202 – The Chemical Crusher: Drilling and Blasting

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QUARRY ACADEMY

Improving Processes. Instilling Expertise.

Dyno Nobel

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How to Create Value and Maximize Profit in the New Economy

- **Answer:**

1. Provide exactly the right amount of energy to each rock as it moves:
   - Out of the bench, (Chemical Crushing)
   - Through the production process, and
   - Into product piles.
2. Minimize the activity required to produce

   (time to do the necessary steps)
3. Minimize the energy required to produce.

   (equipment and men to do the necessary steps)

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As the Chemical Crusher, drilling and blasting represents by far the most economical and efficient of methods to facture, fragment, tear apart, and move rock into a pile that can be easily excavated, hauled and further crushed by the primary crusher.

Traditional Drilling & Blasting practice focuses on powder factor.

Chemical Crushing focuses on controlled energy distribution.

Why now and not before this time?
What has changed!

- **Our production capability is not broken.**
  - ✓ **We can still put down a lot of rock and move it out the gate.**

- **It is the economic model for our industry that is broken**
  - ✓ **If we can't control our selling price, we have to control our cost.**

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Why now and not before this time?

Availability of advanced tools

- Models
  - Blast Fragmentation
  - Blast Vibration
  - Plant Process Optimization
- More accurate and precise rock drills
- Accurate and precise electronic detonators
- Advanced bulk emulsion explosive loading systems

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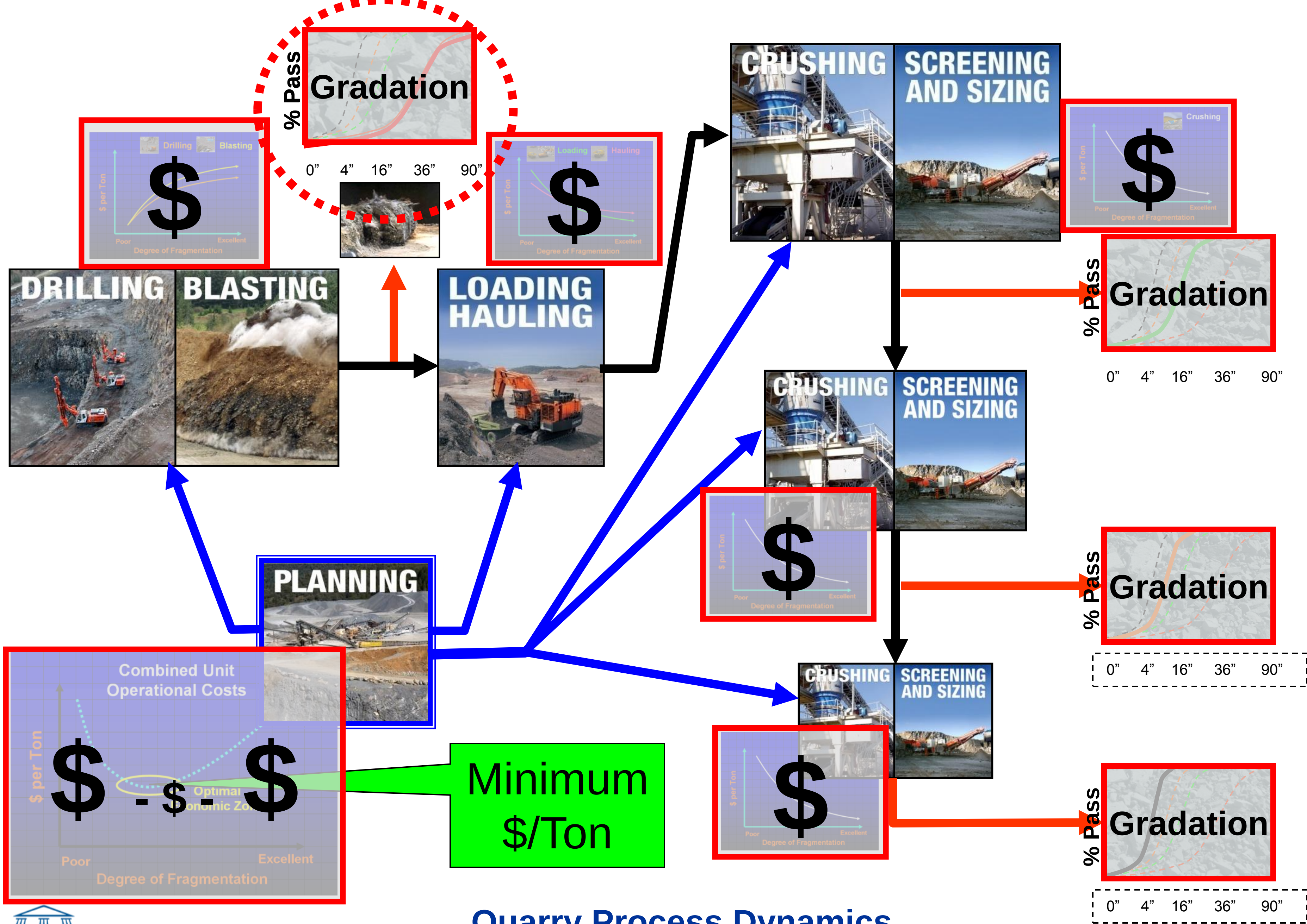

Quarry Process Dynamics

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Chemical Crusher

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

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As Chemical Crusher, Drill and Blast targets extend one step further than the old norm.

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

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Basic Drill and Blast Principles Still Apply.

- To do efficient work in rock, explosives need to be confined in drill hole. Without the drill hole, explosives would not be a practical tool for the quarry industry.
- In a correctly designed blast, accurately placed drill holes put 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!

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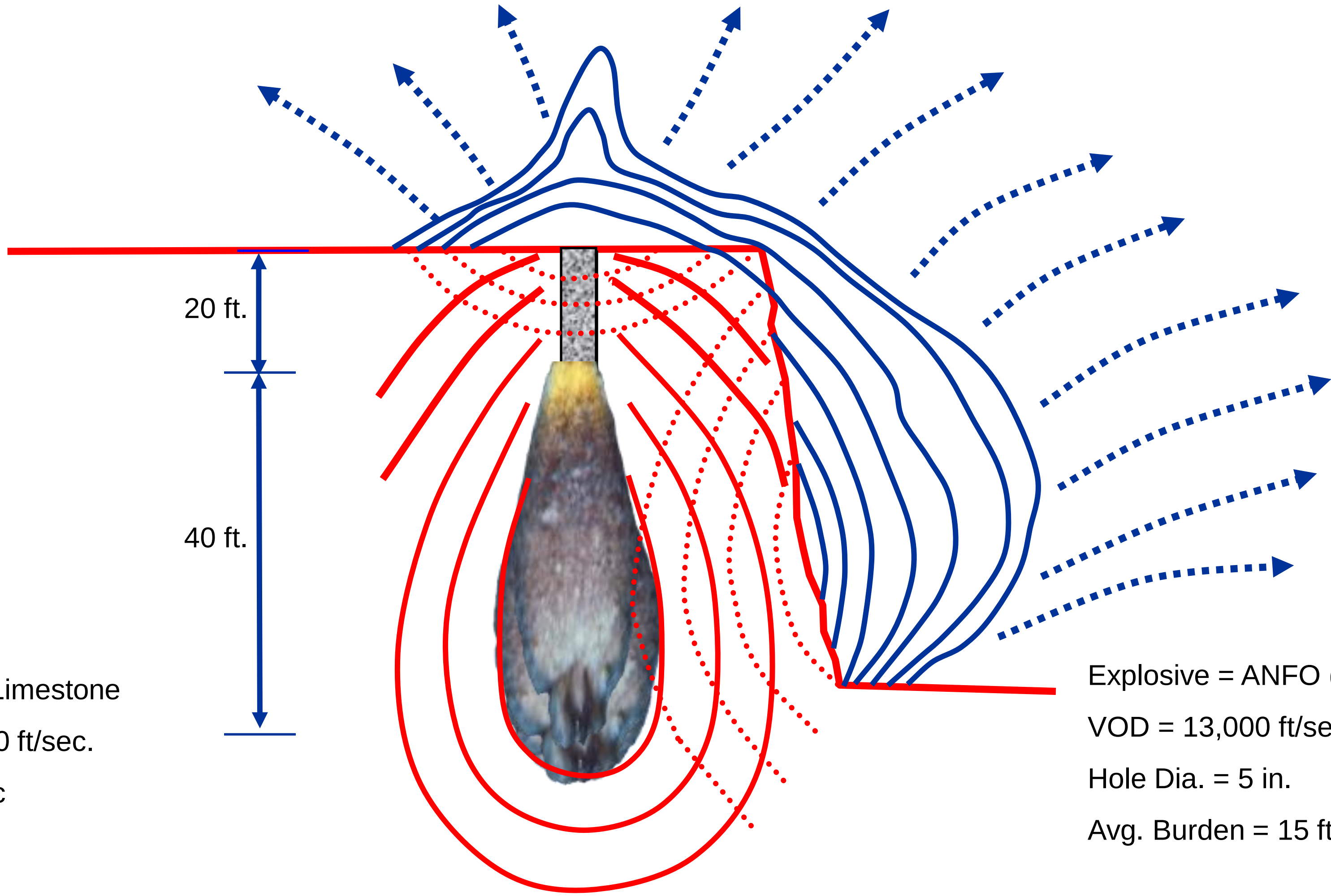
Without the Drill Hole.

Explosives Produce Shock and Awe!

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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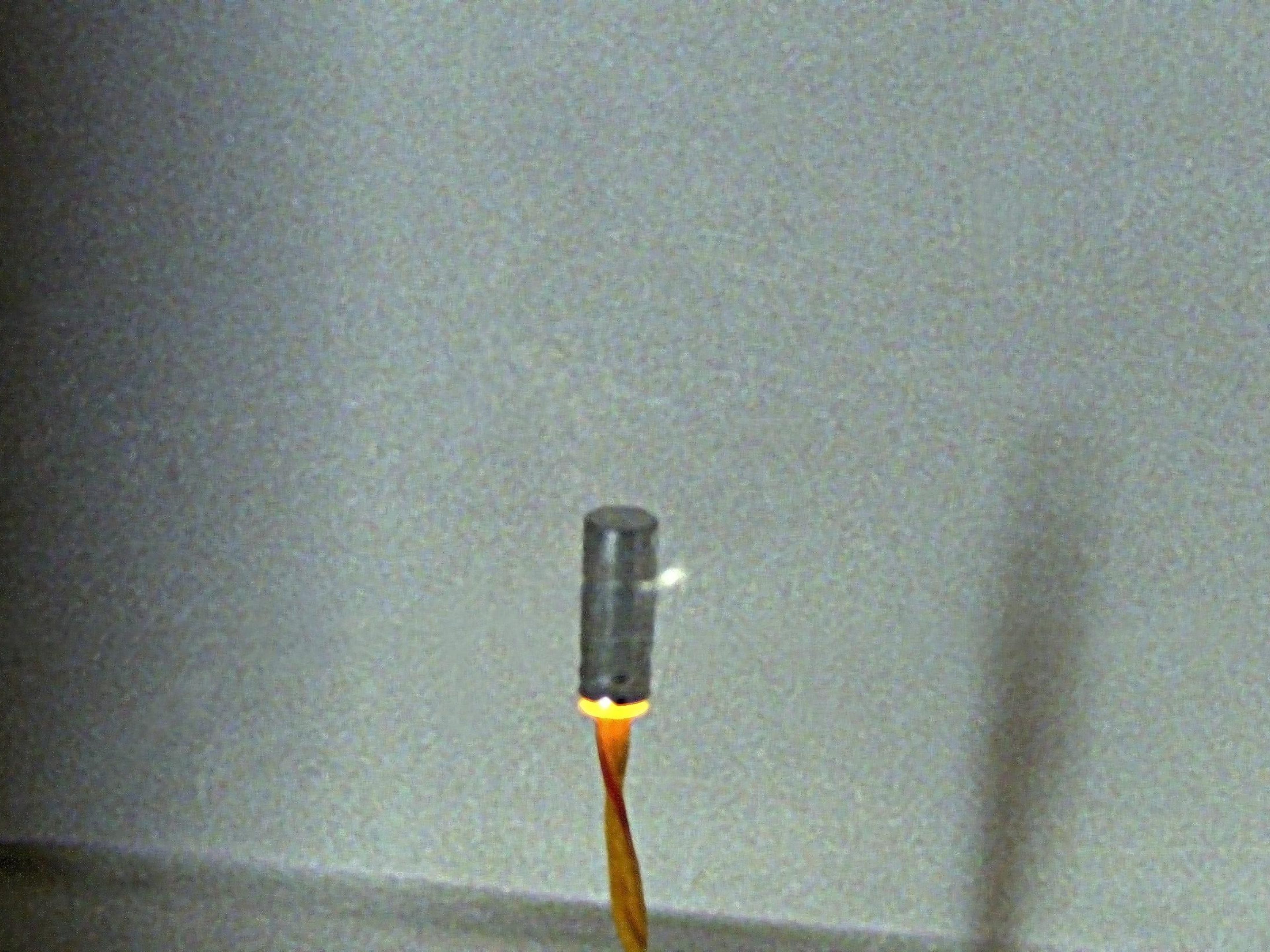
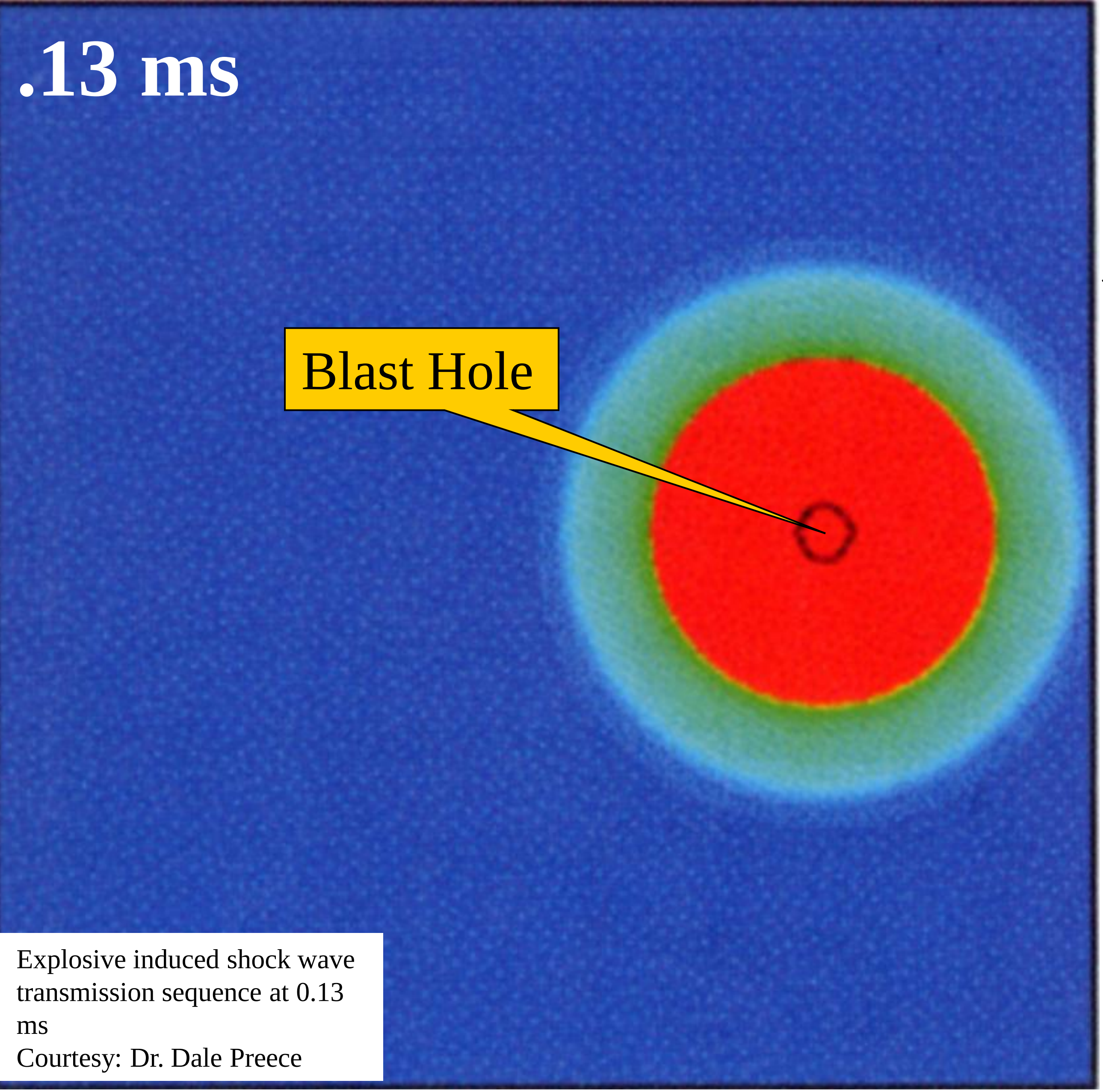


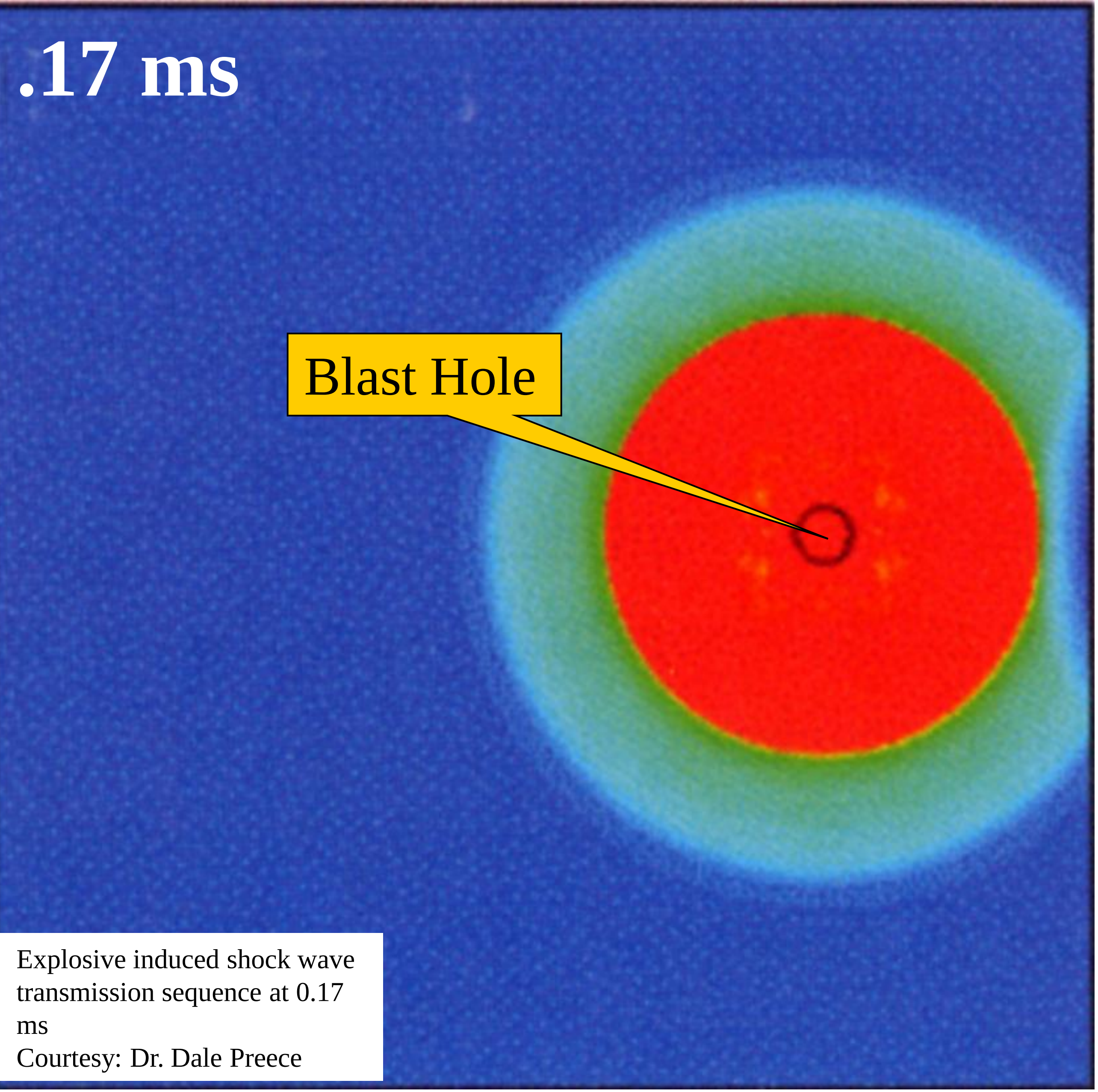


Explosive induced shock wave transmission sequence at 0.13 ms
Courtesy: Dr. Dale Preece

Bench Free Face

Stress In Vicinity of Blast Hole

Pressure		
	kPa	PSI
	54,000	372,317
	48,000	330,948
	42,000	289,580
	36,000	248,211
	30,000	206,843
	24,000	165,474
	18,000	124,106
	12,000	82,737
	6,000	41,369
	-	-
	(6,000)	(41,369)



Explosive induced shock wave transmission sequence at 0.17 ms
Courtesy: Dr. Dale Preece

Stress In Vicinity of Blast Hole

	Pressure	
	kPa	PSI
	54,000	372,317
	48,000	330,948
	42,000	289,580
	36,000	248,211
	30,000	206,843
	24,000	165,474
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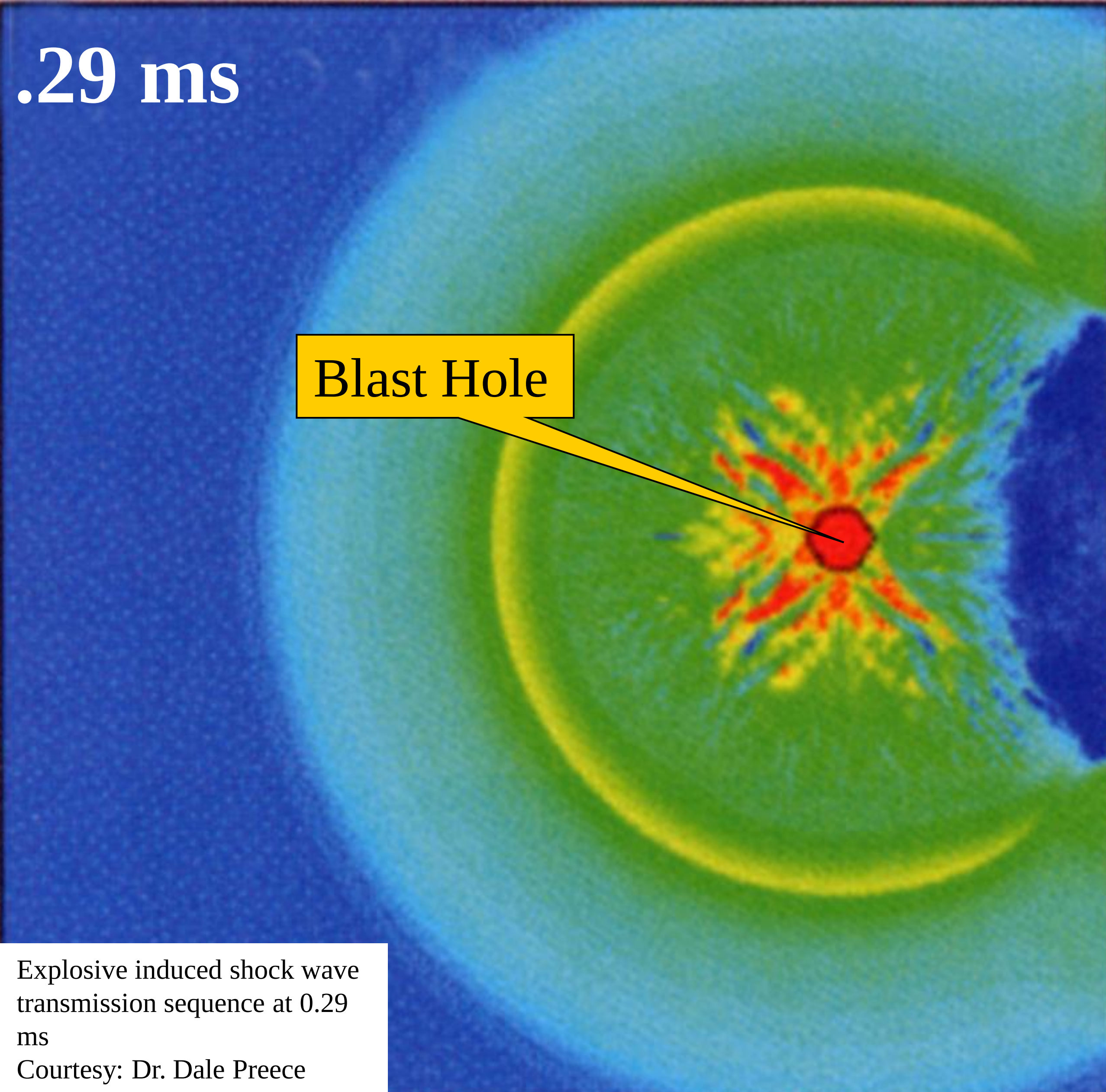
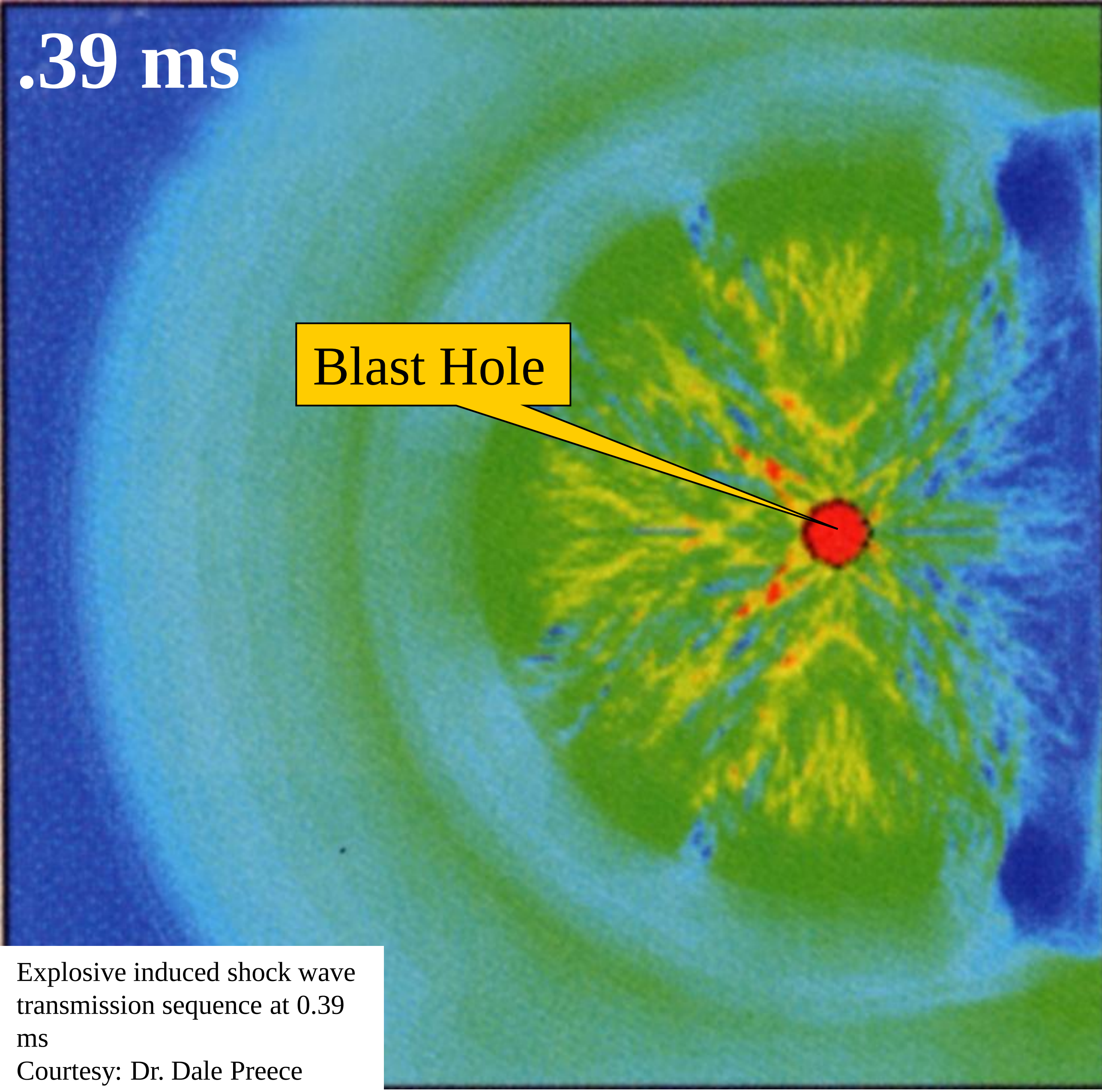
QUARRY ACADEMY



Explosive induced shock wave transmission sequence at 0.29 ms
Courtesy: Dr. Dale Preece

Stress In Vicinity of Blast Hole

Pressure		
	kPa	PSI
	54,000	372,317
	48,000	330,948
	42,000	289,580
	36,000	248,211
	30,000	206,843
	24,000	165,474
	18,000	124,106
	12,000	82,737
	6,000	41,369
	-	-
	(6,000)	(41,369)



Explosive induced shock wave transmission sequence at 0.39 ms
Courtesy: Dr. Dale Preece

Stress In Vicinity of Blast Hole

Pressure		
	kPa	PSI
	54,000	372,317
	48,000	330,948
	42,000	289,580
	36,000	248,211
	30,000	206,843
	24,000	165,474
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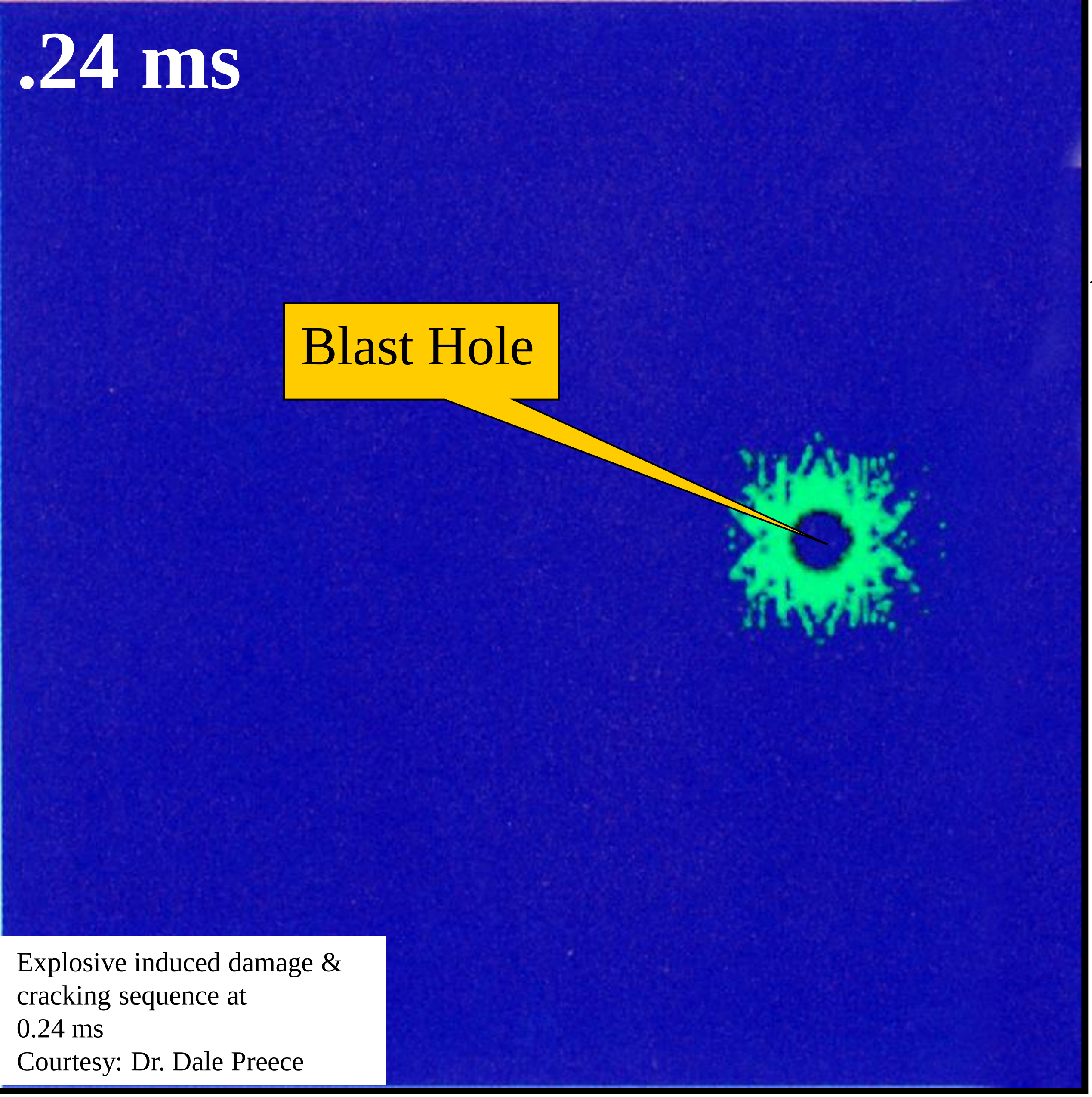
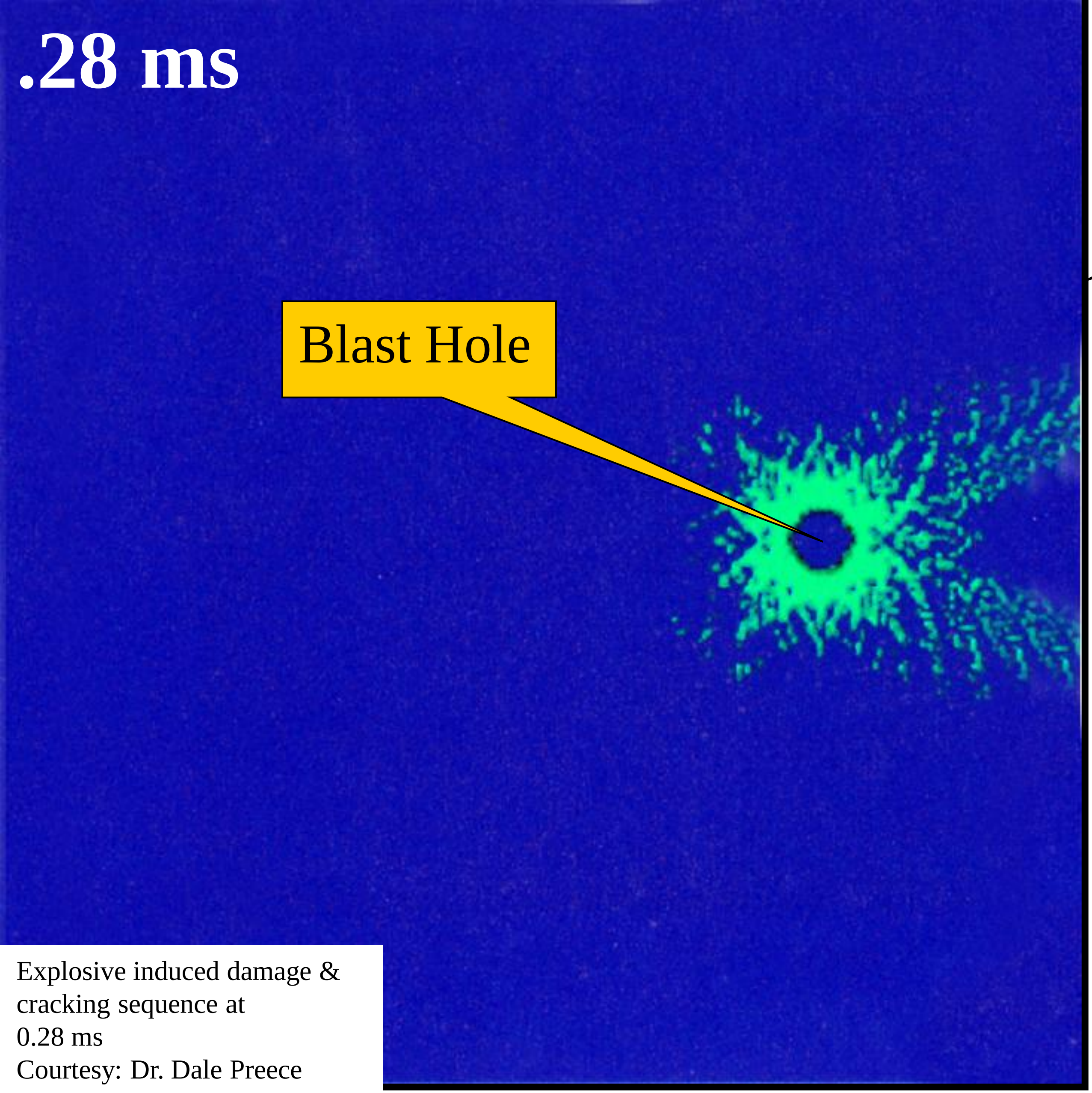


Explosive induced damage & cracking sequence at 0.24 ms
Courtesy: Dr. Dale Preece

Bench Free Face

Cracking In Vicinity of Blast Hole

QUARRY ACADEMY



Explosive induced damage &
cracking sequence at
0.28 ms
Courtesy: Dr. Dale Preece

Cracking In
Vicinity of
Blast Hole

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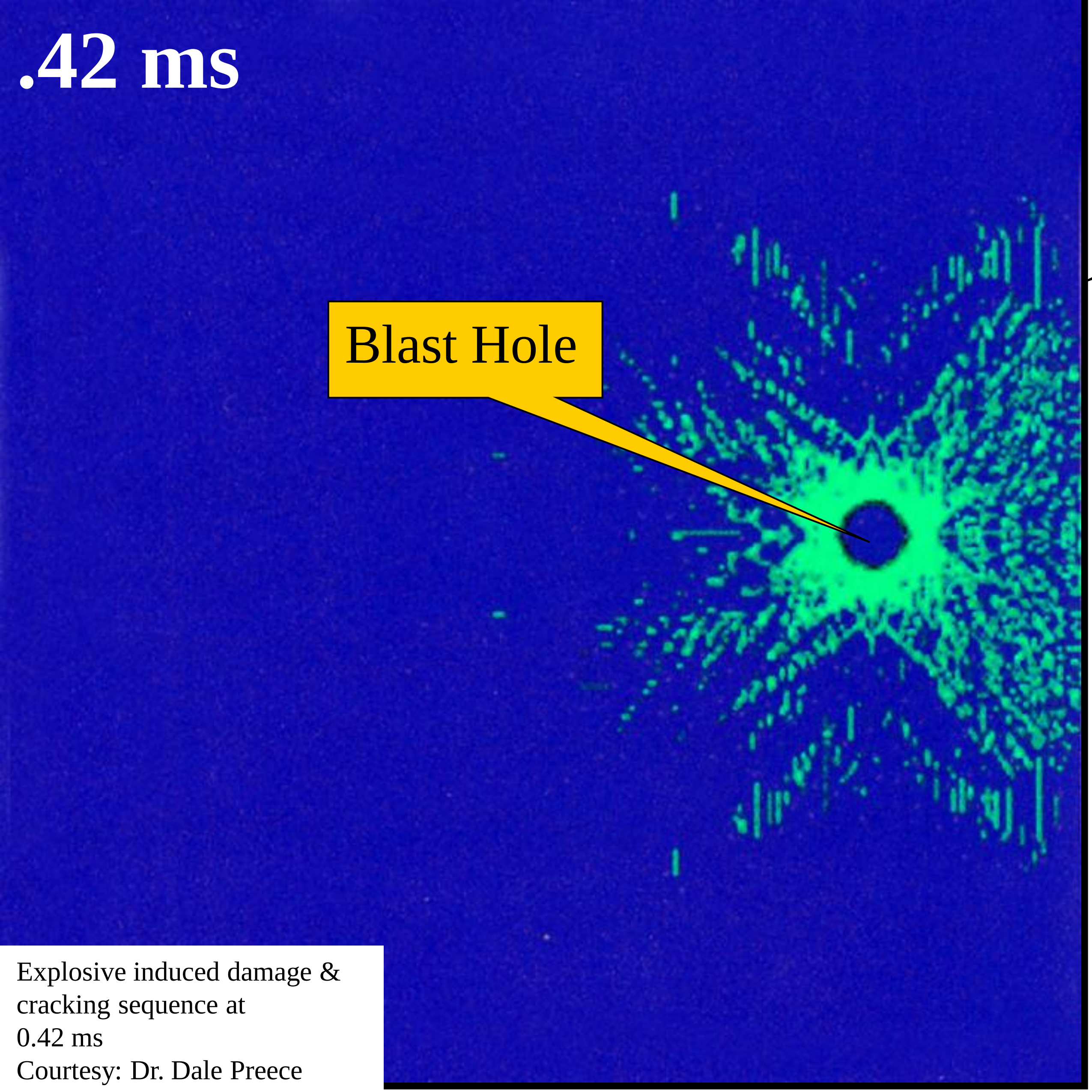
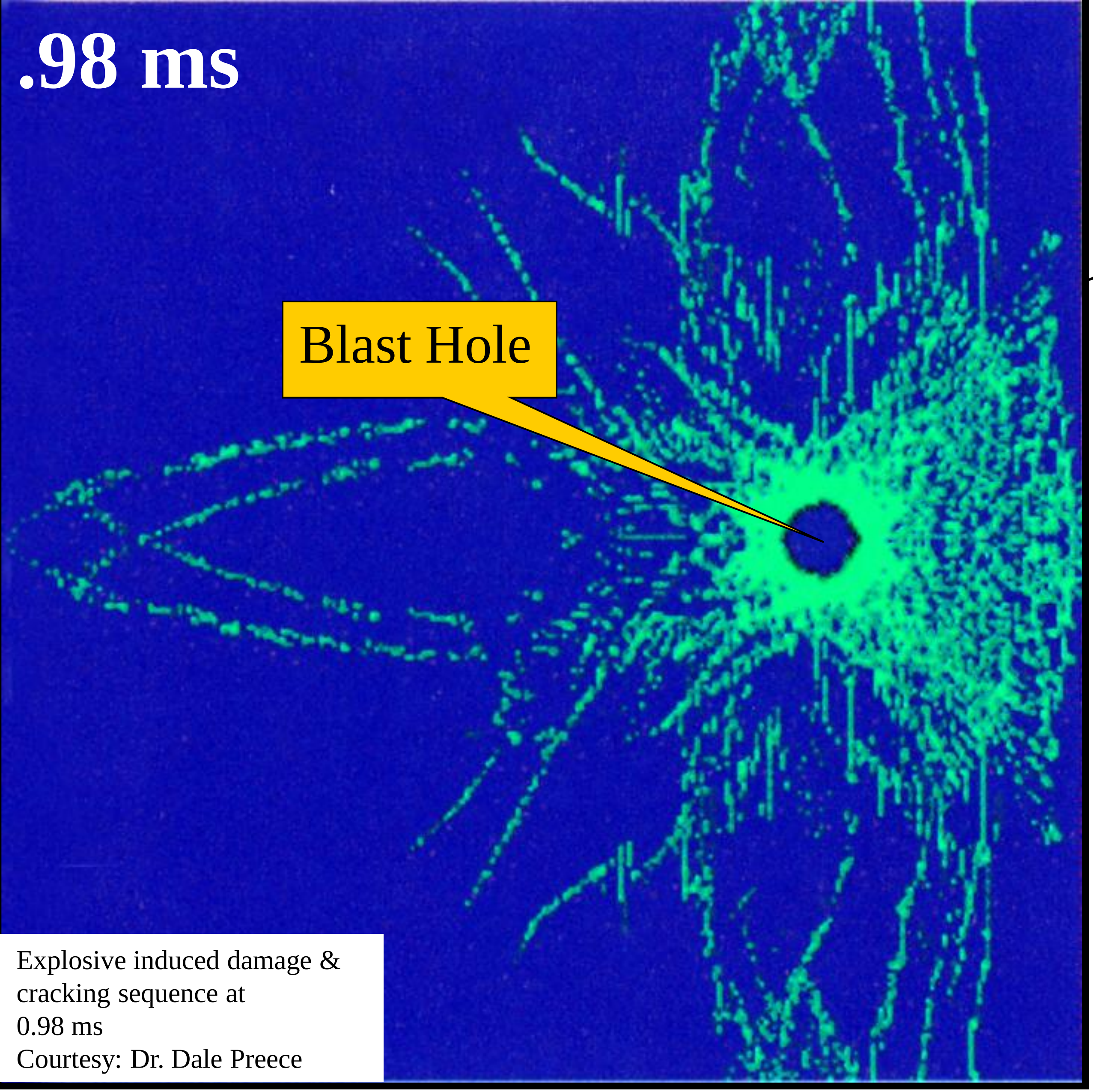


Explosive induced damage &
cracking sequence at
0.42 ms
Courtesy: Dr. Dale Preece

Cracking In Vicinity of Blast Hole

QUARRY ACADEMY



Explosive induced damage & cracking sequence at 0.98 ms
Courtesy: Dr. Dale Preece

Cracking In Vicinity of Blast Hole

Blast Dynamics
Stress / Pressure Dissipation

H_d = Hole Diameter

UCS = Unconfined compressive Strength of rock

Step 1= Pulverized Zone

Blast hole diameter expanded

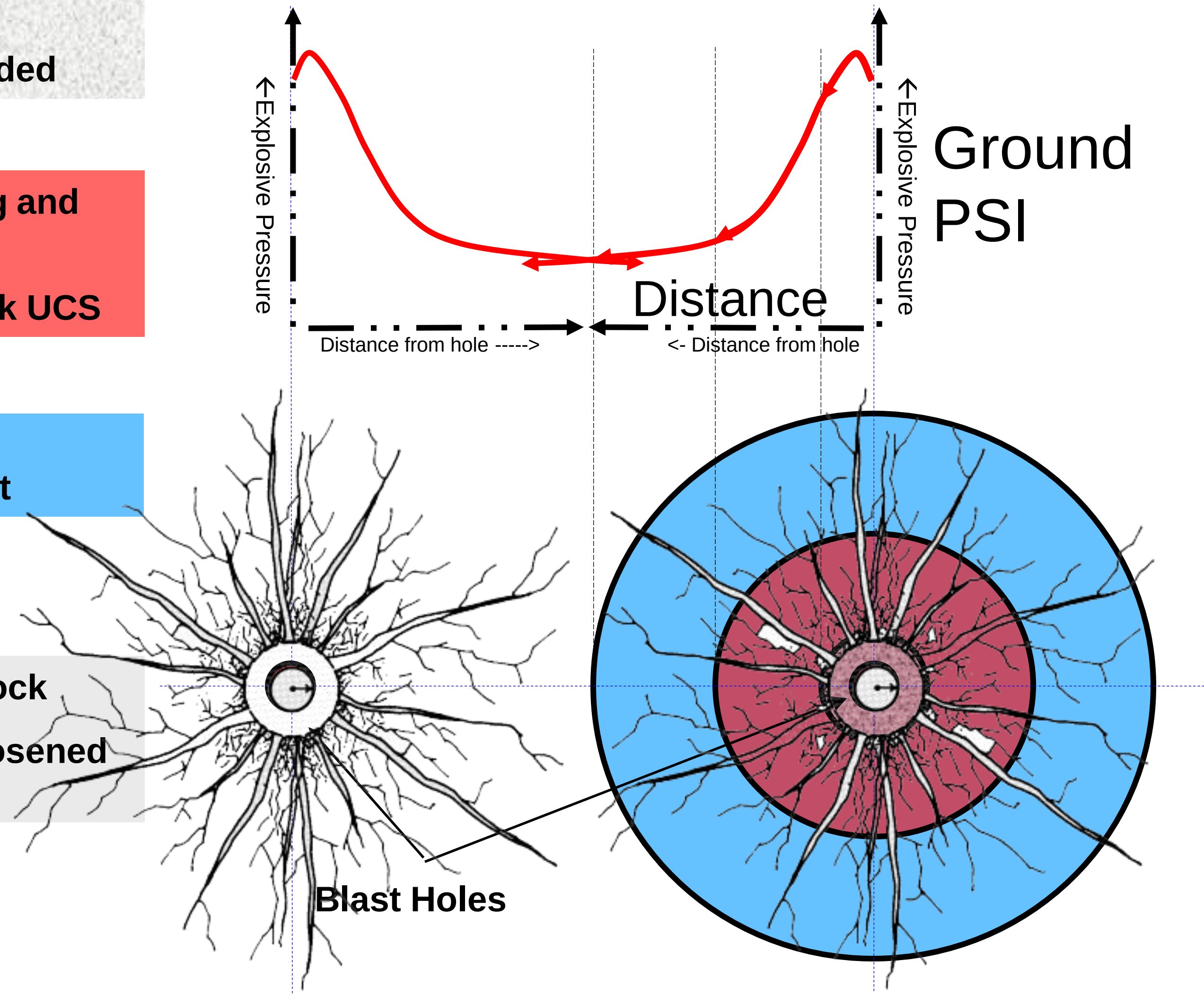
Step 2 = Intense fracturing and cleaving of minerals

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



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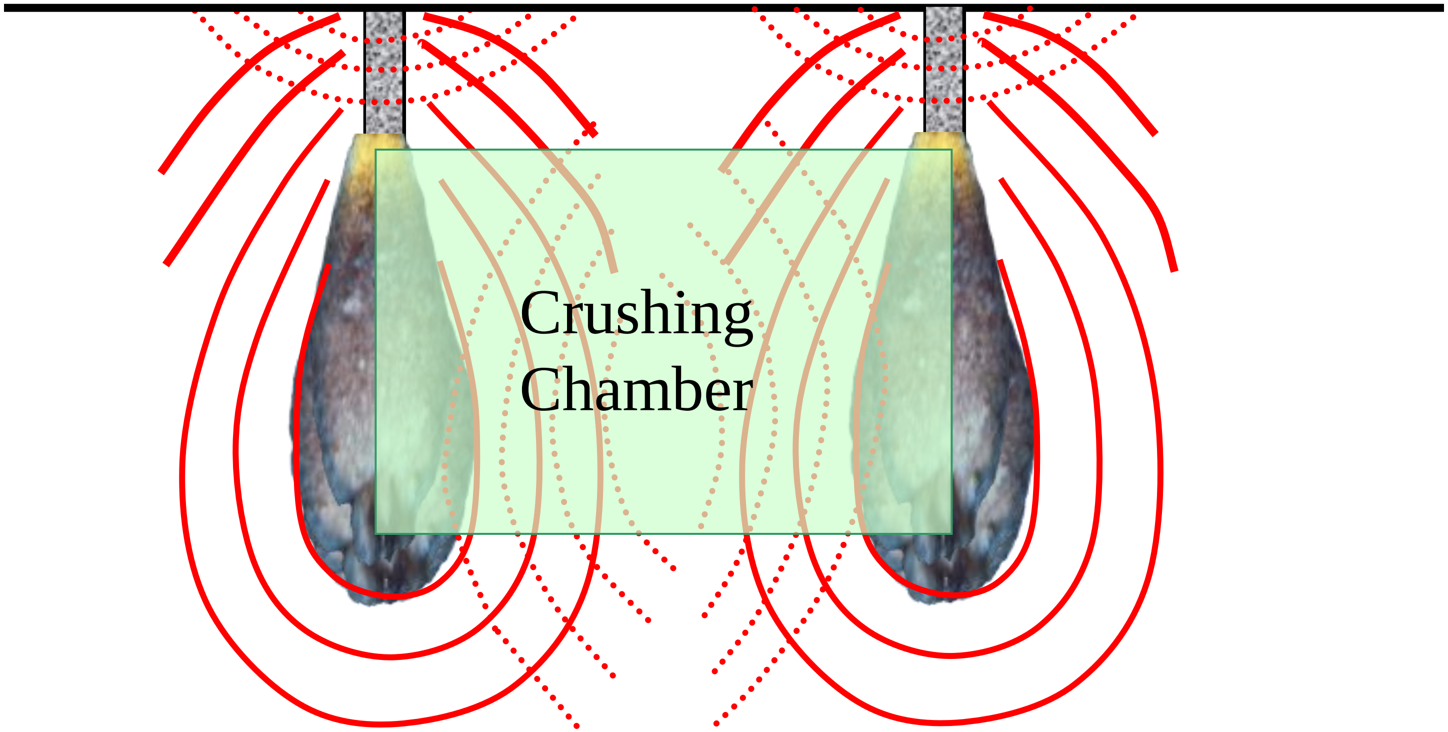
Chemical Crusher (conceptually)



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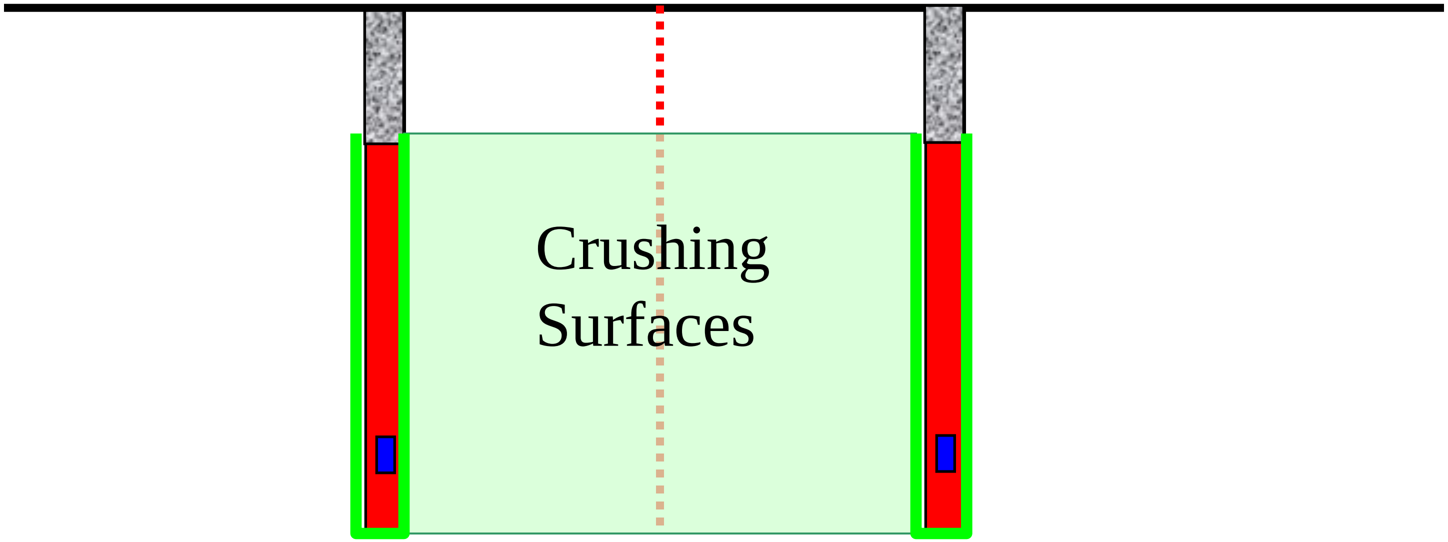
Chemical Crusher (conceptually)



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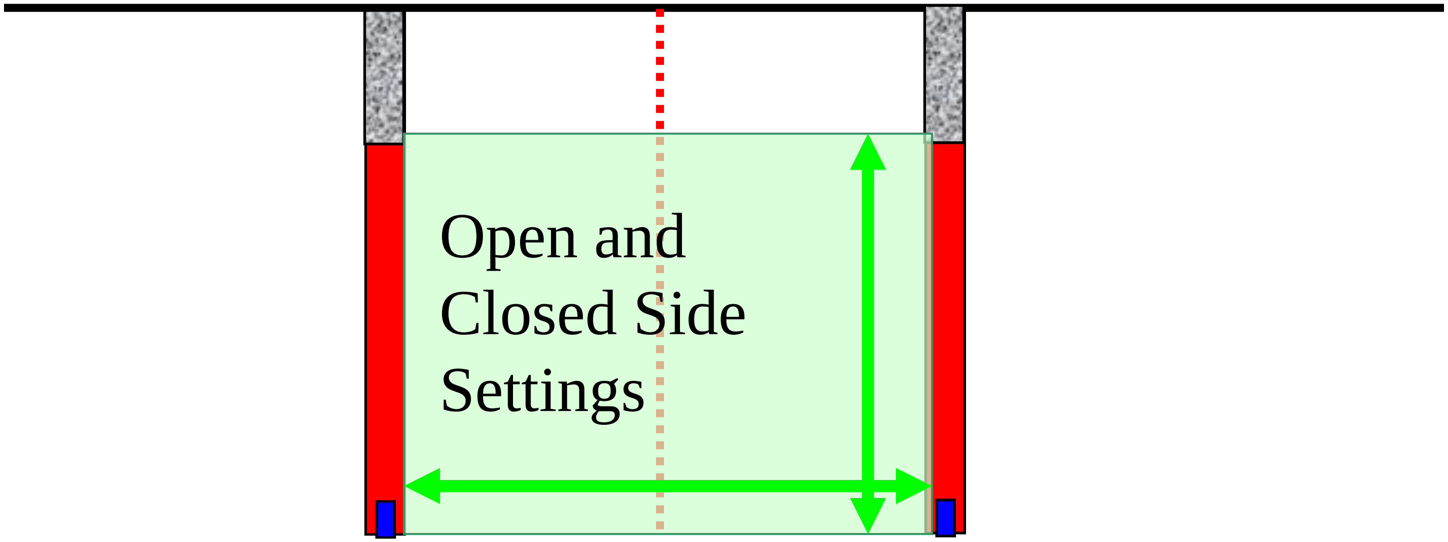
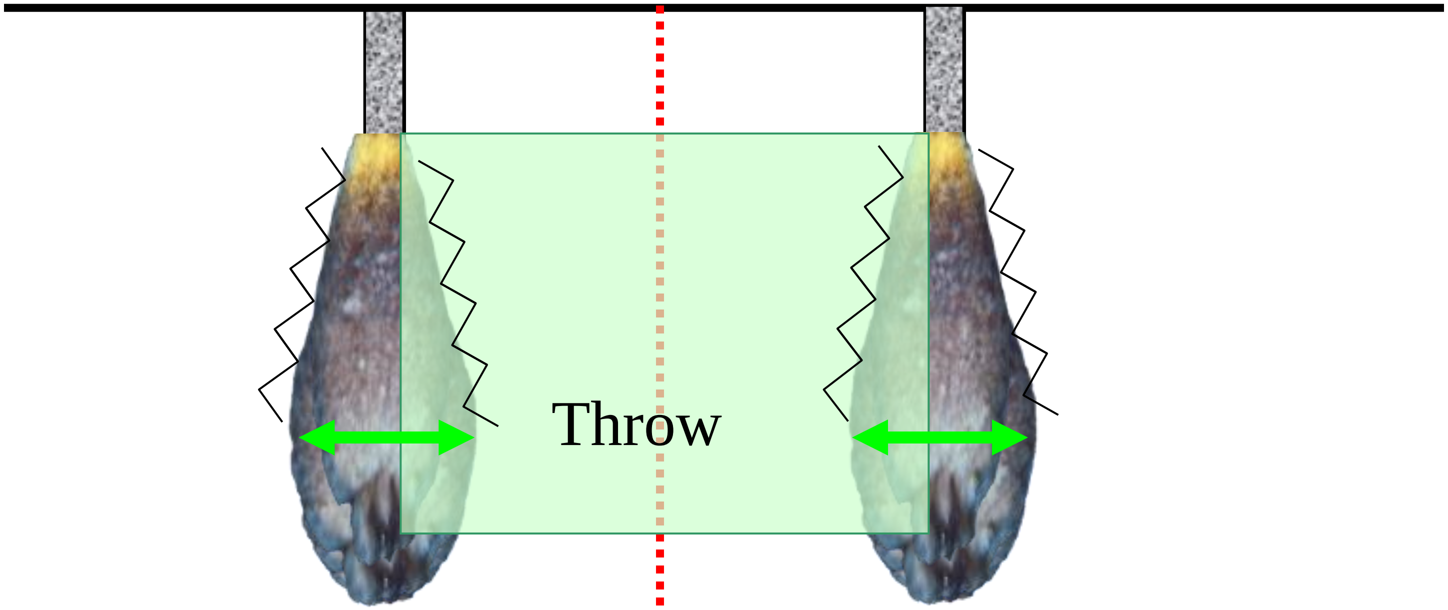
Chemical Crusher (conceptually)



Chemical Crusher (conceptually)



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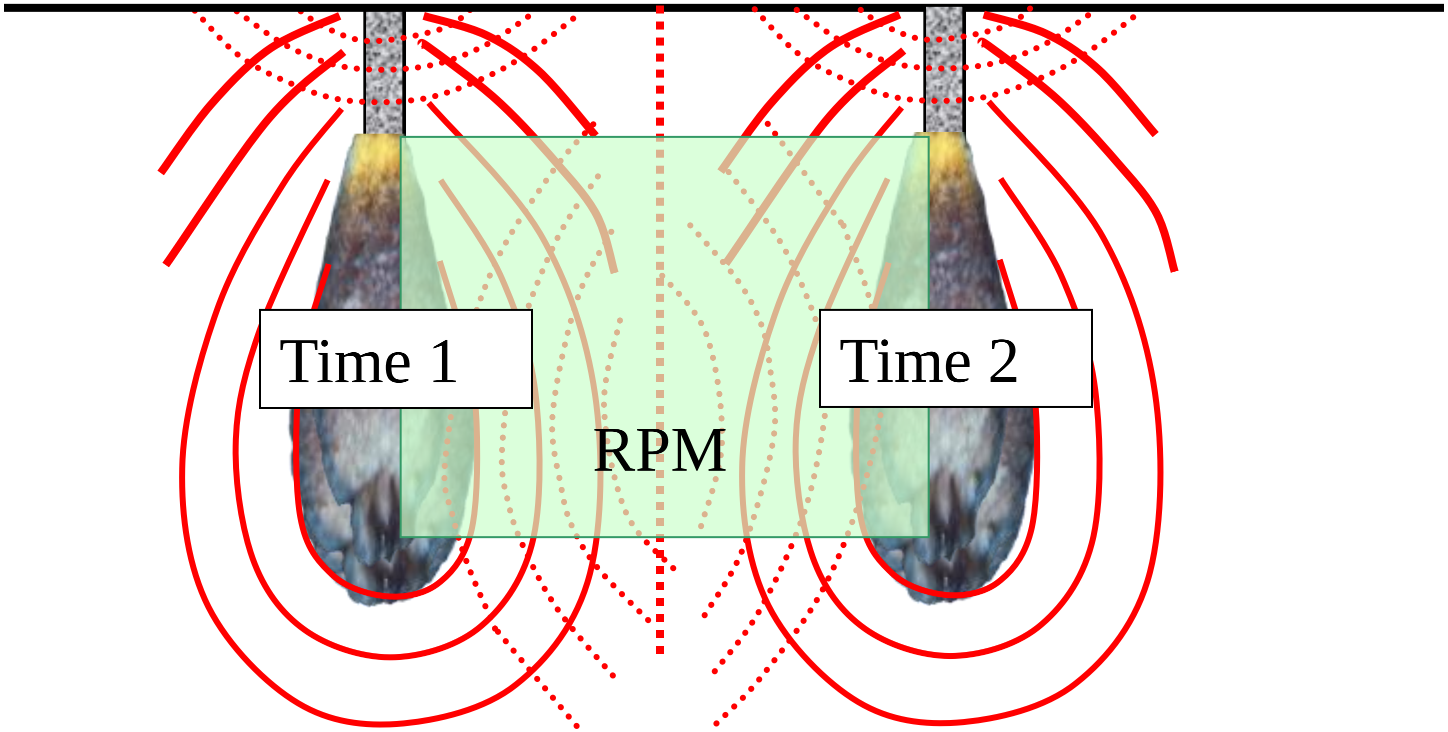
Chemical Crusher (conceptually)



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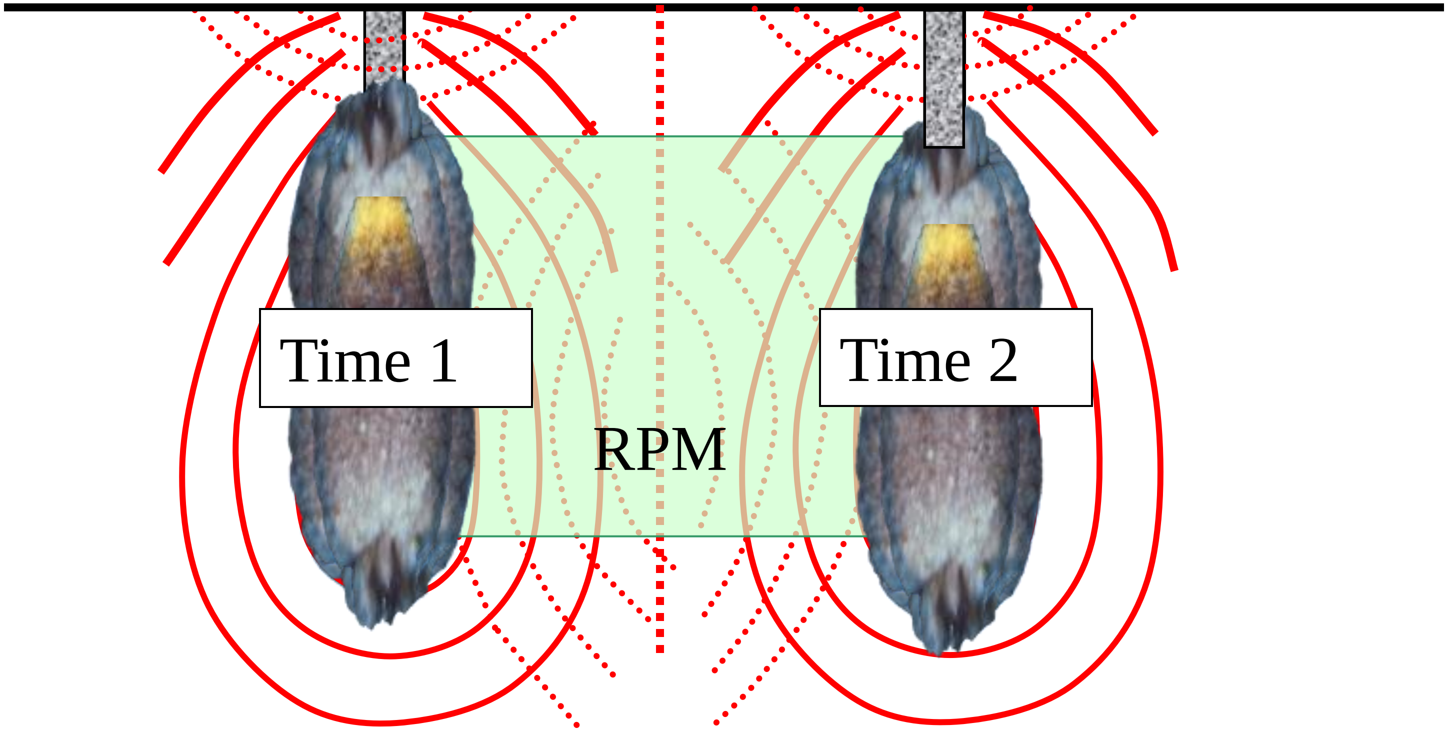
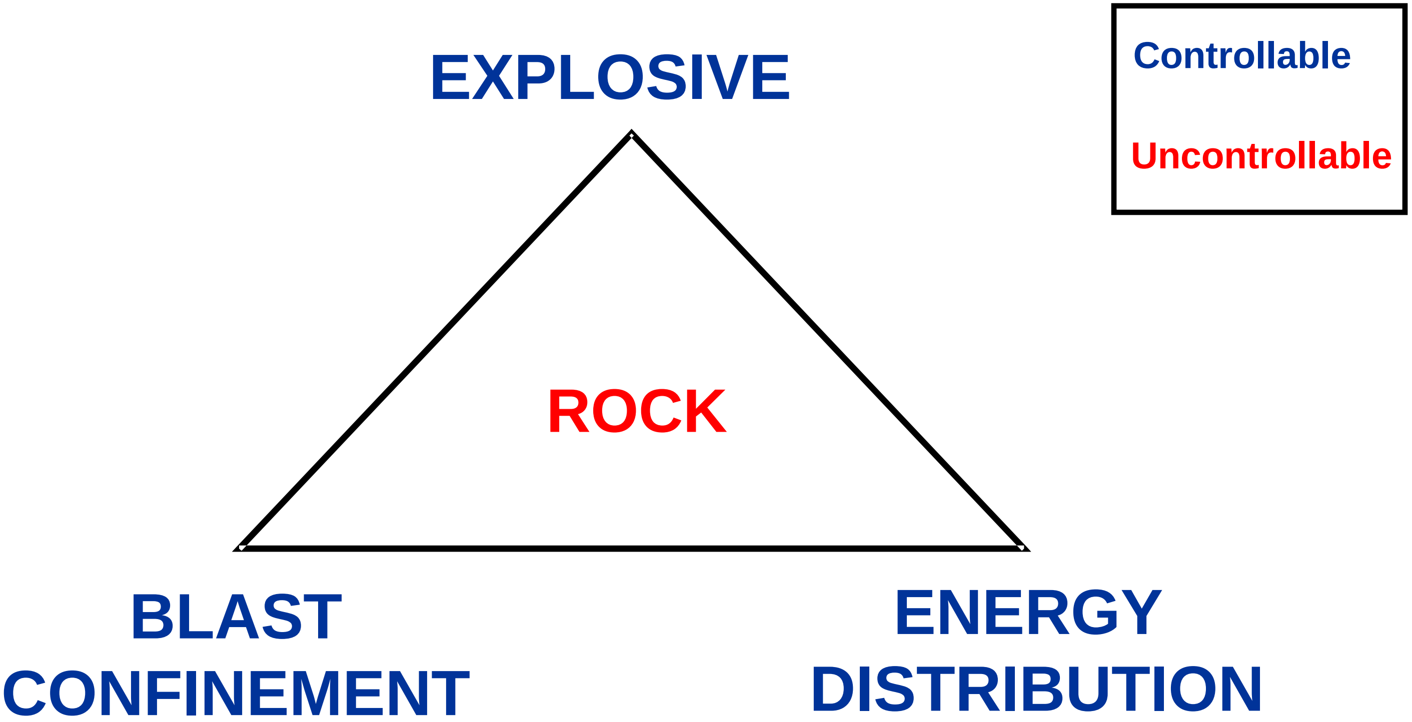
Chemical Crusher (conceptually)



Chemical Crusher - Key Design Factors



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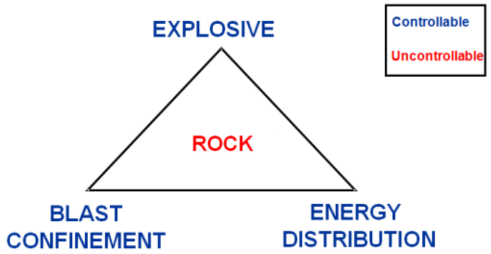
Explosive

A controllable factor in building the Chemical Crusher

- **The energy, pressure and after blast fumes generated by an explosive detonation are determined by the explosives:**
  - ✓ **Composition**
  - ✓ **Density (g/cc)**
  - ✓ **Diameter**
  - ✓ **Velocity of Detonation (ft/sec)**
- **Commercial explosives are available in both:**
  - ✓ **Packaged**
  - ✓ **Bulk**
    - Dry Blend / Free Flowing
    - Wet Blend / Augerable
    - Pumpable Blend



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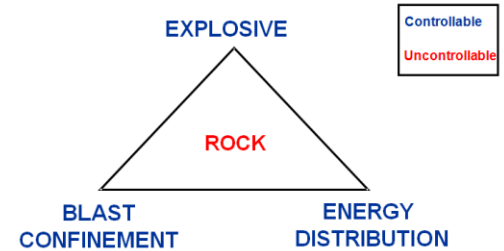
Blast Confinement

A controllable factor in building the Chemical Crusher

- **Confinement determines the amount of the explosive's energy that does effective work. Confinement is provided by:**
  - ✓ **Material surrounding the explosive in the drill hole.**
  - ✓ **The amount of material between the drill hole and any static or dynamic free space or what we call the burden.**
    - **Burden is a critical blast dimension. All blast design parameters are based on burden.**
  - ✓ **The distance between drill holes (Spacing) relative to one another in a row.**
  - ✓ **Stemming / non explosive decking. Size and quality is critical.**
  - ✓ **Initiation sequence and time between and within individual blast holes.**



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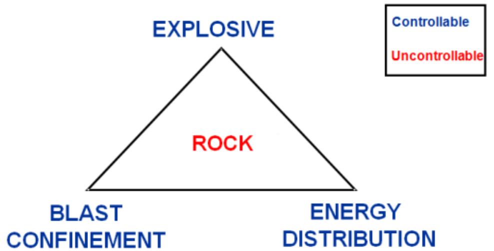
Energy Distribution
A controllable factor in building the Chemical Crusher

- **How the explosive energy is distributed throughout the rock mass to be blasted – vertically and horizontally to do work. Energy Distribution is controlled by:**
  - ✓ **Diameter of the drill hole.**
    - ✓ **Limits the diameter of explosive.**
  - ✓ **Diameter of the explosive.**
    - ✓ **Packaged explosive limits the effective diameter of the blast hole.**
  - ✓ **Depth / Length of the drill hole.**
    - ✓ **Single column of explosive - Amount loaded with explosive versus amount filled with stemming.**
    - ✓ **Multiple separated columns of explosive – the amount loaded with explosive and the amount filled with stemming and their relative positioning throughout the rock mass**
  - ✓ **Orientation of drill holes**
    - ✓ **Relative to one another – staggered, in-line**



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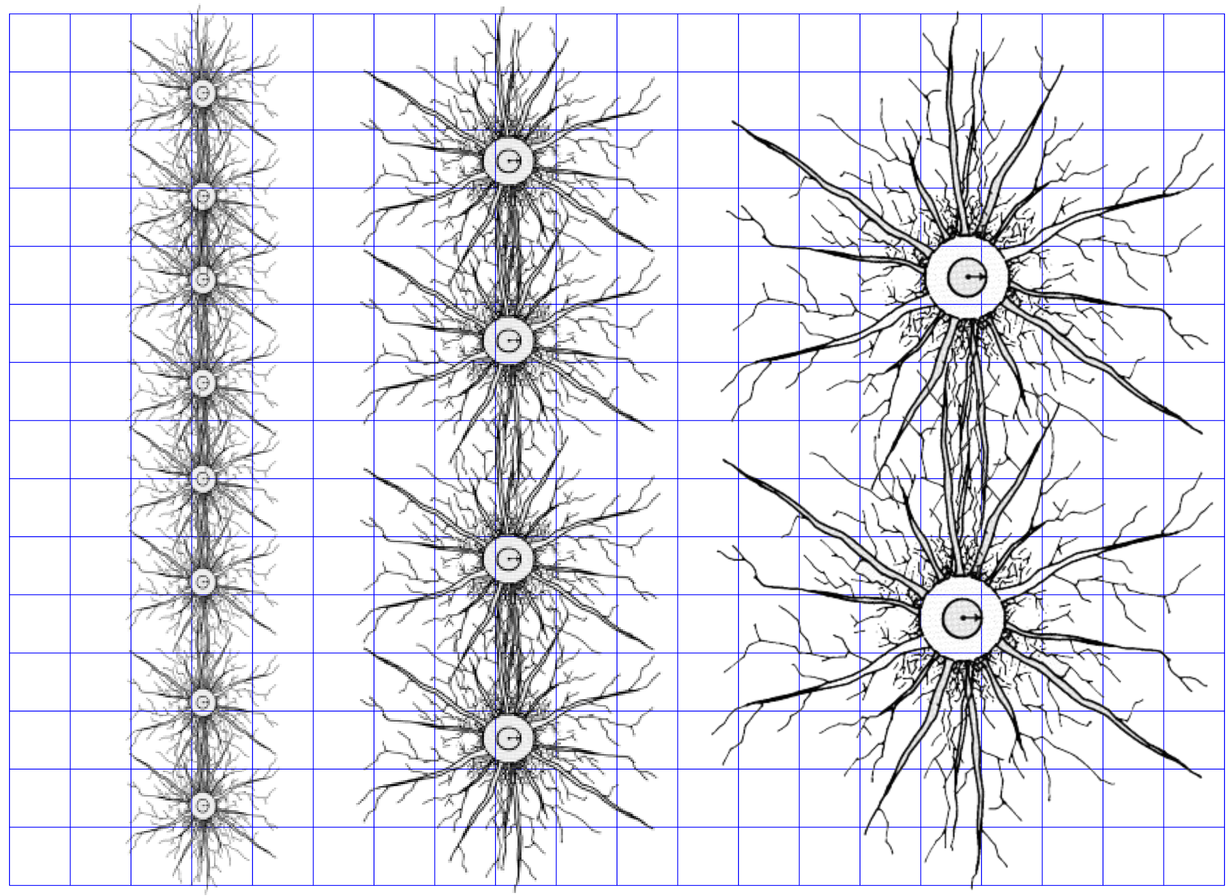
Effect of Hole Diameter on Fragmentation Control (Small to Large)

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



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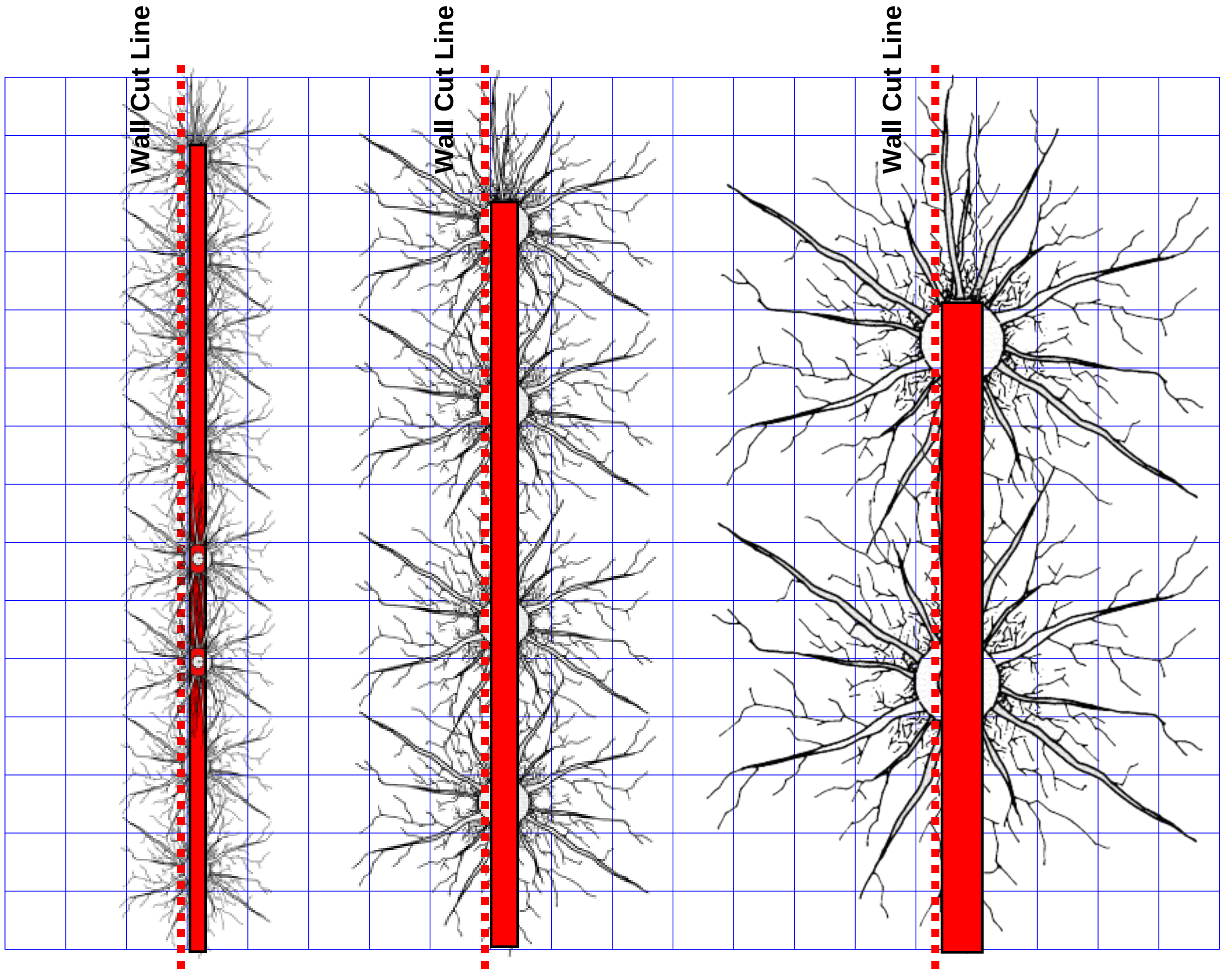
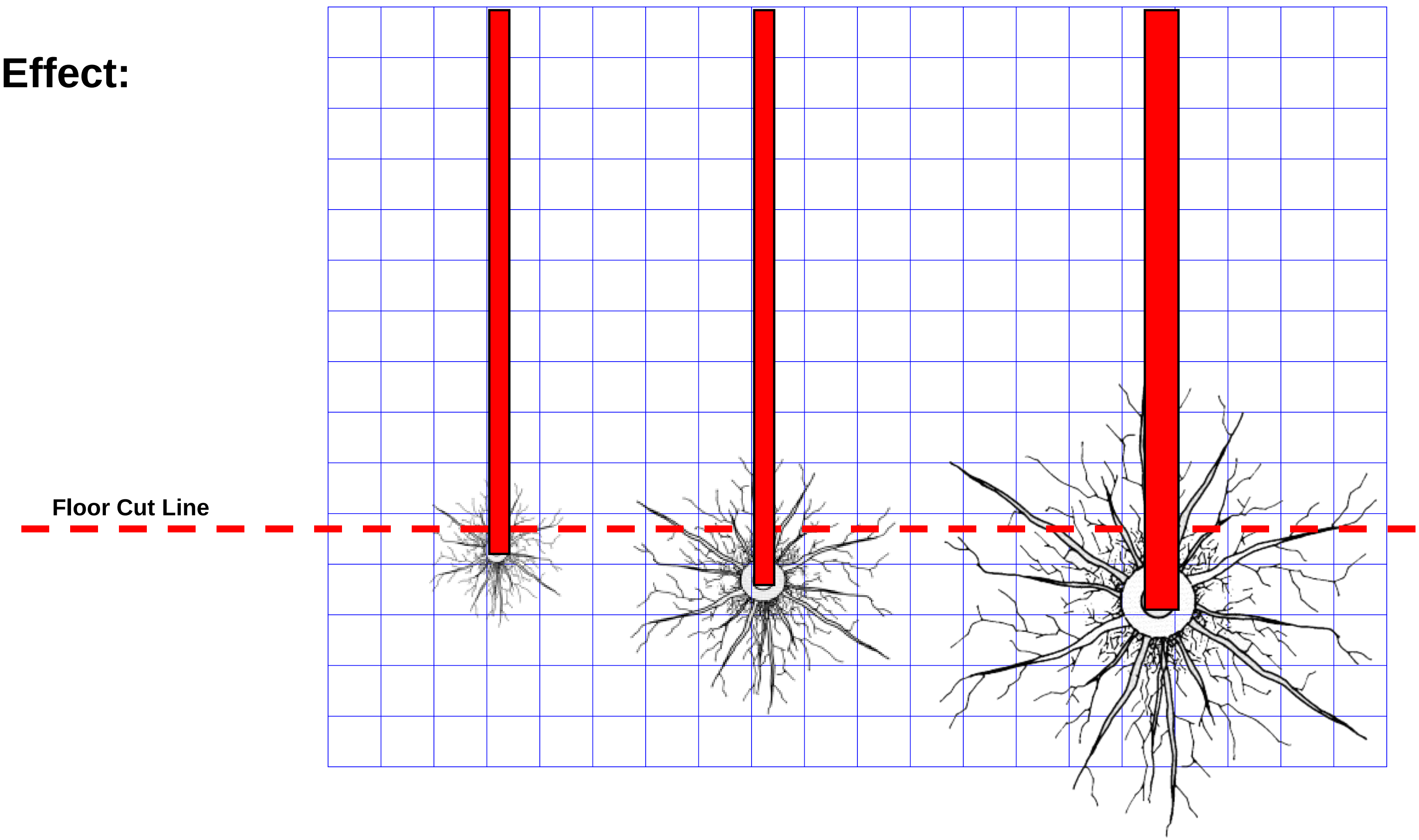
Effect of Hole Diameter on Fragmentation Control (Small to Large)

Wall Effect:



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

Floor Effect:



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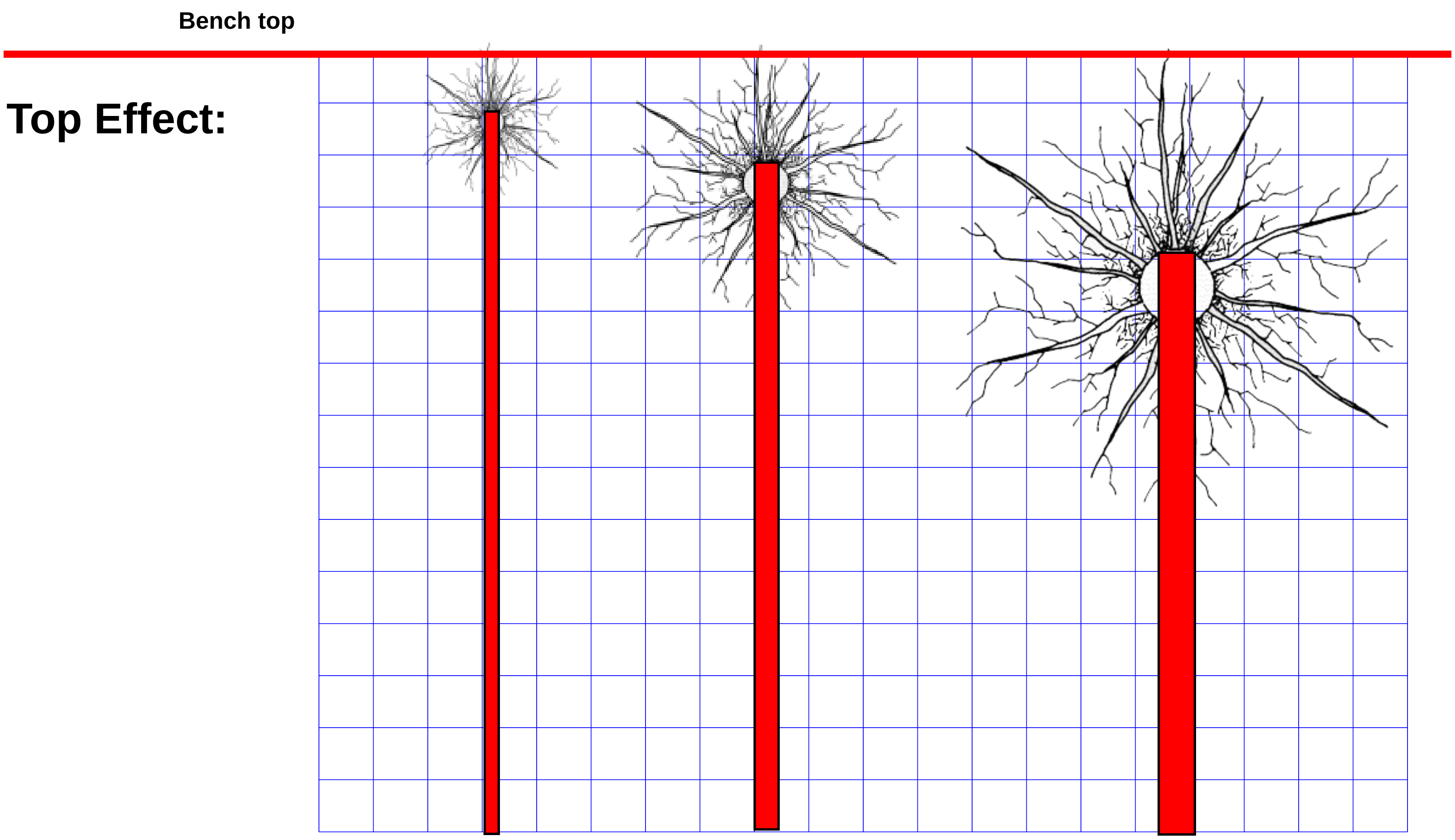
Effect of Hole Diameter on Fragmentation Control (Small to Large)

Bench Top Effect:



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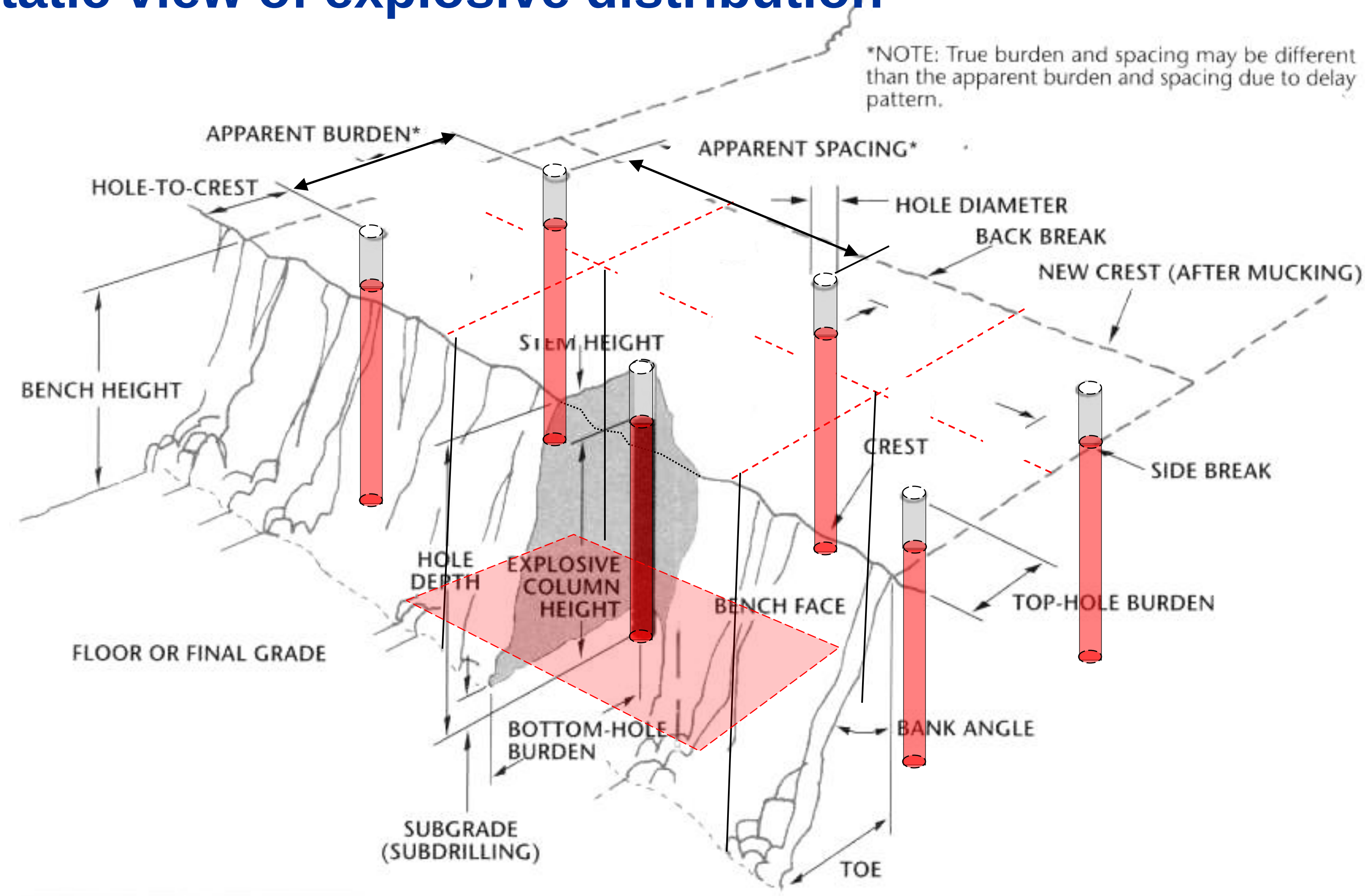
Building the Chemical Crusher
Static view of explosive distribution



Larger Diameter Holes

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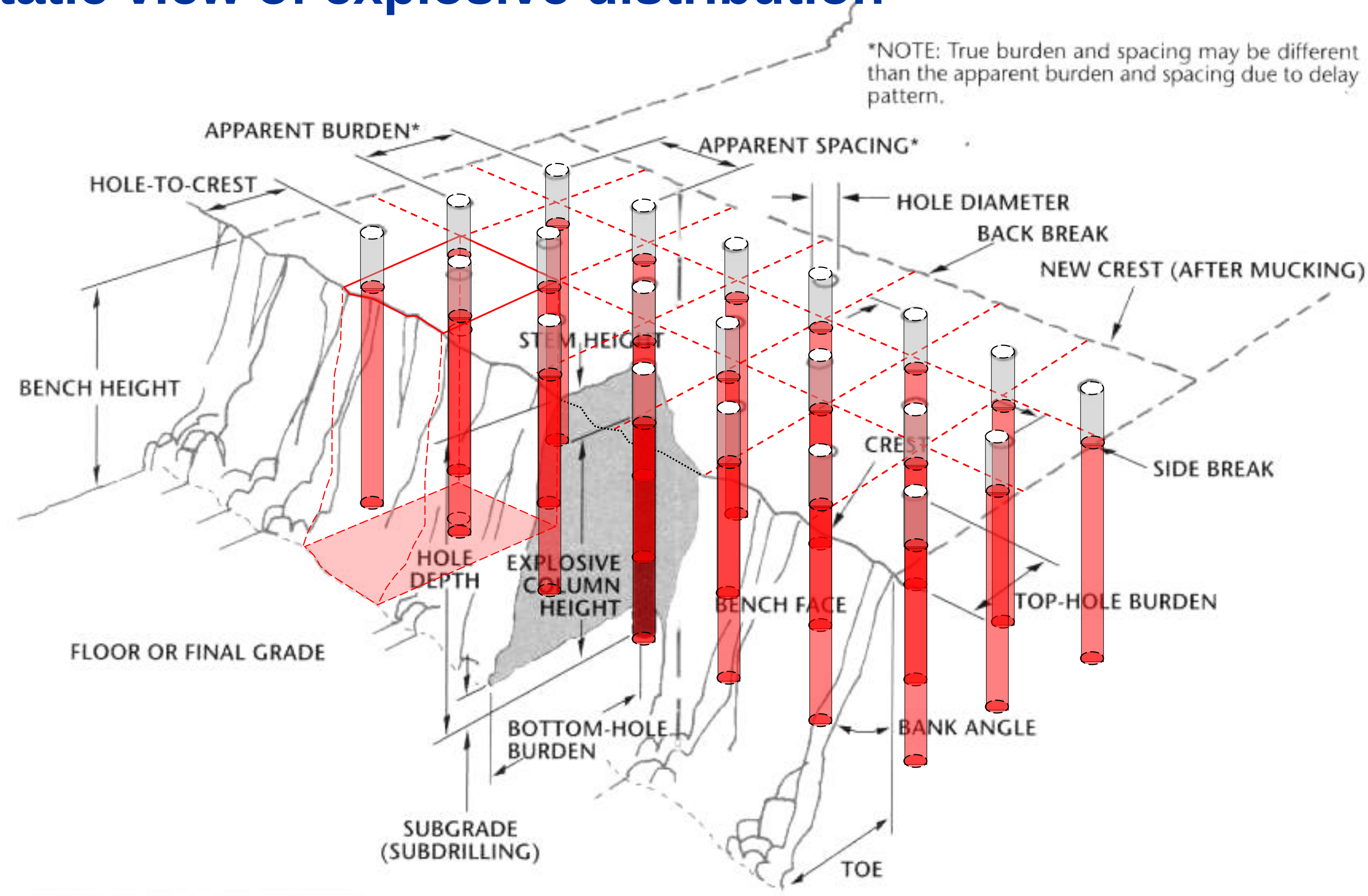
Building the Chemical Crusher

Static view of explosive distribution



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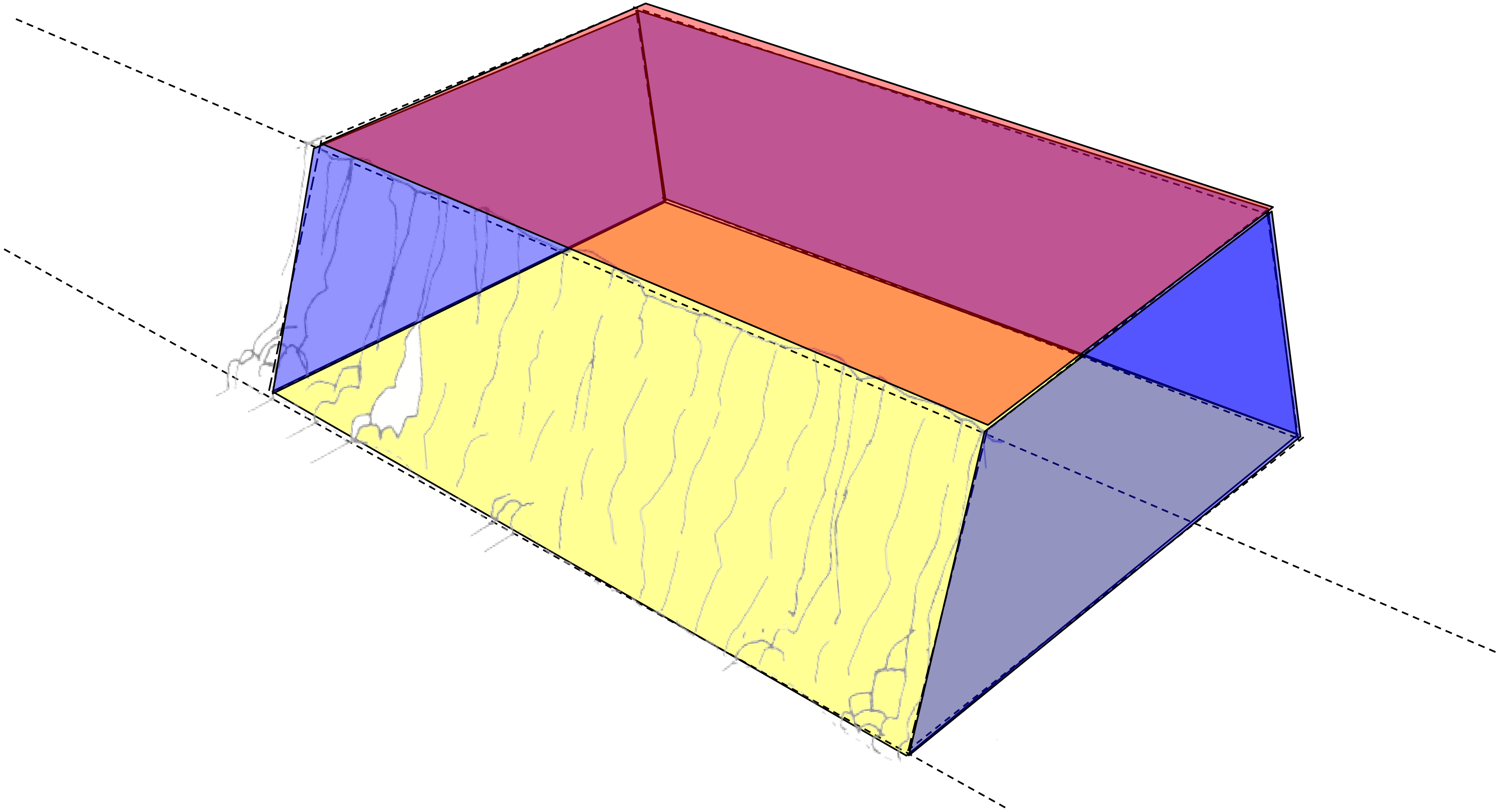
Smaller Diameter Holes

Target Work Zone for Chemical Crusher



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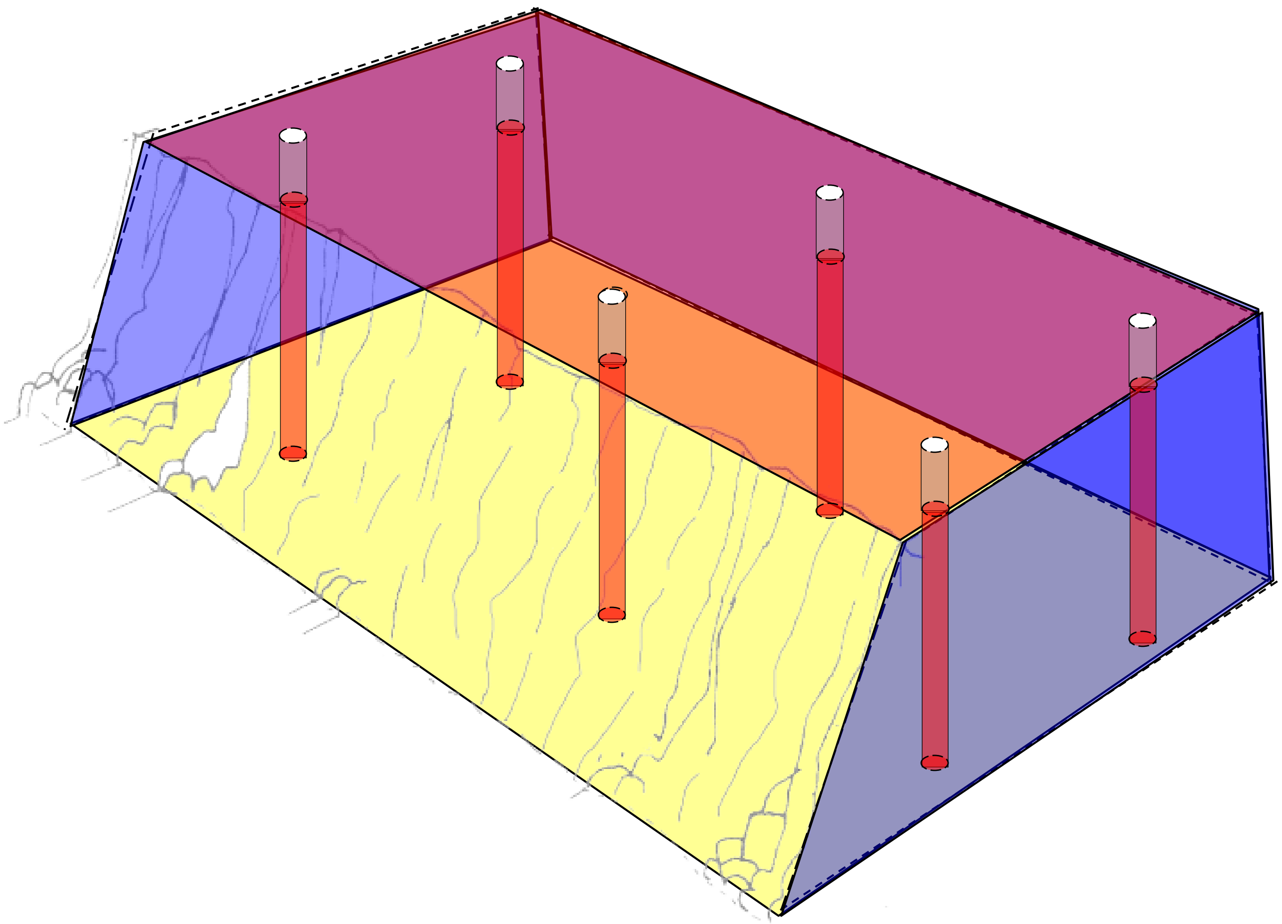
Larger diameter holes in Target Work Zone



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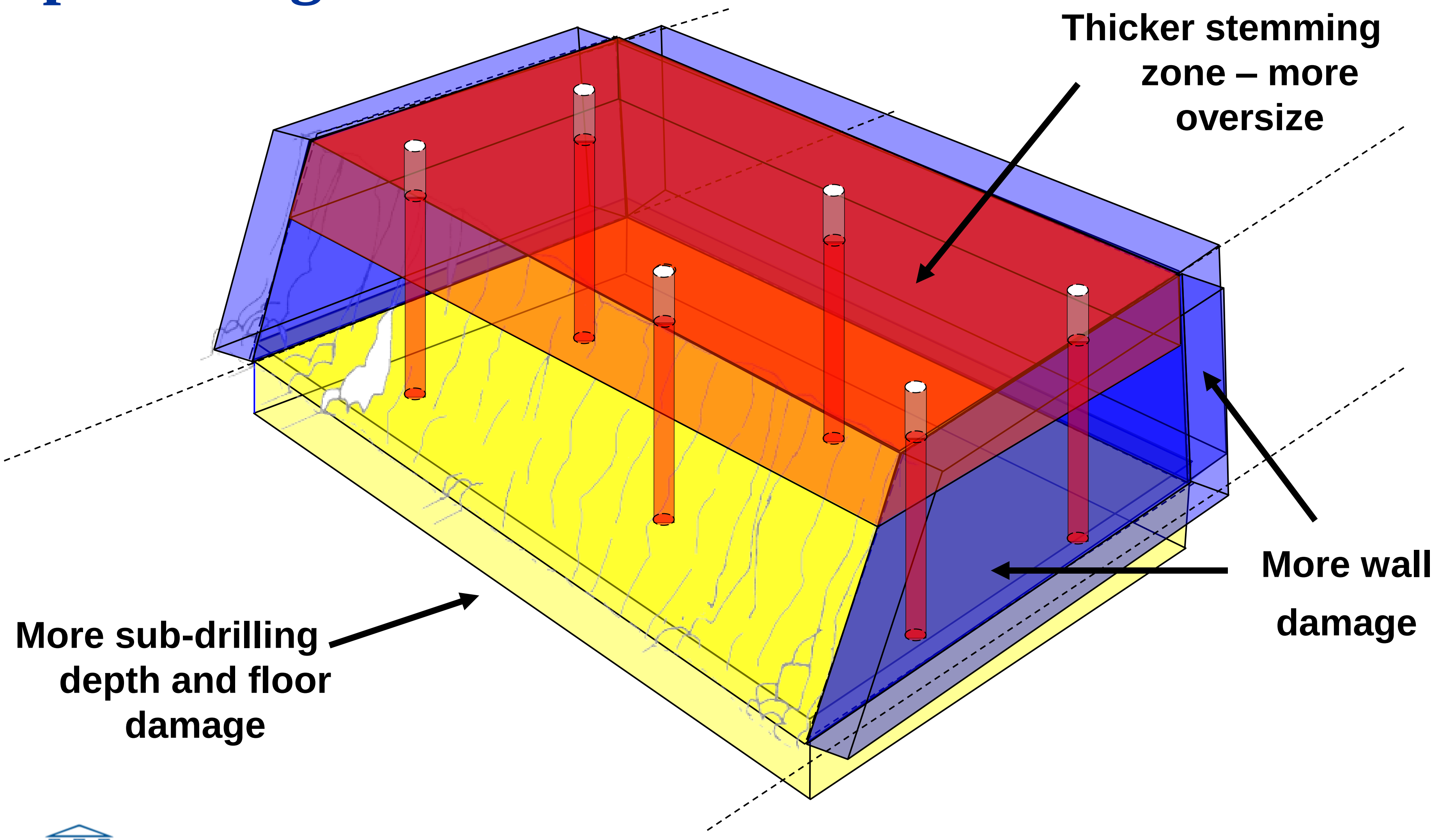
Larger diameter holes allow for smaller overall percentage of crushed rock



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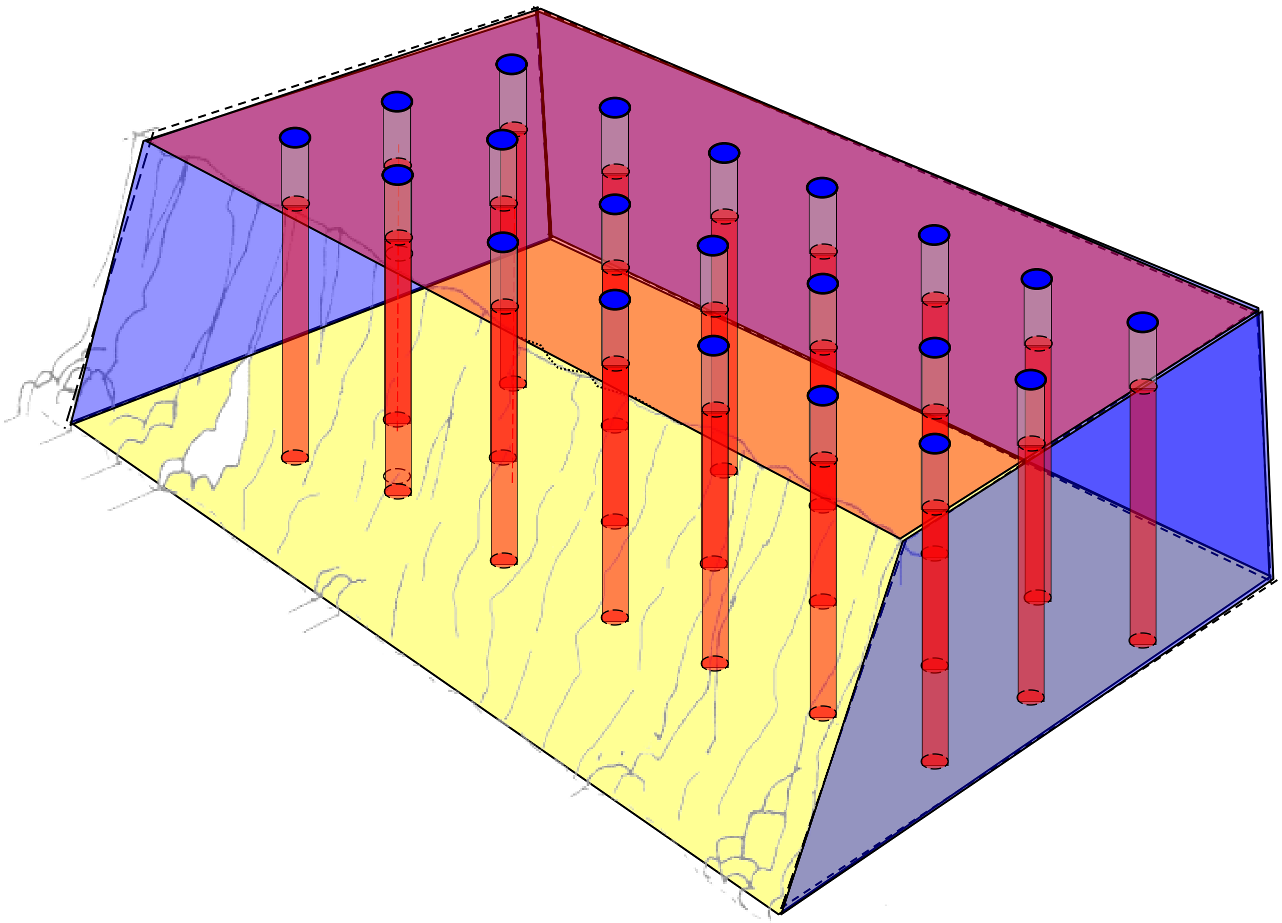
Uniform Gradation - Coarse

Small diameter holes in Target Work Zone



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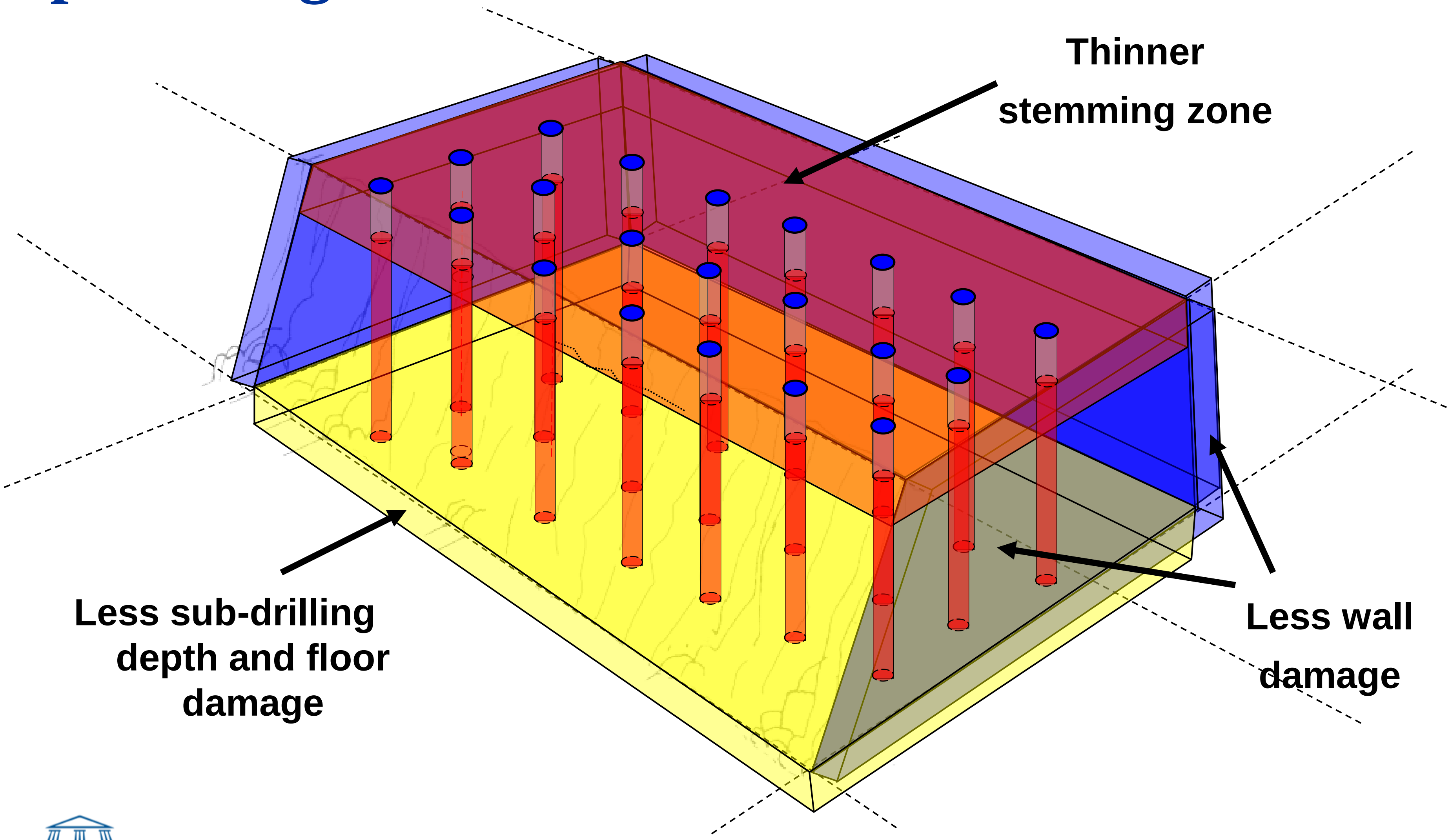
Smaller diameter holes allow for higher overall percentage of crushed rock



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Uniform Gradation - Fine

Uniform Gradation - Coarse

Prior examples come from the same shot!

Program designed shot
using electronic detonators

Drill Hole not charged

"Rubblization"

Chemical Crushing

Fragmentation dictated
by geology

Summary

- **Drill and Blast can be used to produce useful fragmentation that will enable the mechanical crush/screen process to be more cost effective.**
- **Optimized distribution of explosive energy as a function of drill hole diameter, accurate location, explosive product choice, and accurate timing is the key to influencing and controlling rock gradation in the blast muck pile.**
- **Enabling Drill and Blast to influence and control rock gradation leverages it's value as an integral part of the crush and size process - the Chemical Crusher.**

Conclusions

- **A properly designed and built Chemical Crusher can relieve work done by the primary crusher and improve its efficiency.**
- **As is the case with a mechanical crusher, tight tolerances and high quality are a necessity when building the Chemical Crusher.**
- **Implementing drill and blast programs based on the chemical crusher approach, can yield quarry process stream cost savings that are better measured in dollars per ton than in cents per ton.**

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