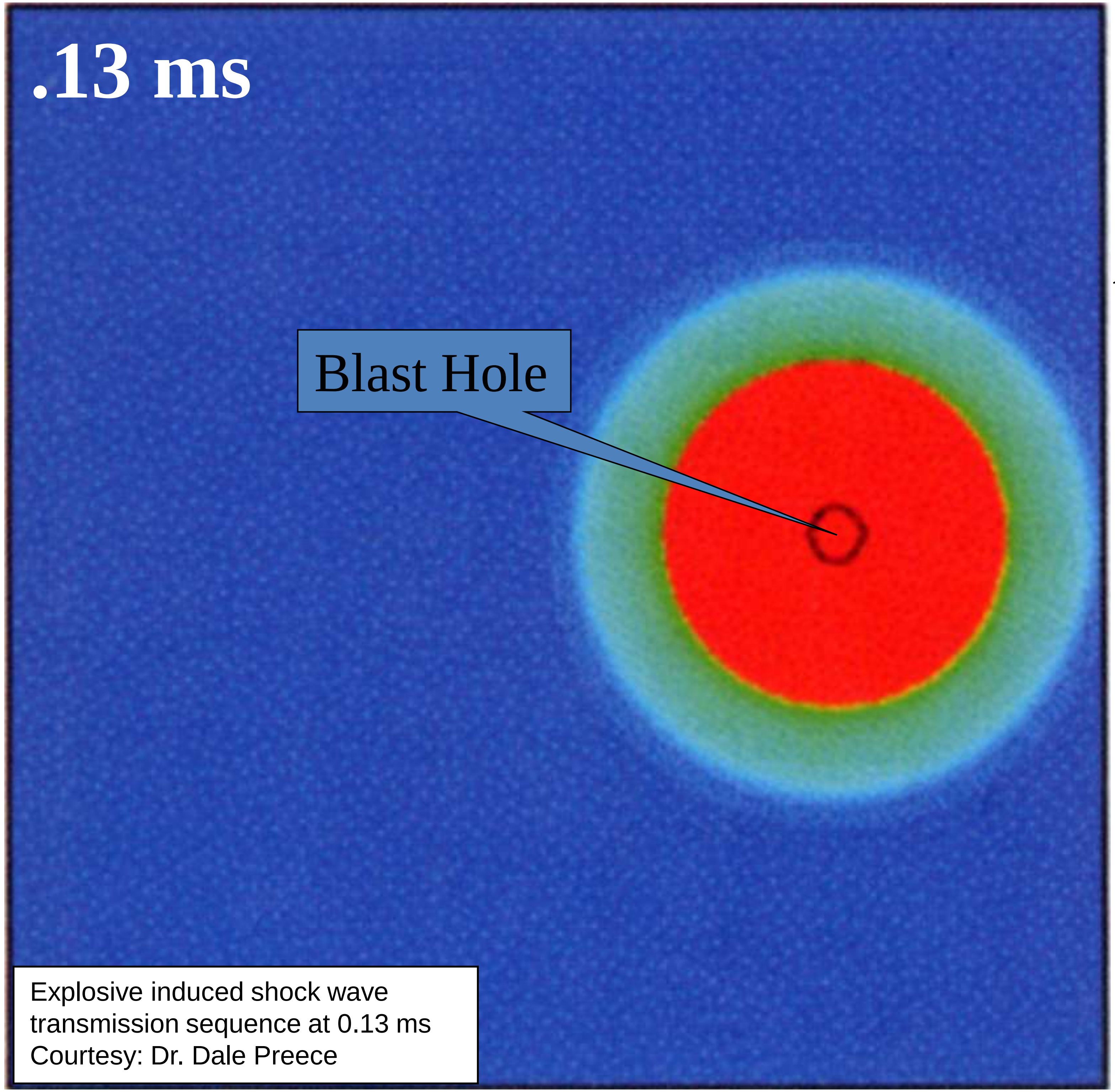


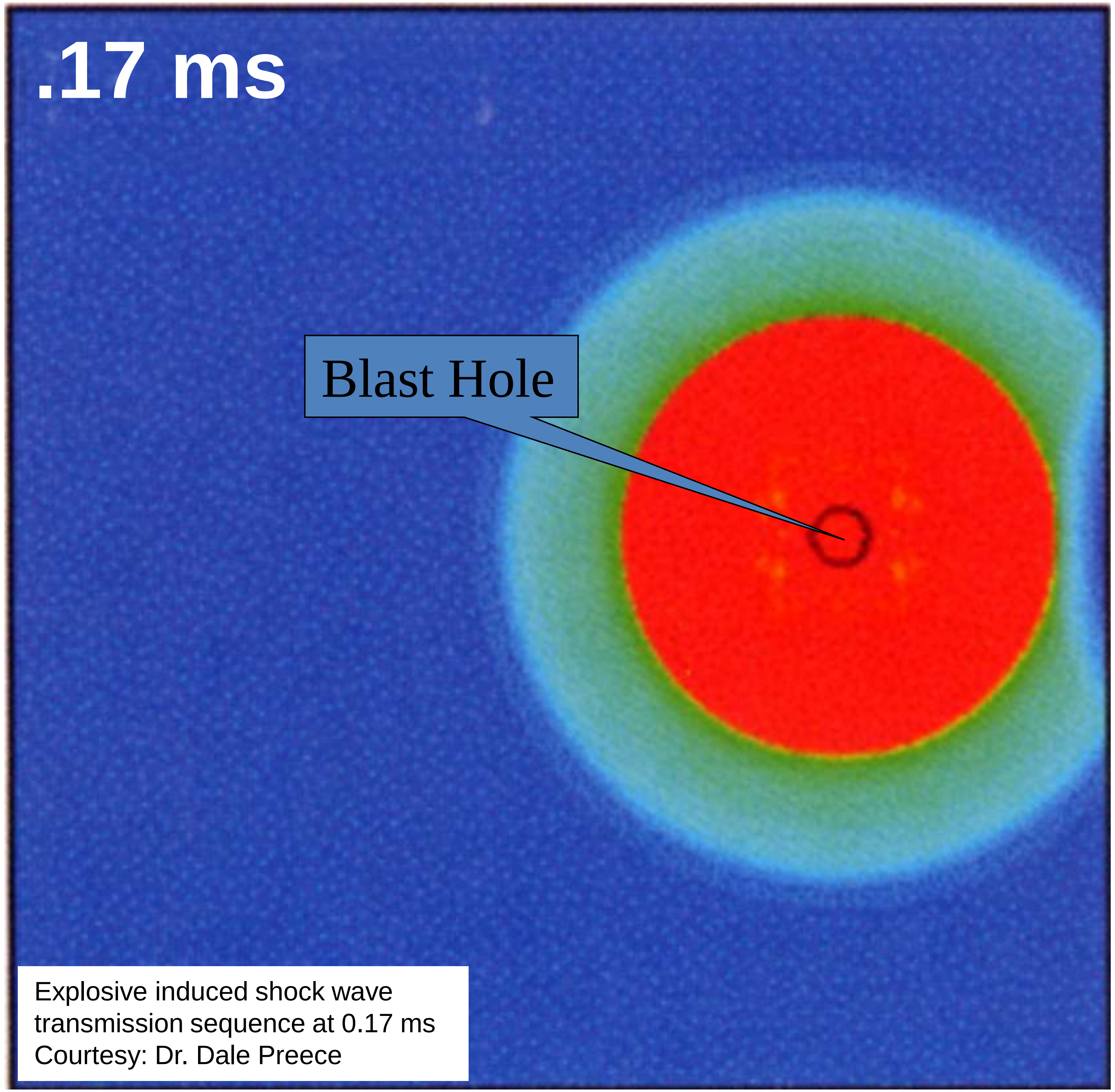
Explosive induced shock wave transmission sequence at 0.13 ms
Courtesy: Dr. Dale Preece

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)

QUARRY ACADEMY

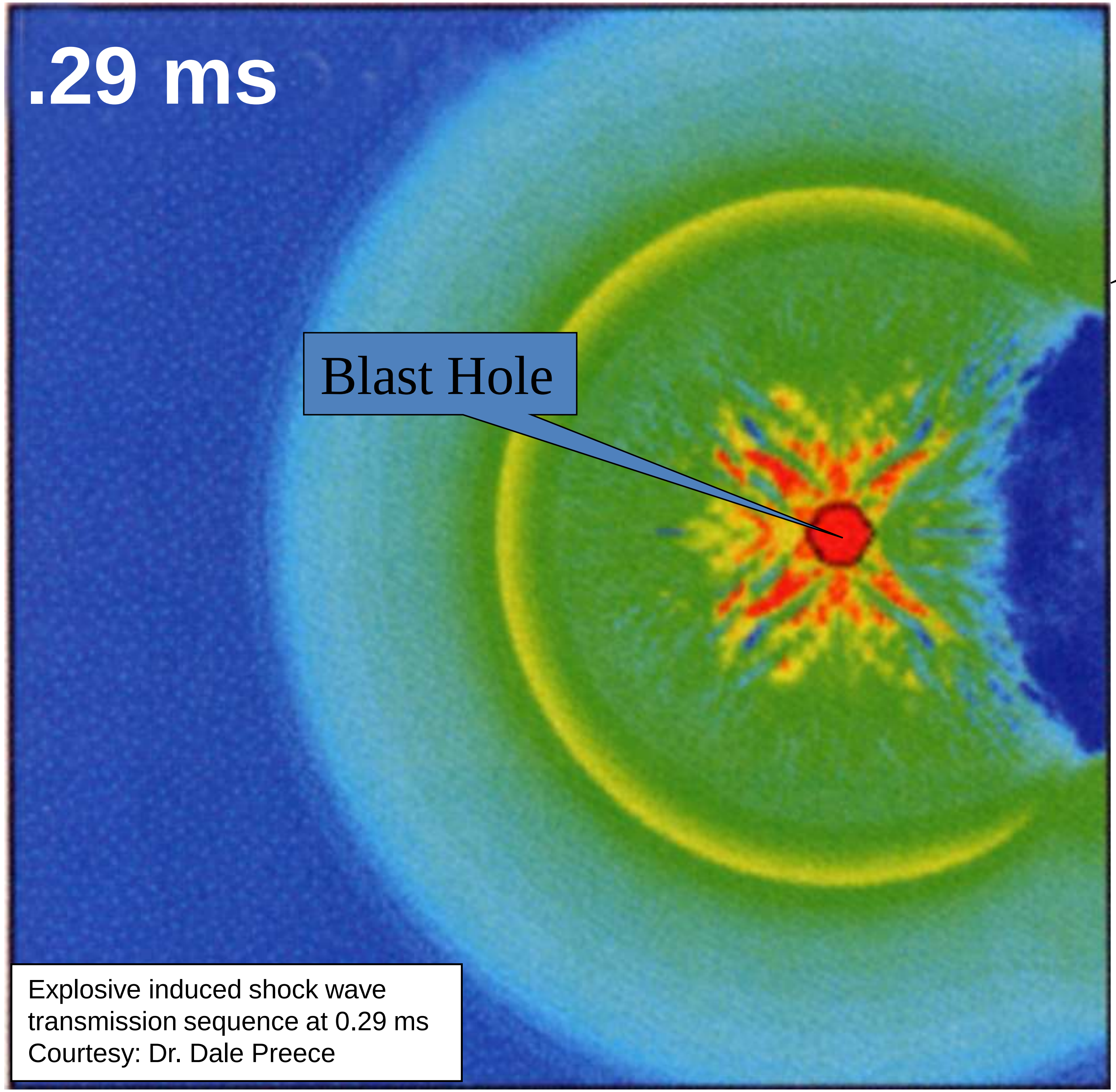


Explosive induced shock wave transmission sequence at 0.17 ms
Courtesy: Dr. Dale Preece

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
	18,000	124,106
	12,000	82,737
	6,000	41,369
	-	-
	(6,000)	(41,369)

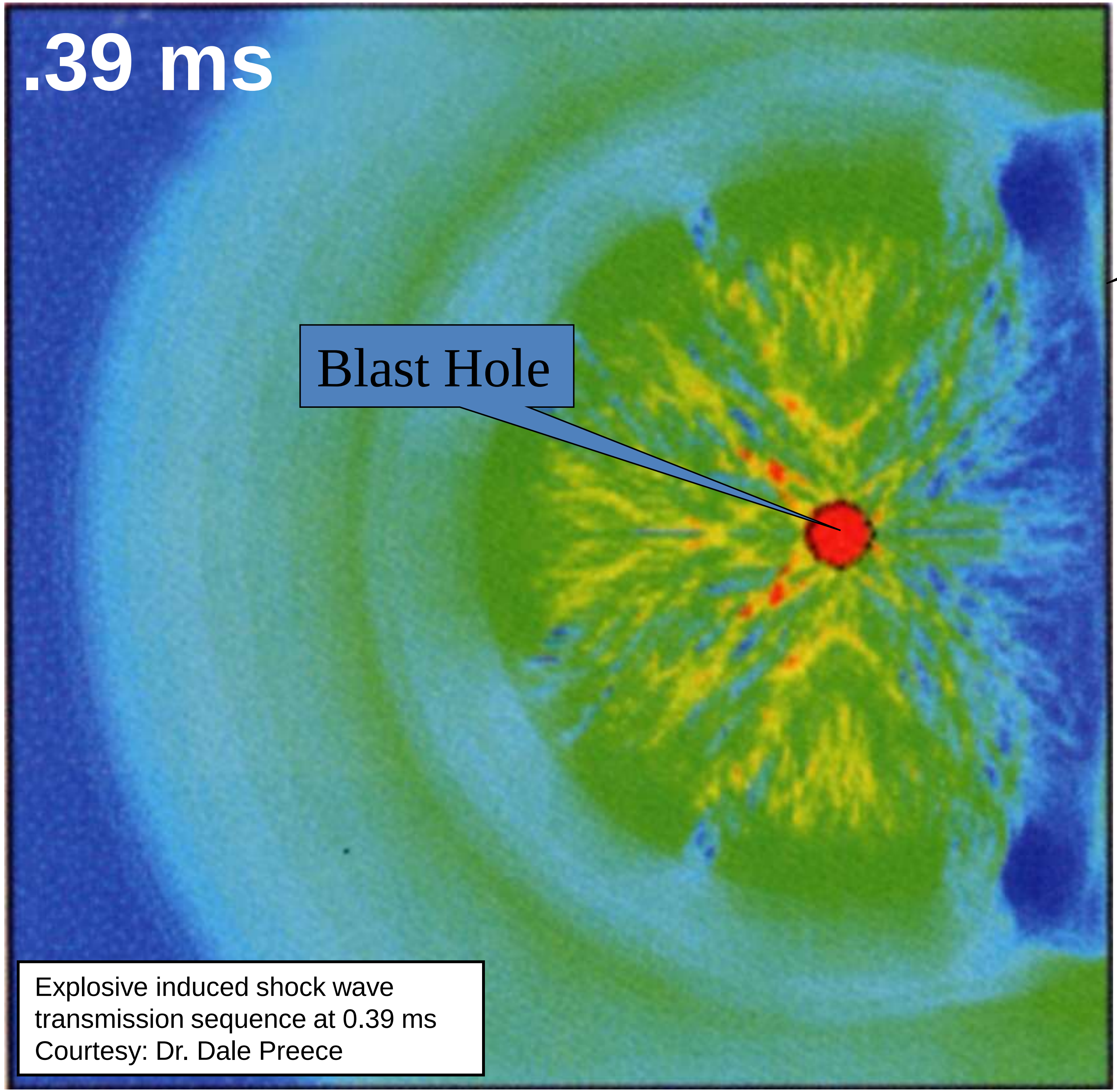
QUARRY ACADEMY



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)

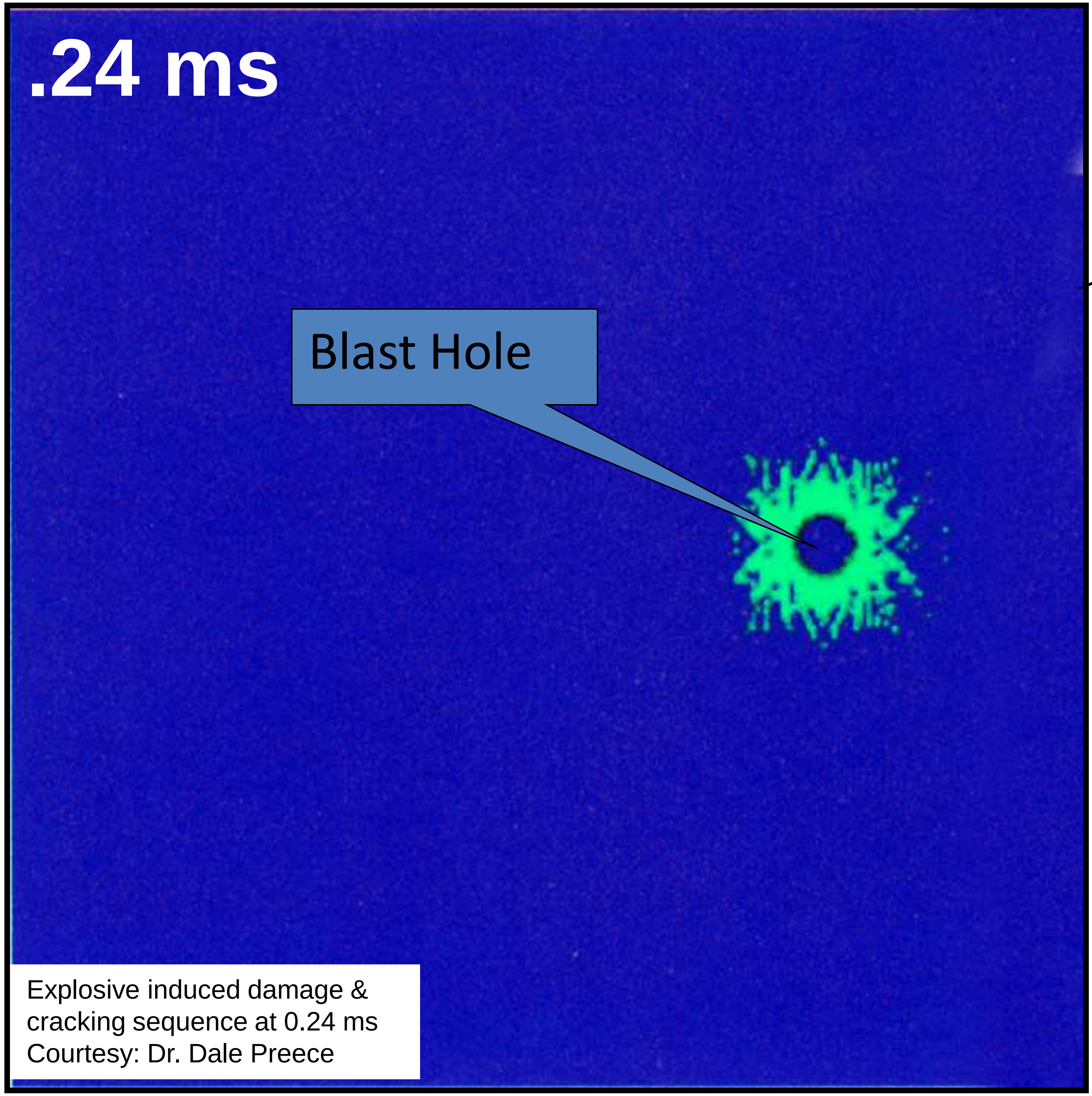


Explosive induced shock wave transmission sequence at 0.39 ms
Courtesy: Dr. Dale Preece

Stress In Vicinity of Blast Hole

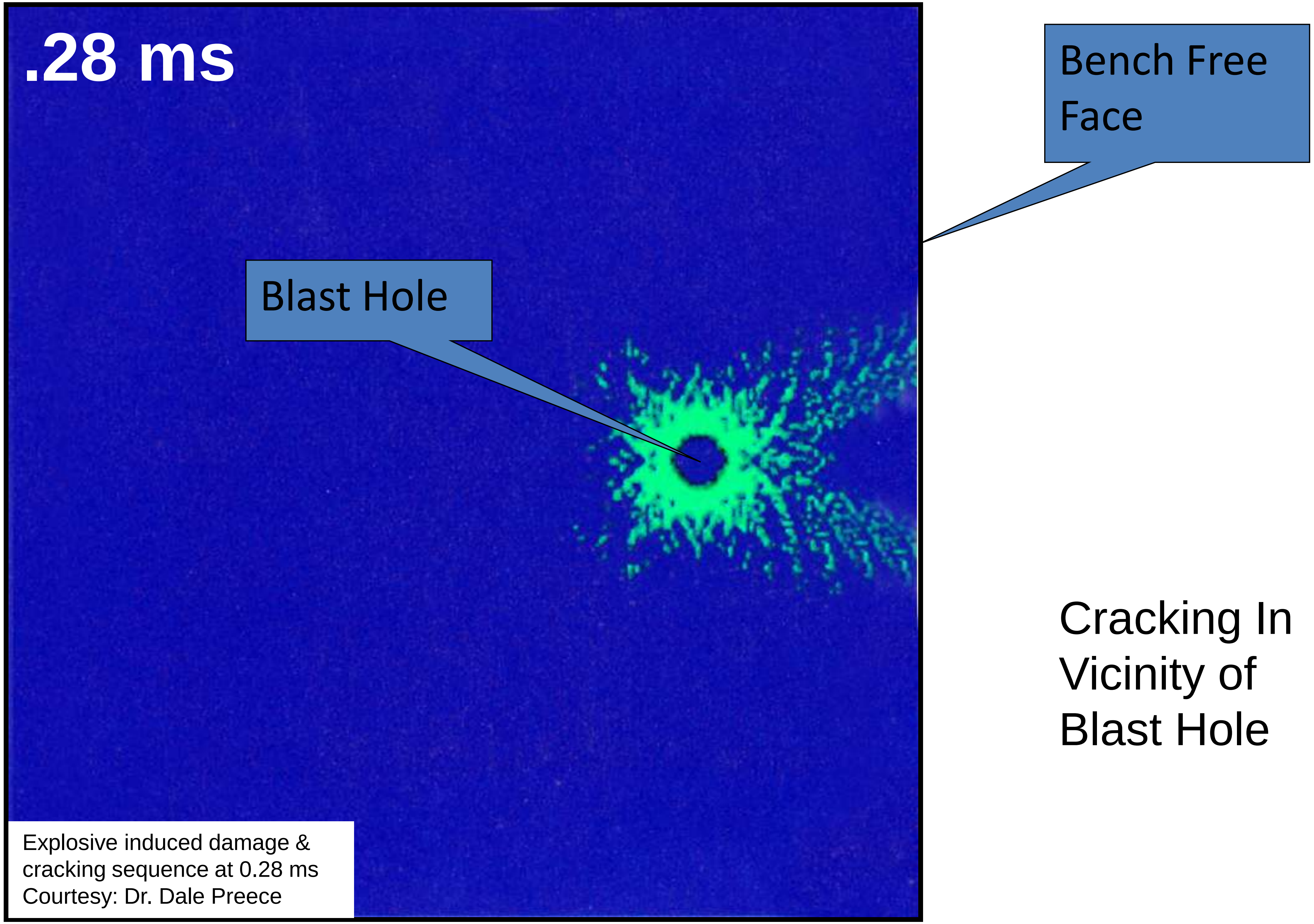
Pressure		
	kPa	PSI
	54,000	372,317
	48,000	330,948
	42,000	289,580
	36,000	248,211
	30,000	206,843
	24,000	165,474
	18,000	124,106
	12,000	82,737
	6,000	41,369
	-	-
	(6,000)	(41,369)

QUARRY ACADEMY



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

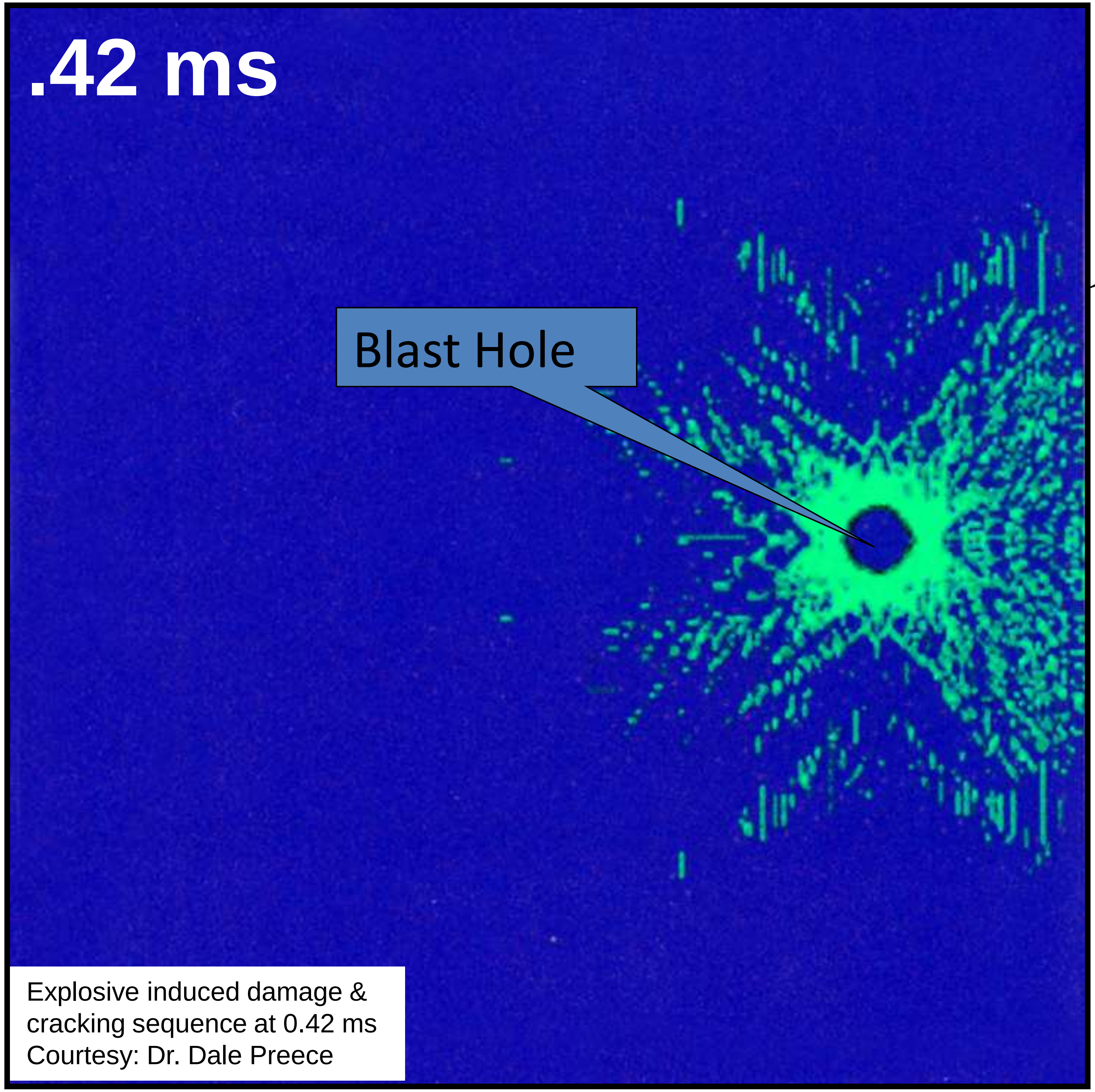
Cracking In Vicinity of Blast Hole



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

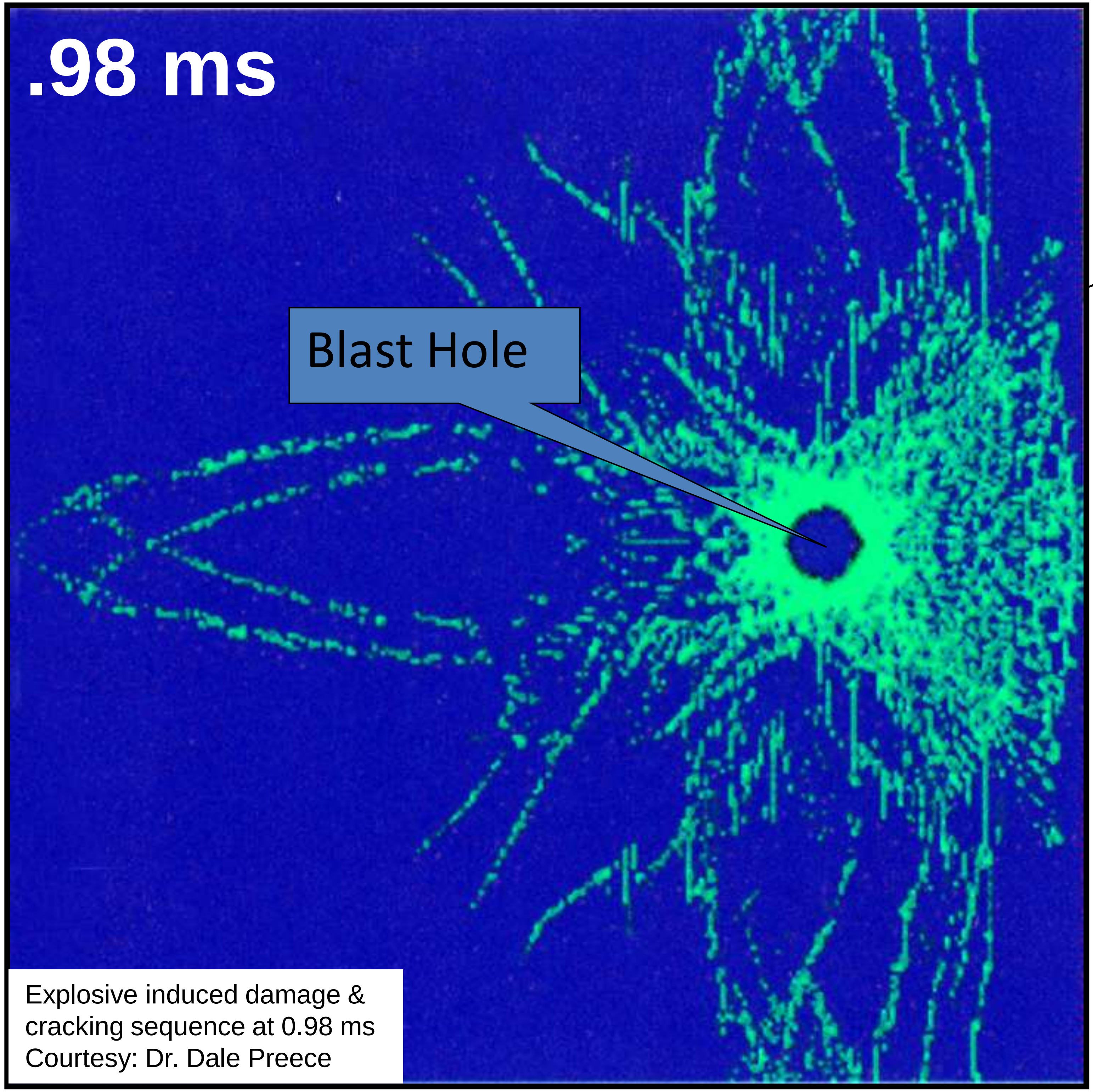
Cracking In Vicinity of Blast Hole

QUARRY ACADEMY



Bench Free Face

Cracking In Vicinity of Blast Hole



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

Cracking In Vicinity of Blast Hole

QUARRY ACADEMY

Basics of Chemical Crushing:

Almost all rock types have a native rock block size in the bench that manifests itself if liberated with sufficient gas pressure. If this native block size is in the desired product or feed range size your operation needs, you have won the lottery.

Most native block sizes are larger than desired for direct saleable product.

QUARRY ACADEMY

Chemical Crusher - Key Design Factors

Exactly Right Energy

Controllable

Uncontrollable

Exactly Right Place Exactly Right Time

Exactly Right Place

QUARRY ACADEMY

Explosive

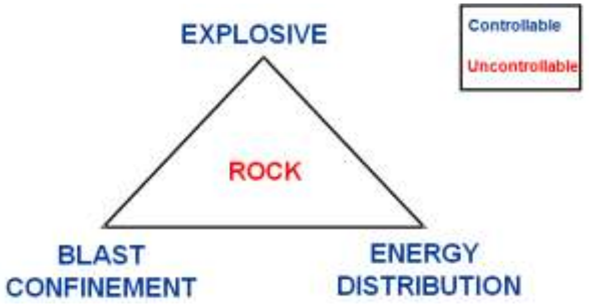
A controllable factor in building the Chemical Crusher

- 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

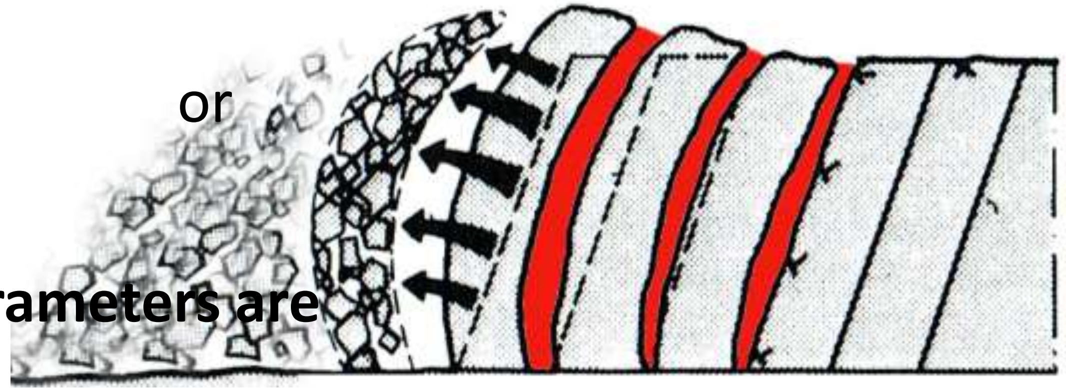
QUARRY ACADEMY

Blast Confinement

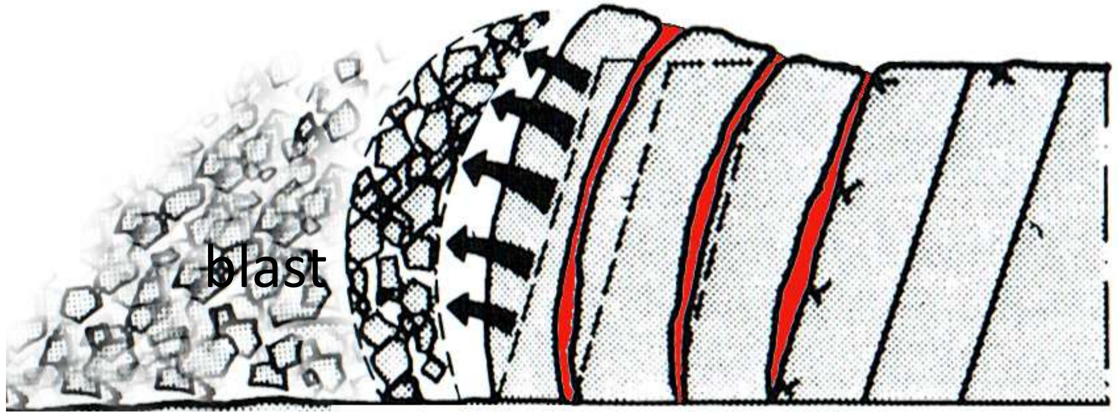
A controllable factor in building the Chemical Crusher



- 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 open 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.



Less Confinement

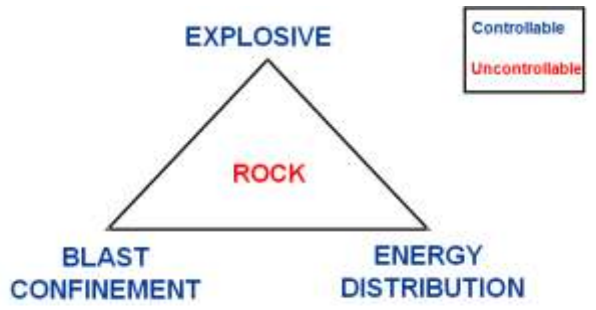


More Confinement

QUARRY ACADEMY

Energy Distribution

A controllable factor in building the Chemical Crusher

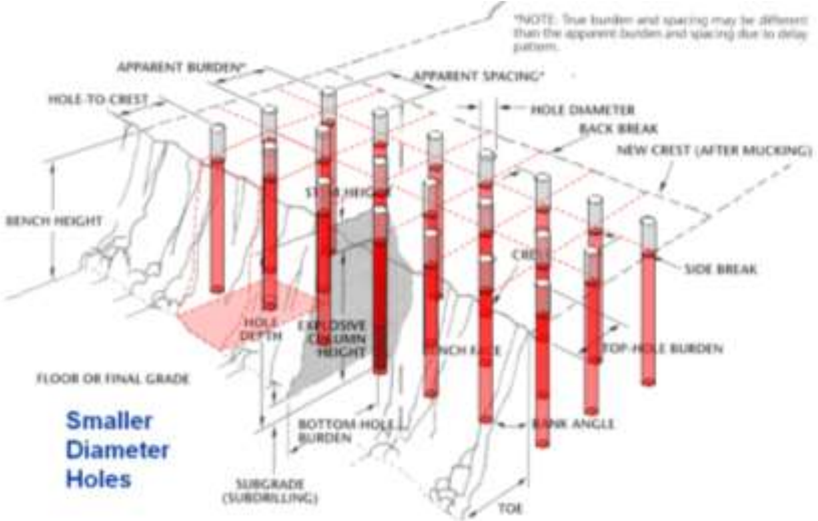


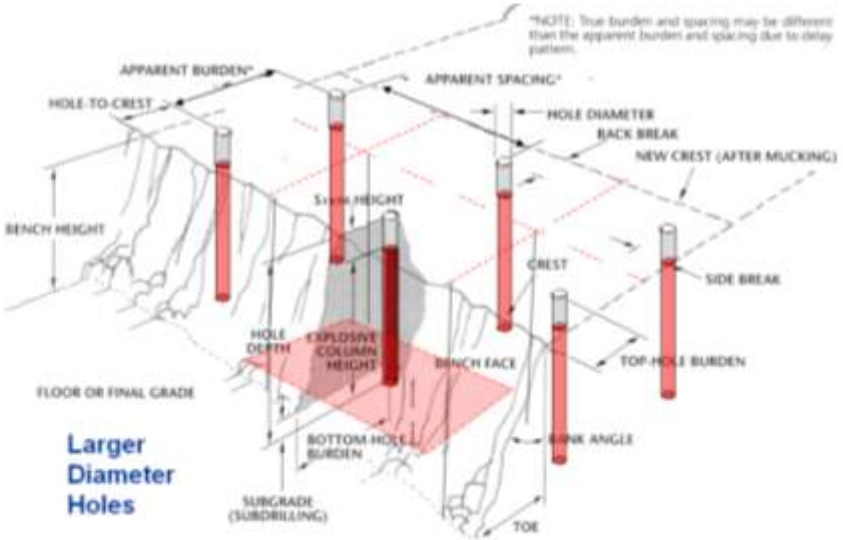
- How the explosive energy is distributed throughout the rock mass to be blasted – vertically and horizontally to do work. Energy Distribution is controlled by:
  - Diameter of the drill hole.

Energy Distribution is the Critical to controlling rock fragment size during the blasting process

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**





QUARRY ACADEMY

Basics of Chemical Crushing:

As with mechanical crushing the rock particle must experience a stress level that exceed it's strength capacity in order for it to be broken.

The trick in a blast is to get that kind of stress applied to each insitu rock particle in the bench during the blast.

QUARRY ACADEMY

The Chemical Crusher: Drilling & Blasting

Exactly Right Energy

Exactly Right Place

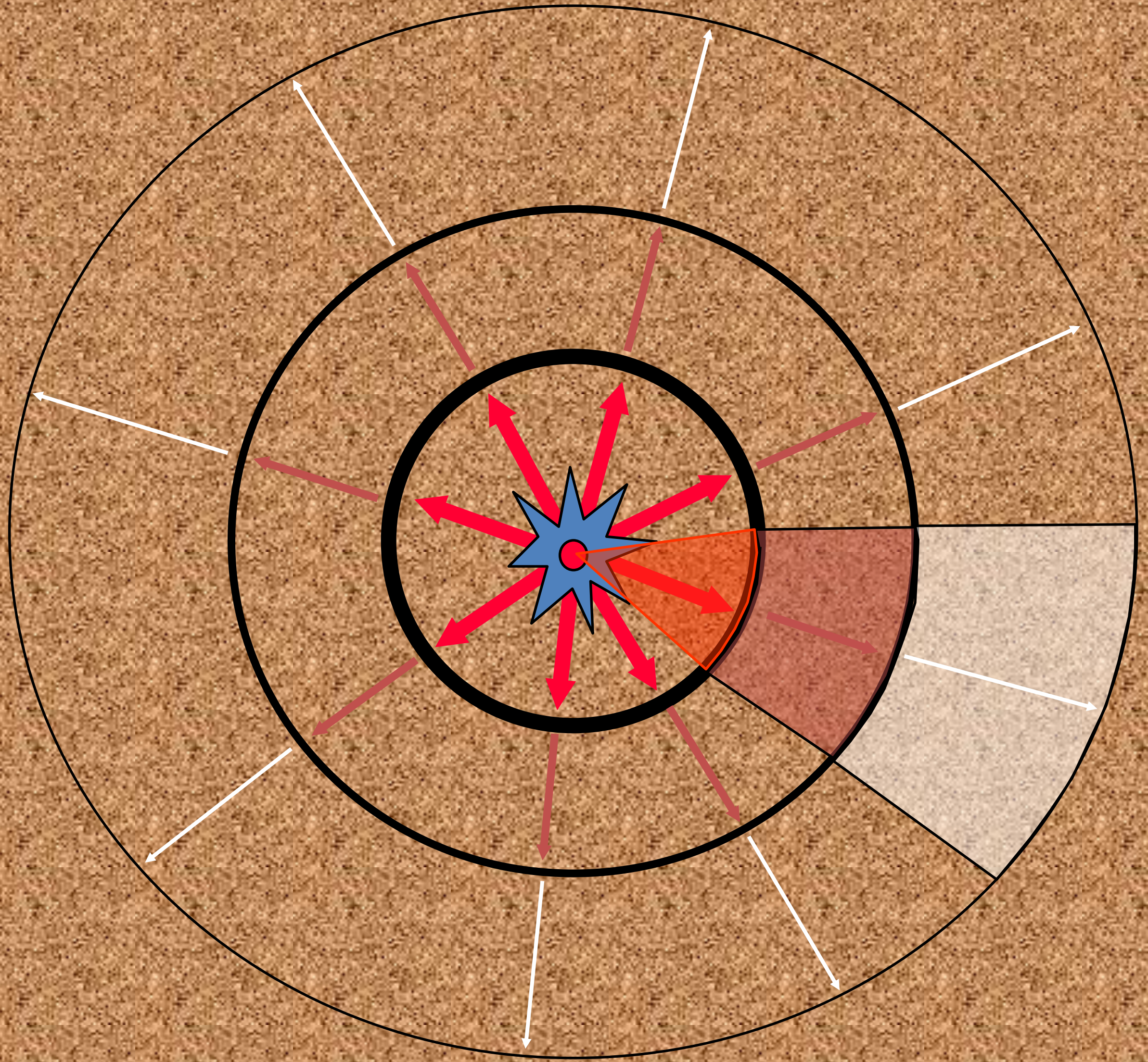
Exactly Right Time

QUARRY ACADEMY

Energy Force Vector Distribution

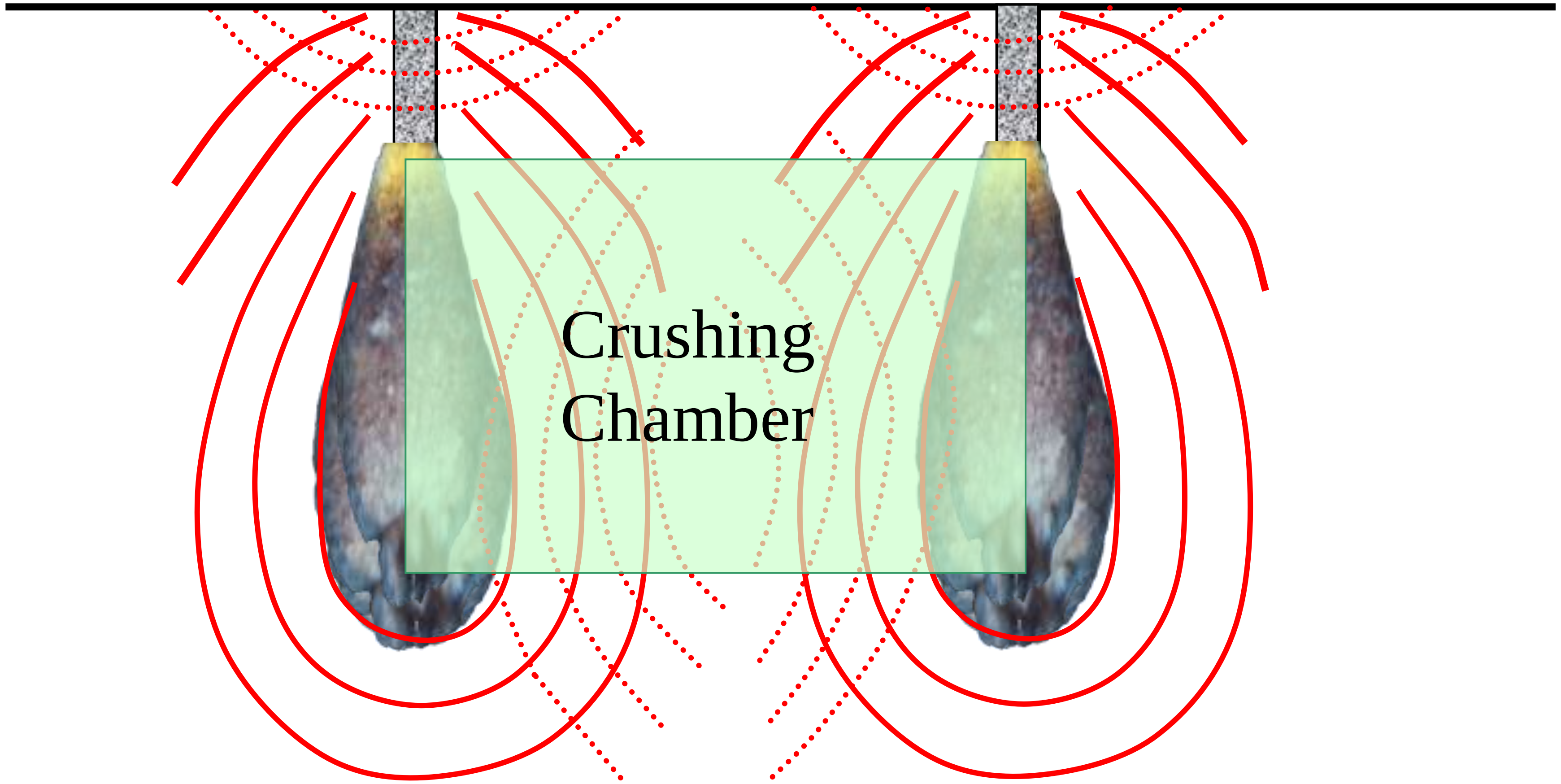
Lower Bench

Upper Bench



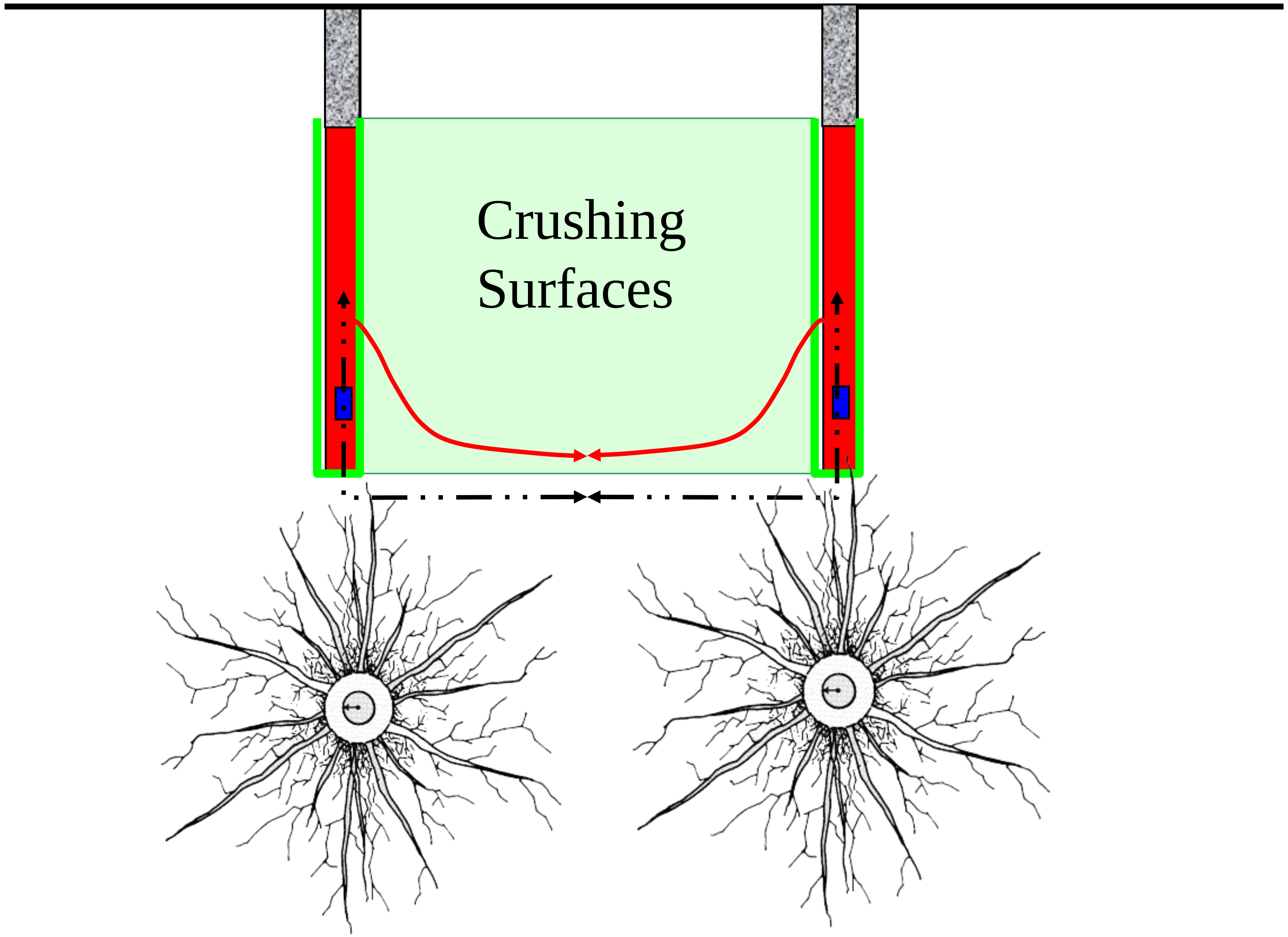
Plan View

Chemical Crusher (conceptually)



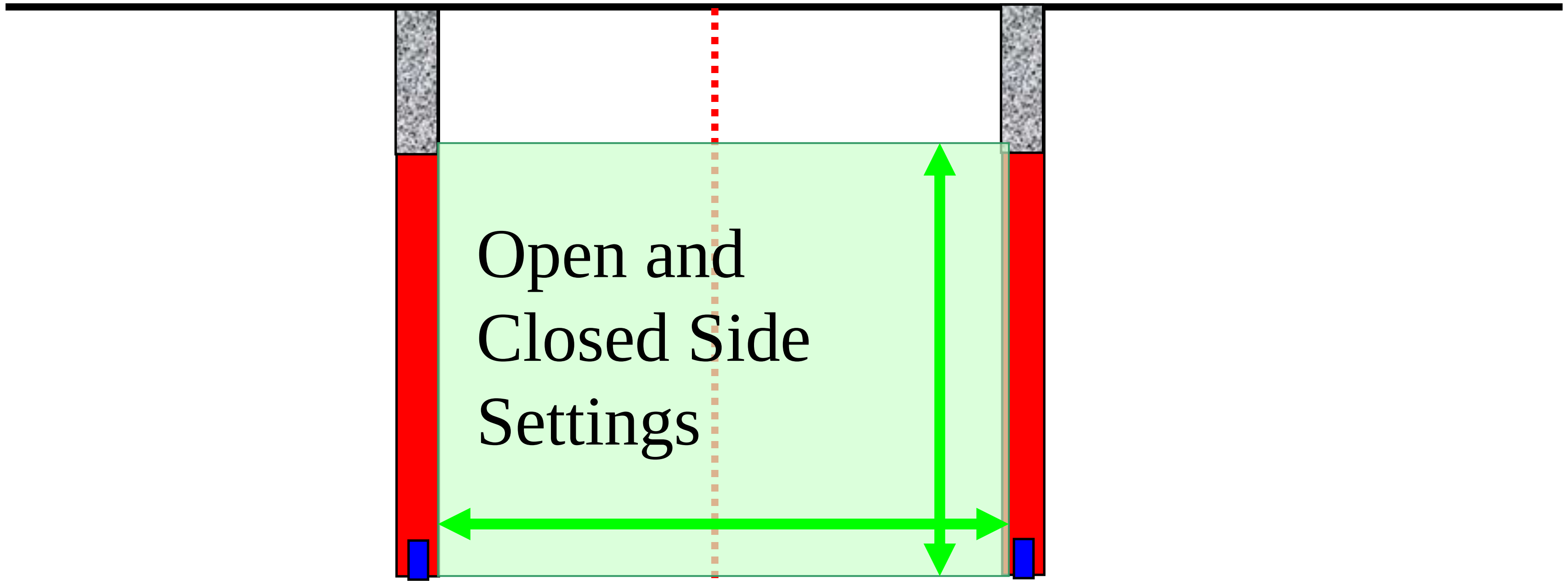
QUARRY ACADEMY

Chemical Crusher (conceptually)

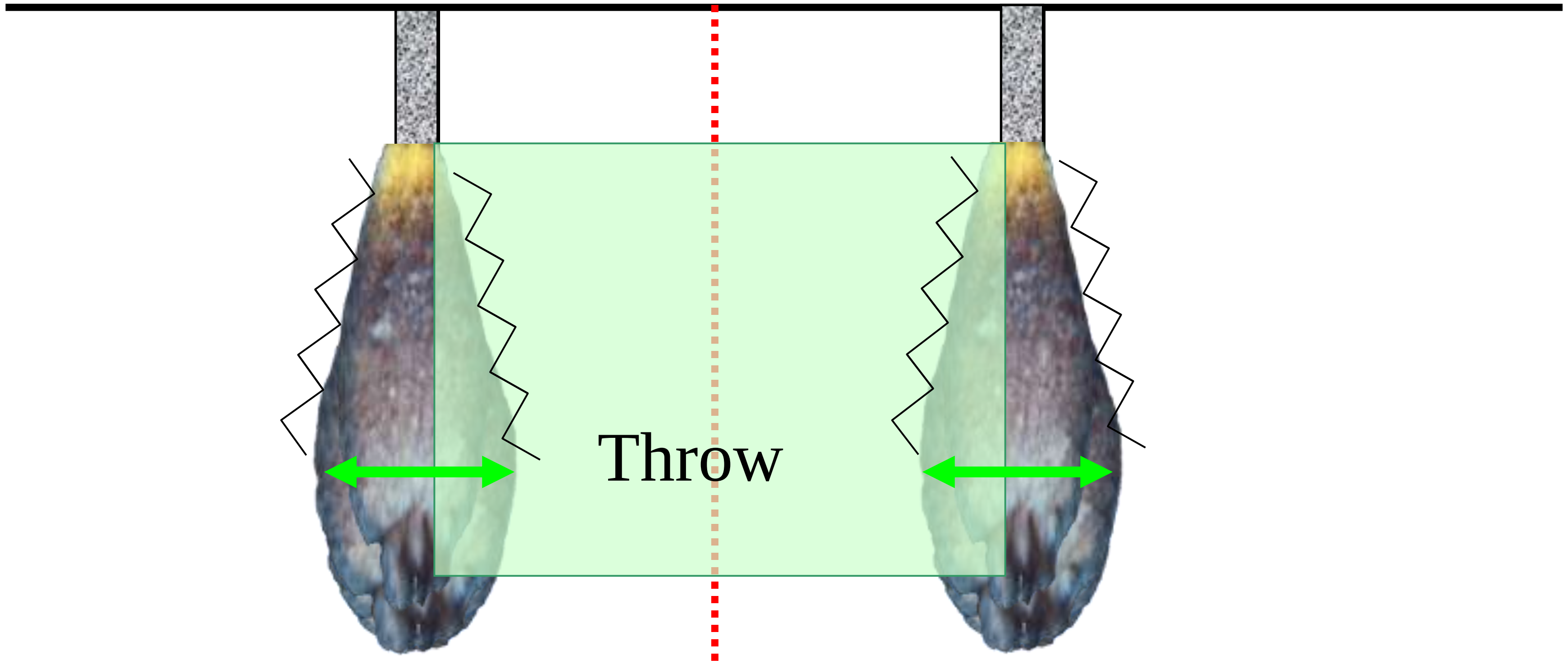


QUARRY ACADEMY

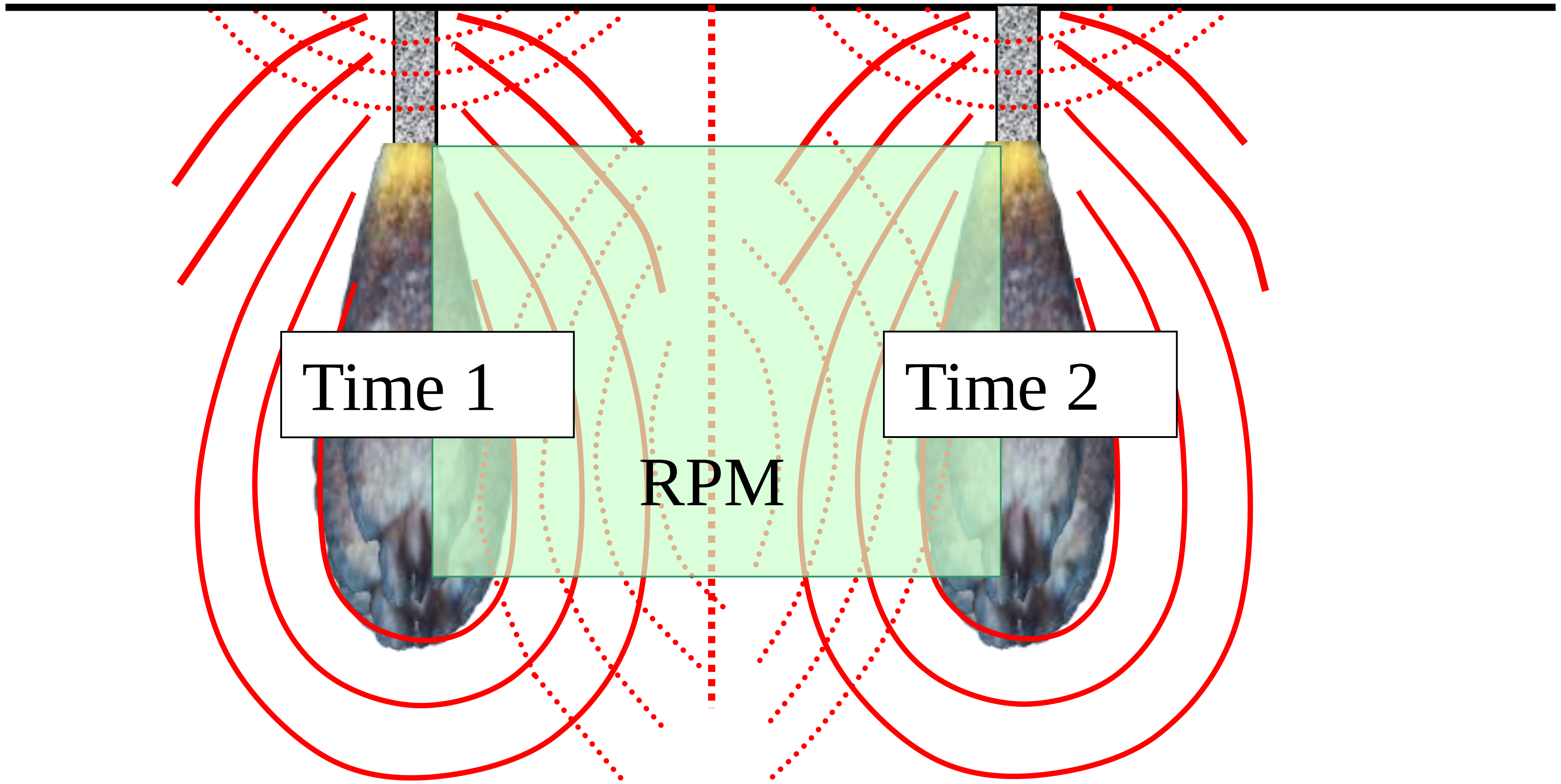
Chemical Crusher (conceptually)



Chemical Crusher (conceptually)

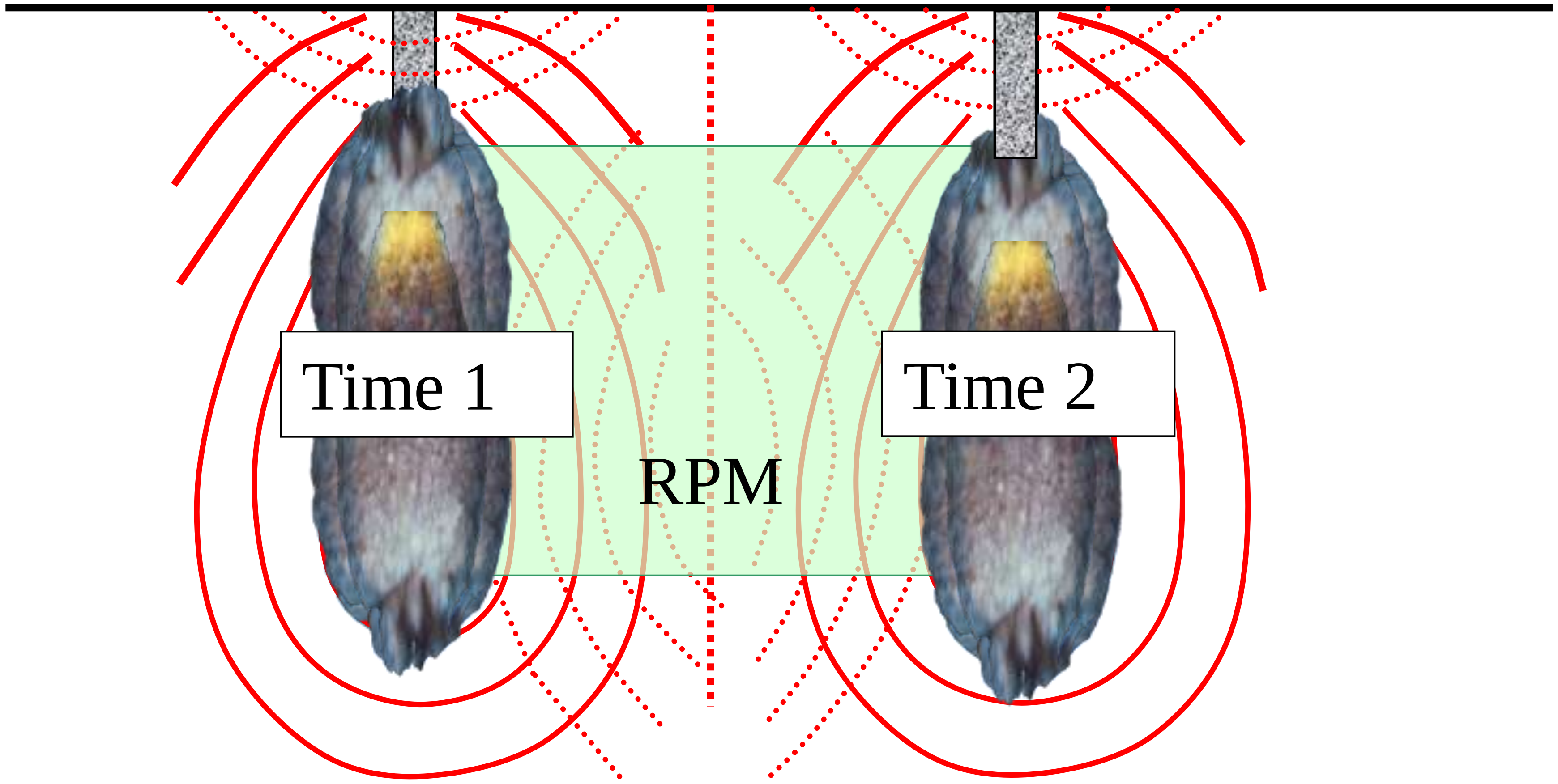


Chemical Crusher (conceptually)



QUARRY ACADEMY

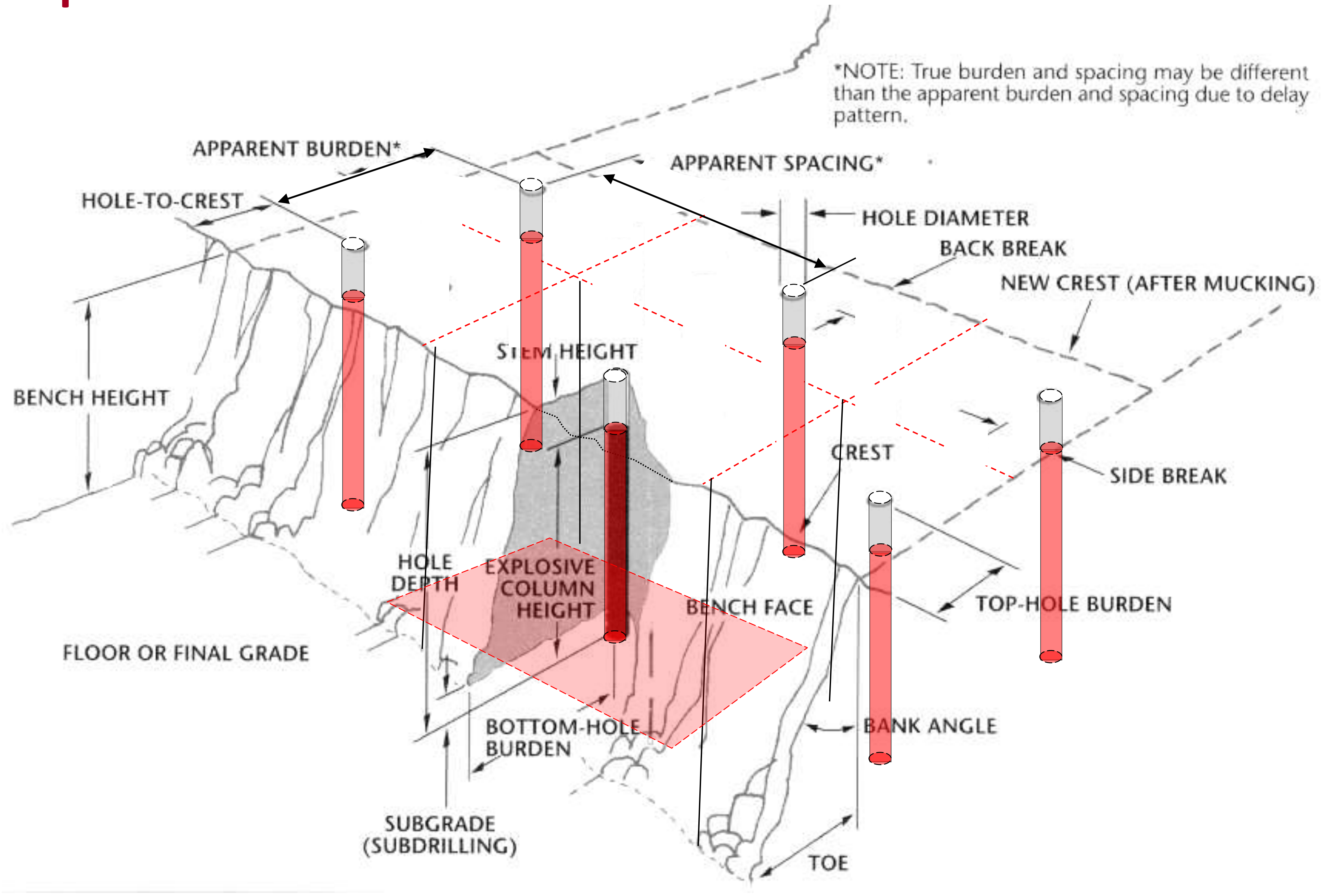
Chemical Crusher (conceptually)



QUARRY ACADEMY

Building the Chemical Crusher

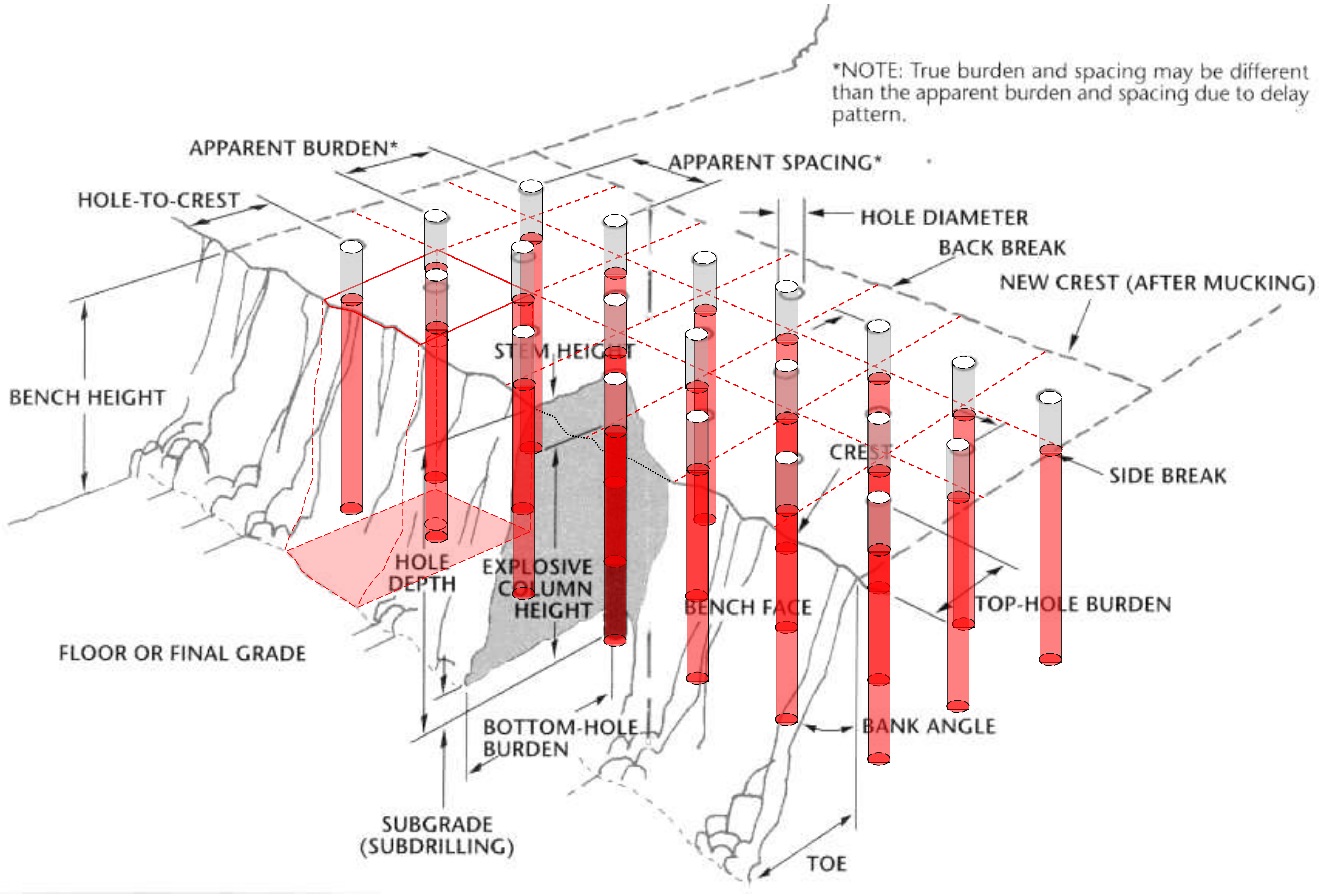
Static view of explosive distribution



Larger Diameter Holes

Building the Chemical Crusher

Static view of explosive distribution

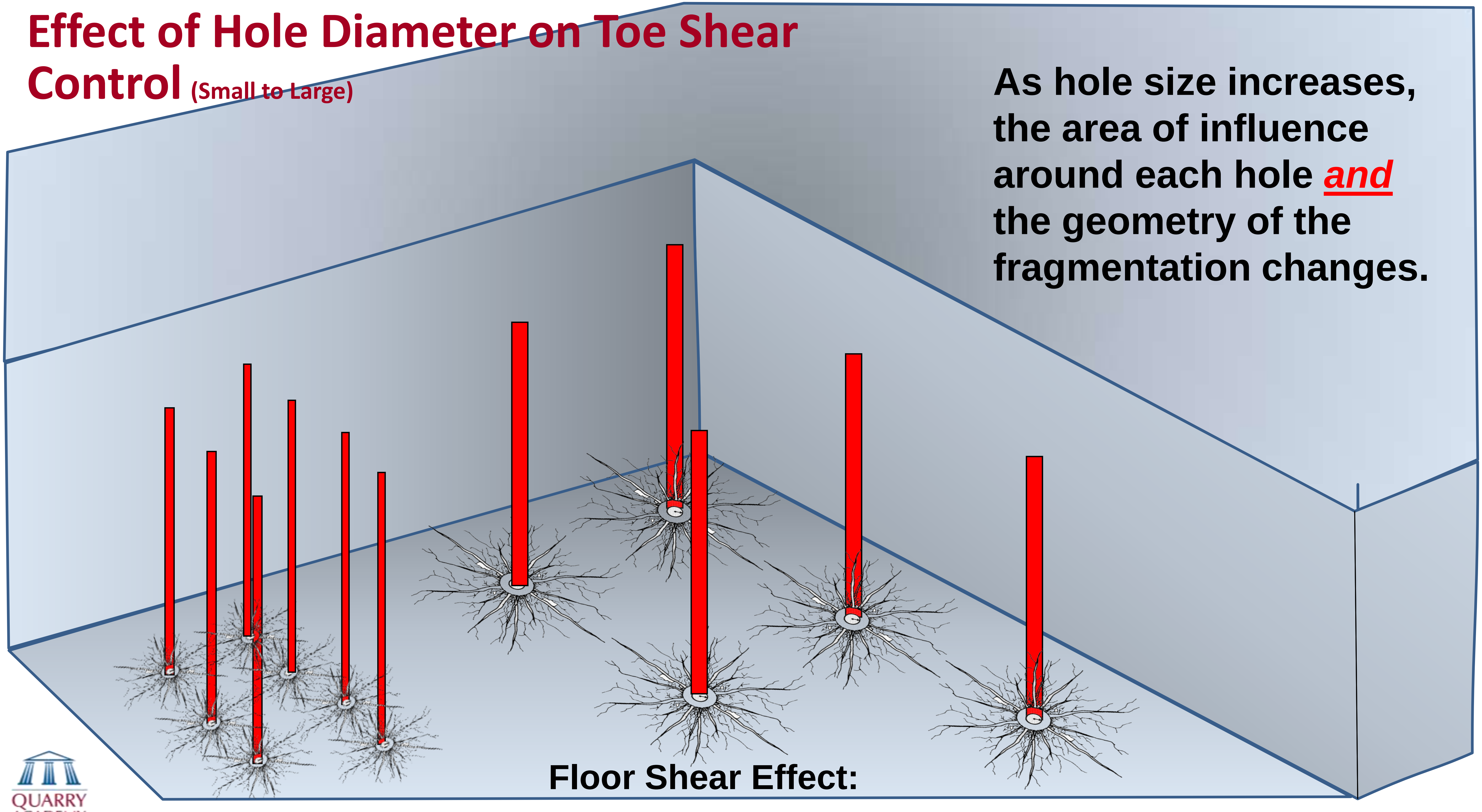


Smaller Diameter Holes

QUARRY ACADEMY

Effect of Hole Diameter on Toe Shear Control (Small to Large)

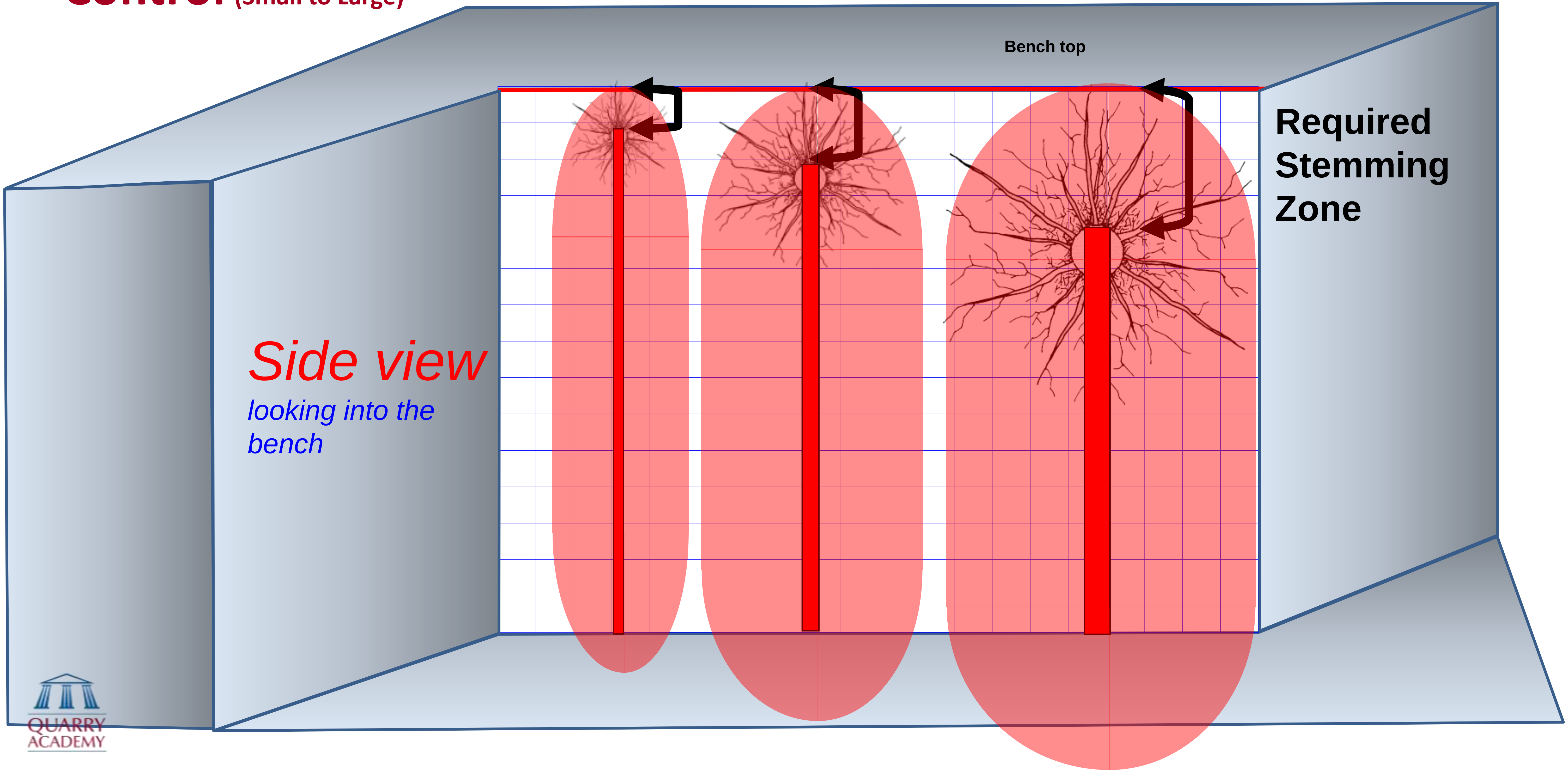
As hole size increases, the area of influence around each hole ***and*** the geometry of the fragmentation changes.



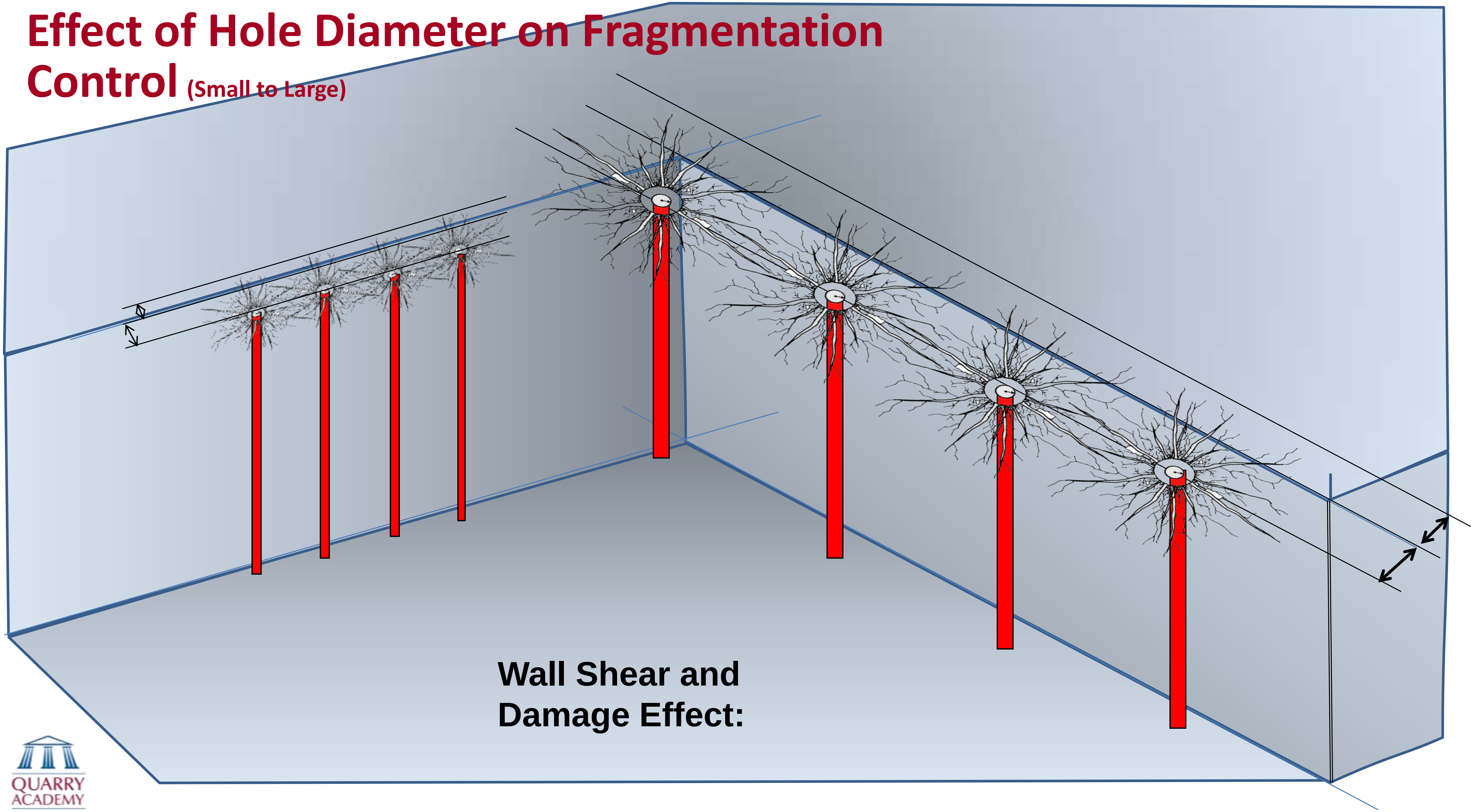
QUARRY ACADEMY

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

Bench Top Effect:

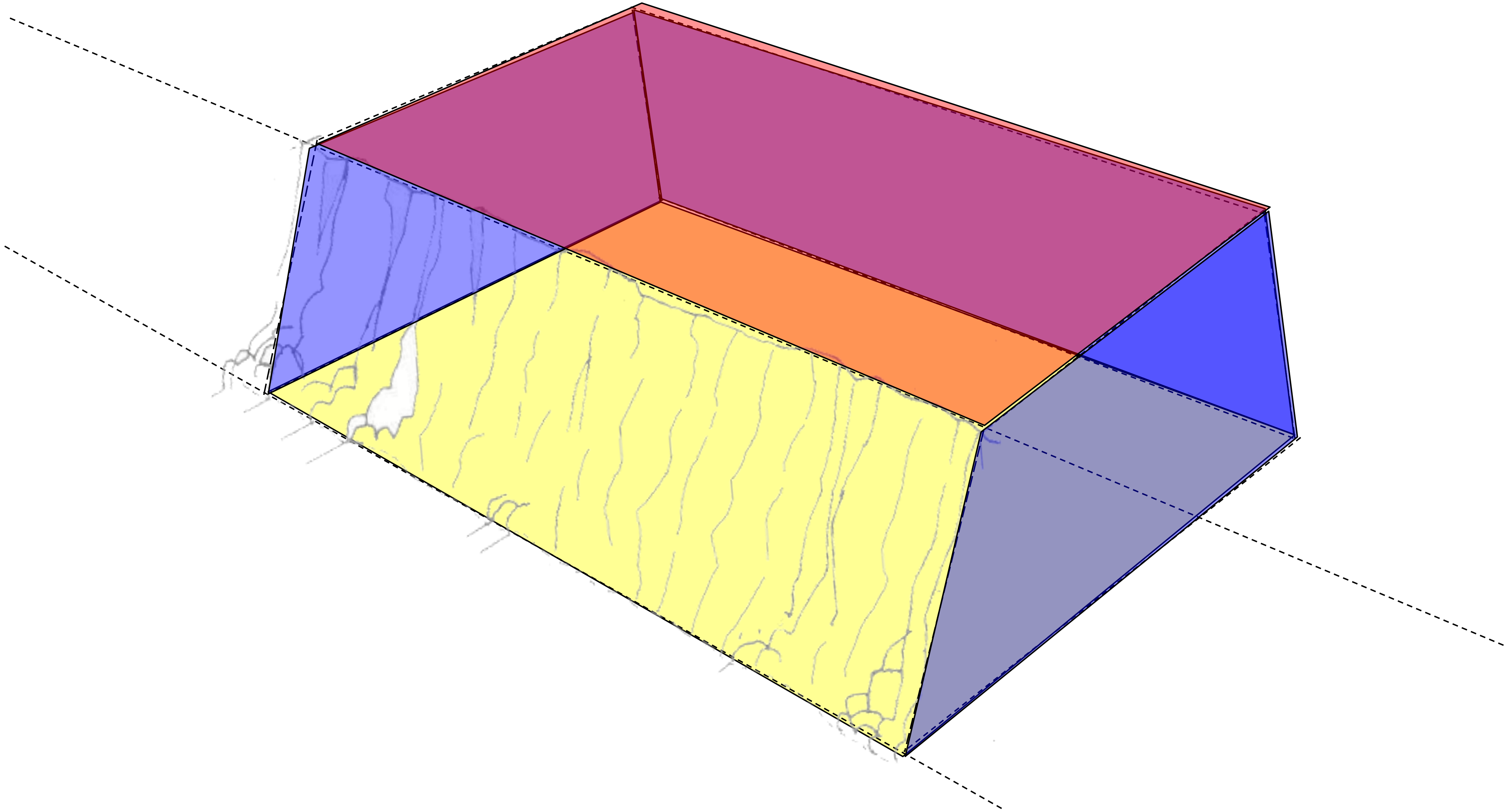


Effect of Hole Diameter on Fragmentation Control (Small to Large)

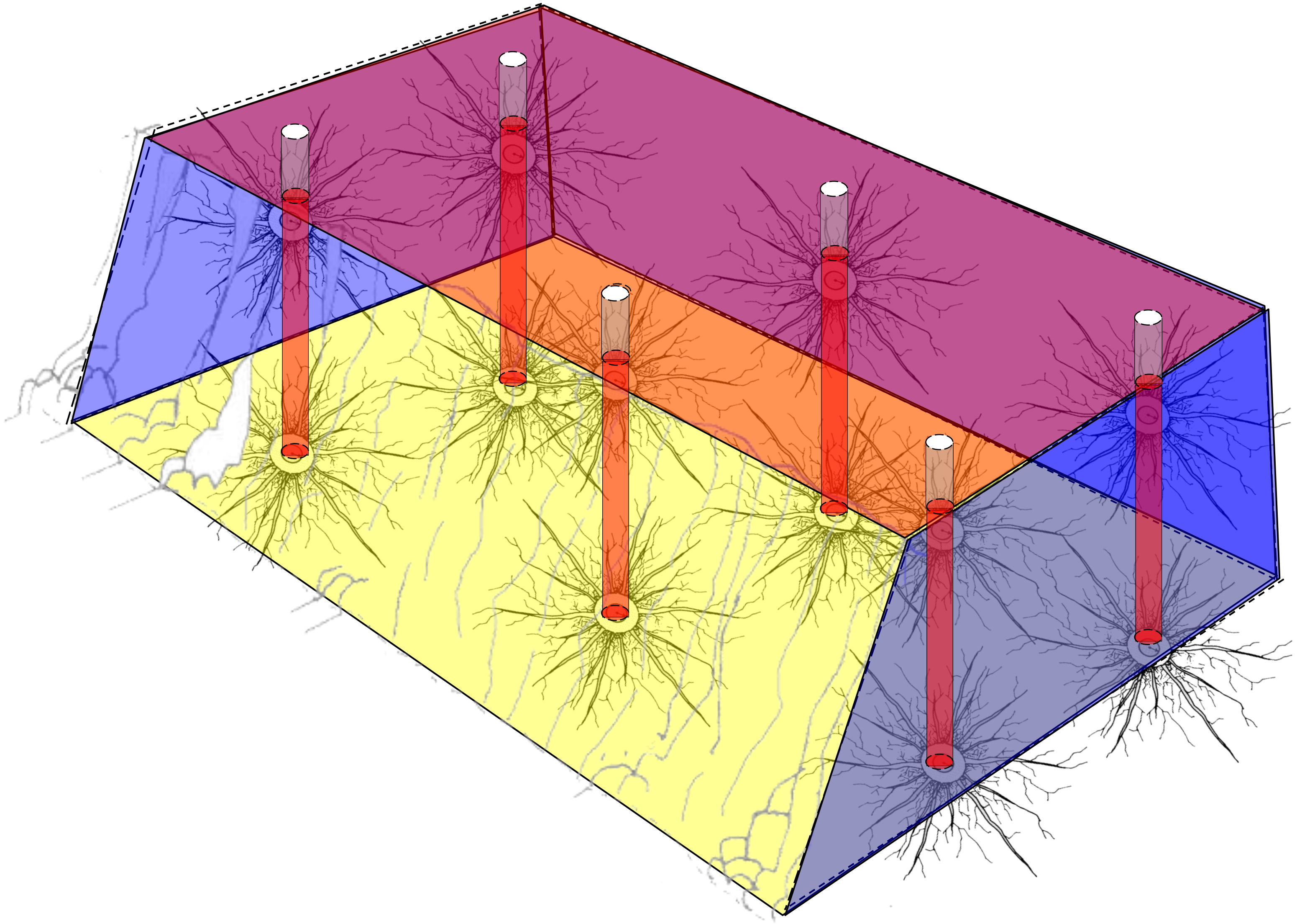


QUARRY ACADEMY

Target Work Zone for Chemical Crusher

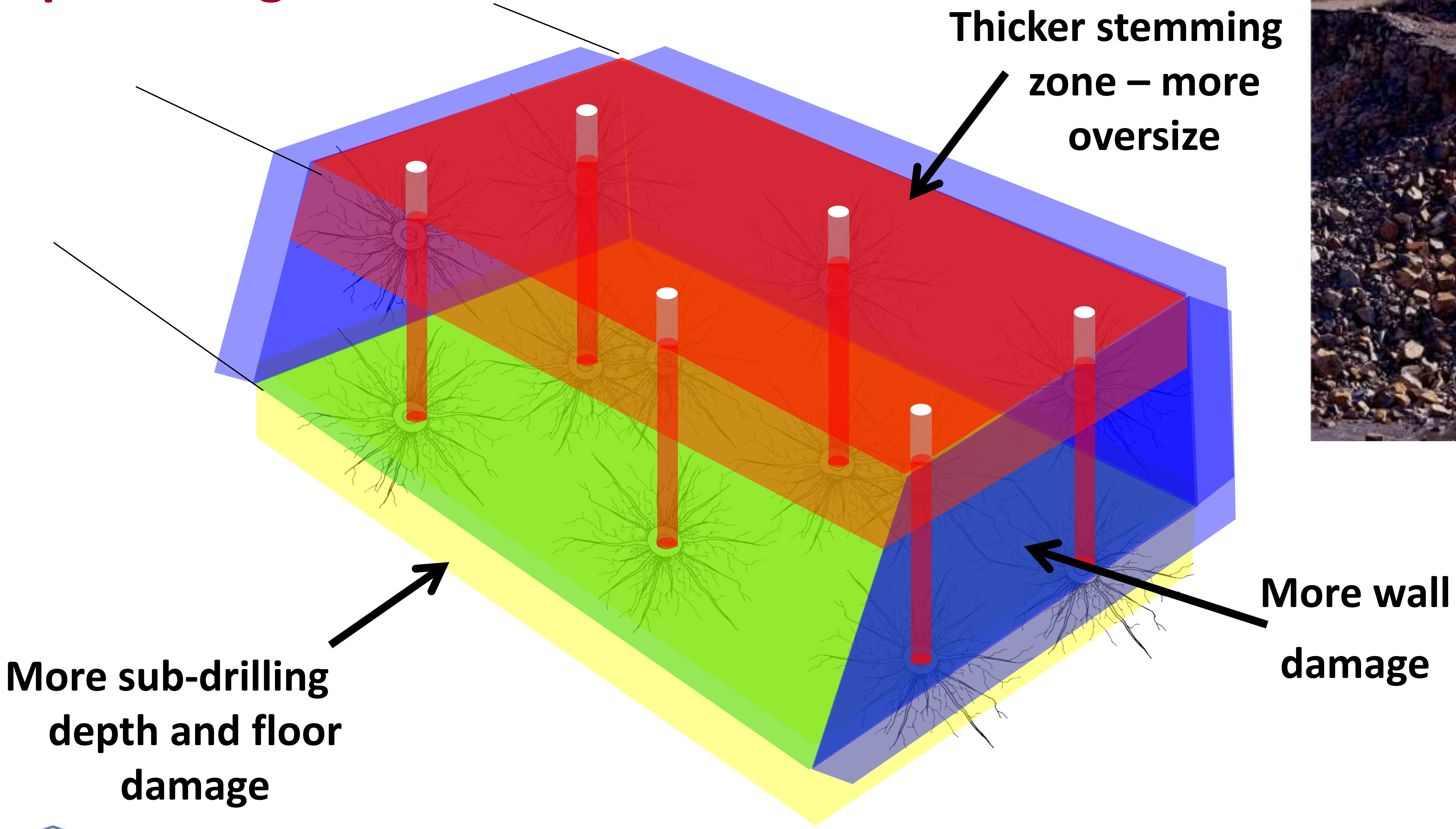


Larger diameter holes in Target Work Zone



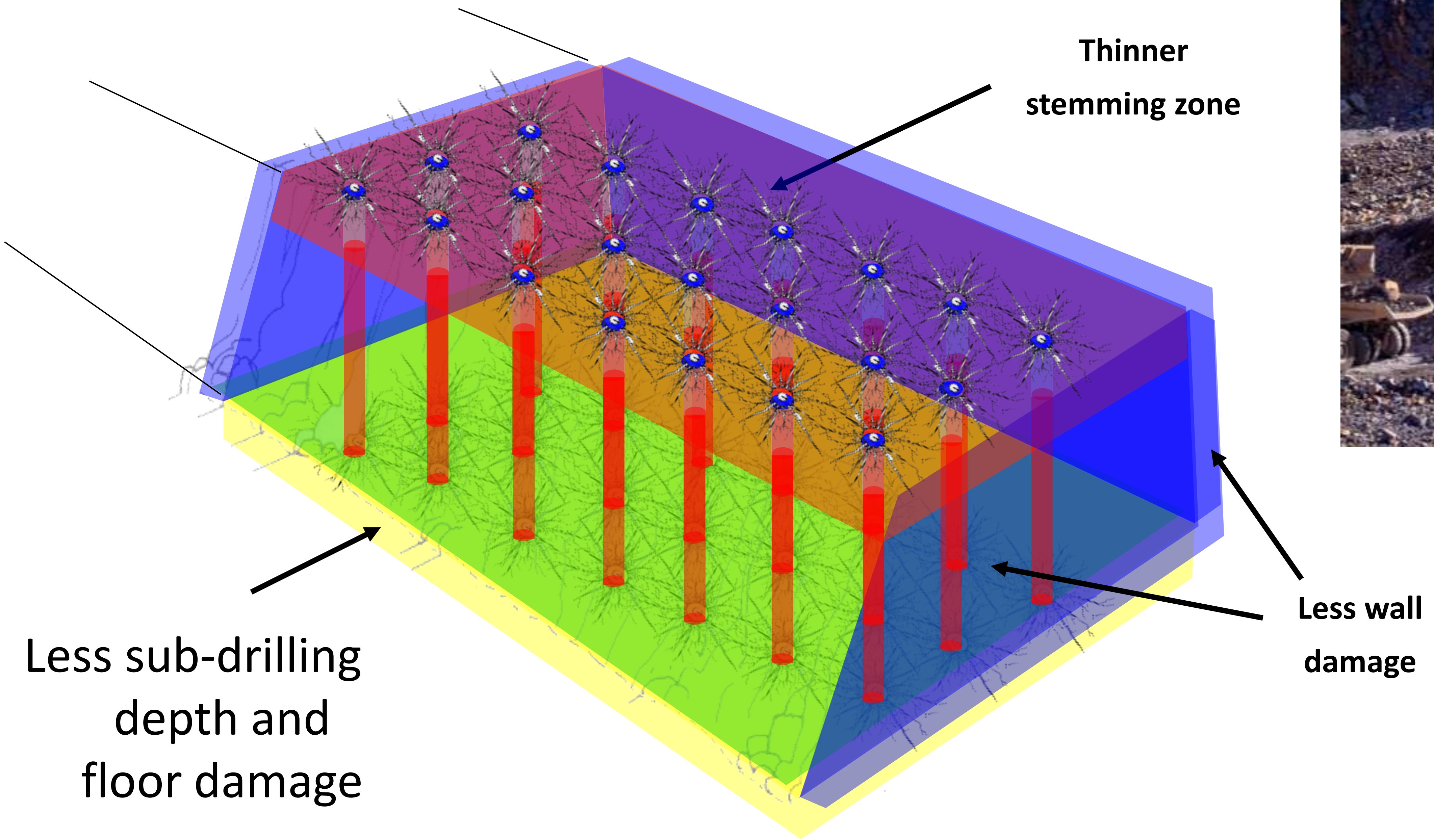
QUARRY ACADEMY

Larger diameter holes allow for smaller overall percentage of crushed rock



QUARRY ACADEMY

Smaller diameter holes allow for higher overall percentage of crushed rock



Less sub-drilling depth and floor damage

QUARRY ACADEMY

Uniform Gradation - Coarse


Uniform Gradation - Fine

Prior examples come from the same shot!

Program designed shot using electronic detonators

Drill Hole not charged

“Rubblization”

Chemical Crushing

Fragmentation dictated by geology

Blast Dynamics
Stress / Pressure Dissipation

H_d = Hole Diameter

UCS = Unconfined compressive Strength of rock

Step 1 = Pulverized Zone

Blast hole diameter expanded

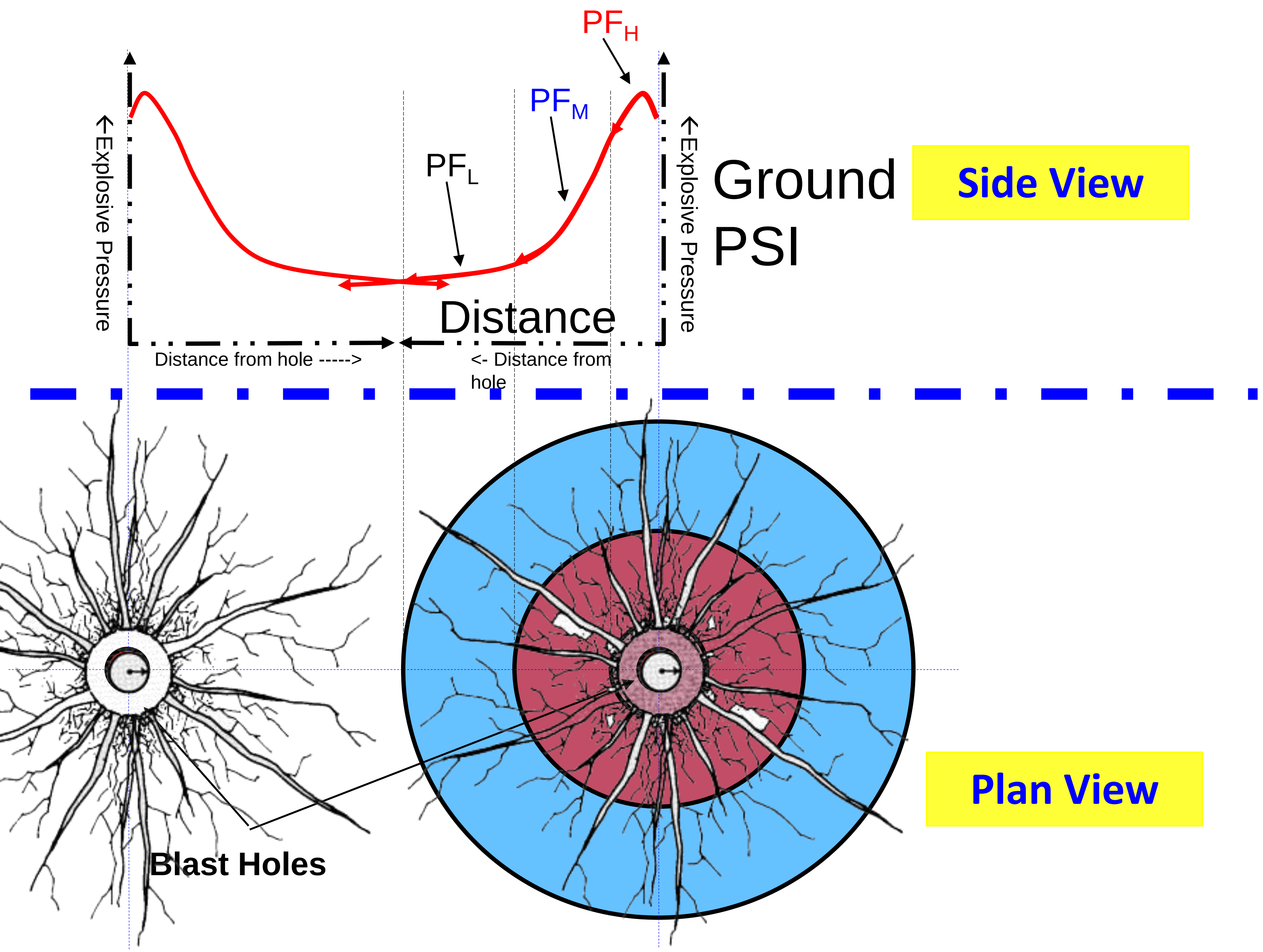
Step 2 = Intense fracturing and cleaving of minerals

Blast Hole Pressure > Rock UCS

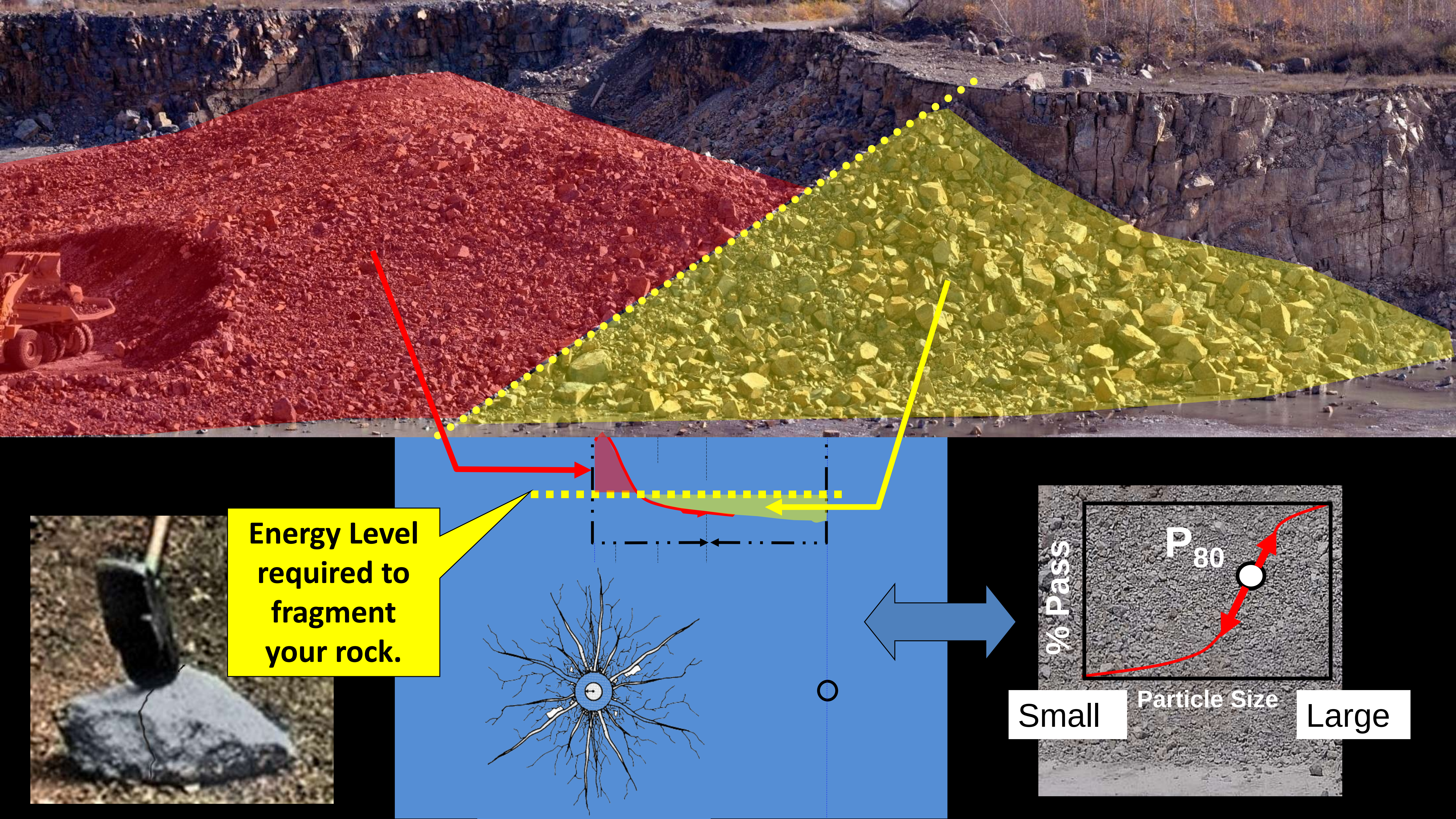
Step 3 = Minimum stress pressure in rock from blast

Step 4 = Damage limit to rock

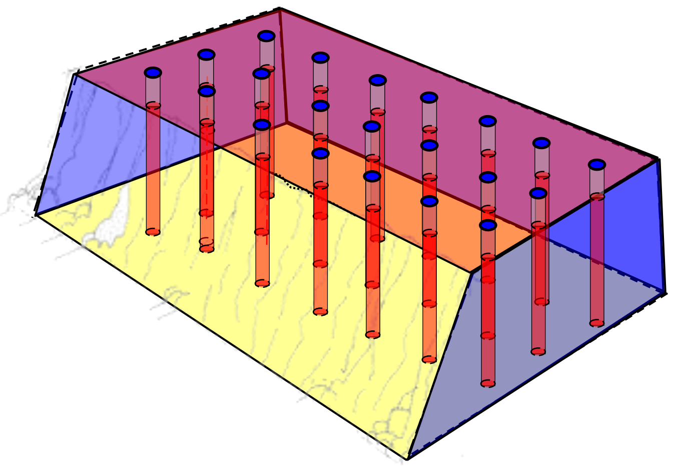
Pre-existing blocks are loosened and moved



QUARRY ACADEMY


Energy Level required to fragment your rock.
% Pass
P_{80}
Particle Size
Small
Large

New Normal Drill/Blast Protocol For Chemical Crushing:



- **Clean up the face.**
- **Survey the face and bench area to be blasted.**
- **Design the shot allowing for actual bench geometry and exposed geology.**
- **Layout the shot according to the shot design.**
- **Generate a driller's log for additional bench data to modify the blast design.**
- **Carefully charge and stem the shot.**
- **Video and photograph the shot to judge blast response.**

Summary

- Drill and Blast can be used to produce useful fragmentation that will enable the mechanical crush/screen process to be more cost effective, productive, and safer.

- 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.

QUARRY ACADEMY

Summary

- 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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