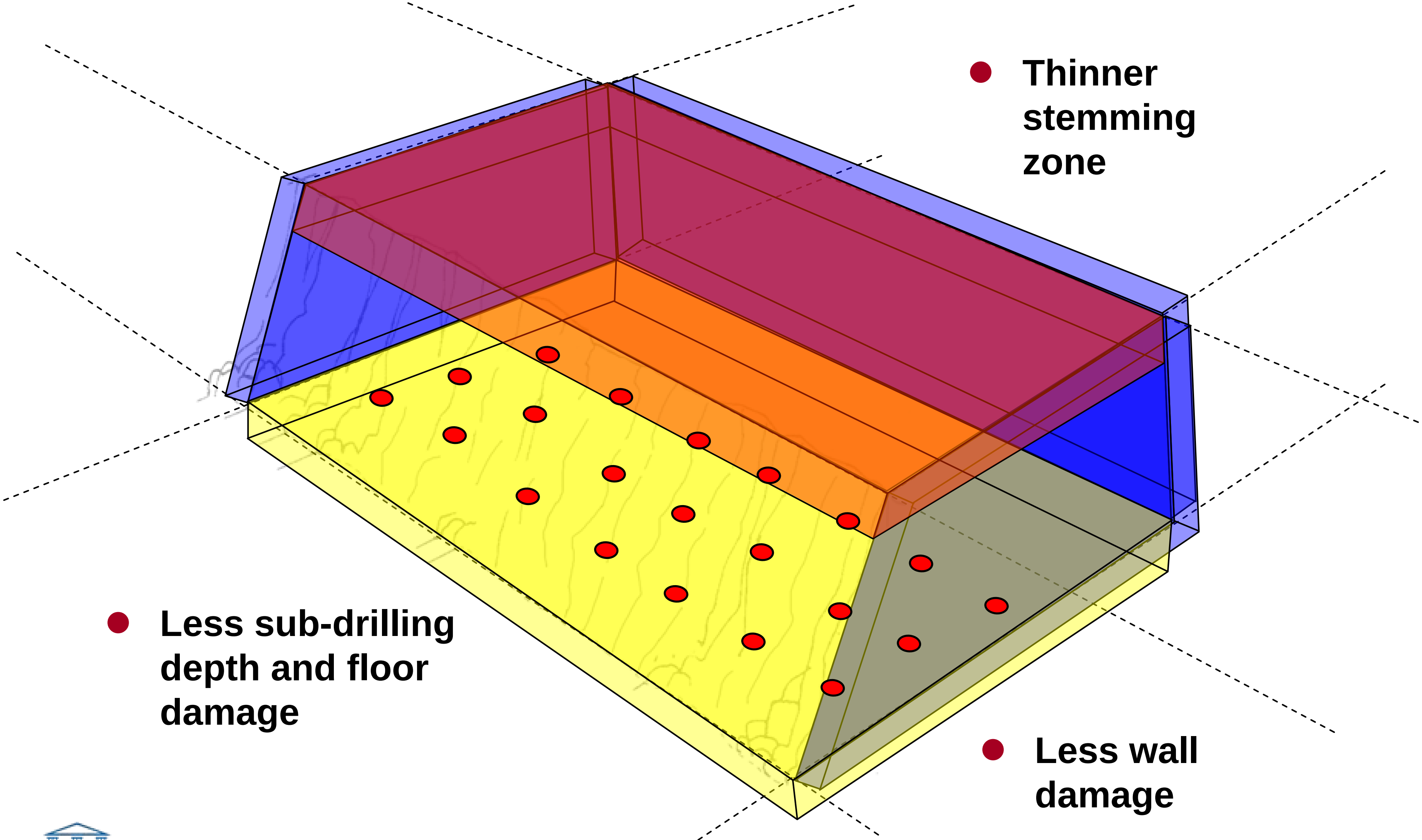


Stemming Zone



Energy Distribution

Smaller diameter holes allow for higher % crushed rock



- Thinner stemming zone
- Less sub-drilling depth and floor damage
- Less wall damage

Operations Process Improvement
Leveraging Drill & Blast

“Blast to -1 inch Product” *

* From Drill to Pre-wash Product.

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 <u>increased</u> by 28%.**
- **Waste was reduced by 19%.**
- **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% <u>increase</u> 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% <u>reduction</u> in net total cost per ton with scalping

Even when scalping was not utilized an 8.8% <u>reduction</u> in the net cost per ton was achieved.

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Drill & Blast Process Improvement
Summary

- **Beyond taking the bench apart, the drill/blast program is the beginning of the crushing process.**
- **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.**
- **While each site is unique, the implementation of drill and blast programs that leverage the chemical crushing of the deposit have yielded *process stream cost savings that are better measured in dollars per ton than in cents per ton.***
- ***Use of smaller holes sizes typically results in more controlled and predictable blasting work.***

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