Managing Muckpile Fragmentation Workshop

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Improving Processes. Instilling Expertise.
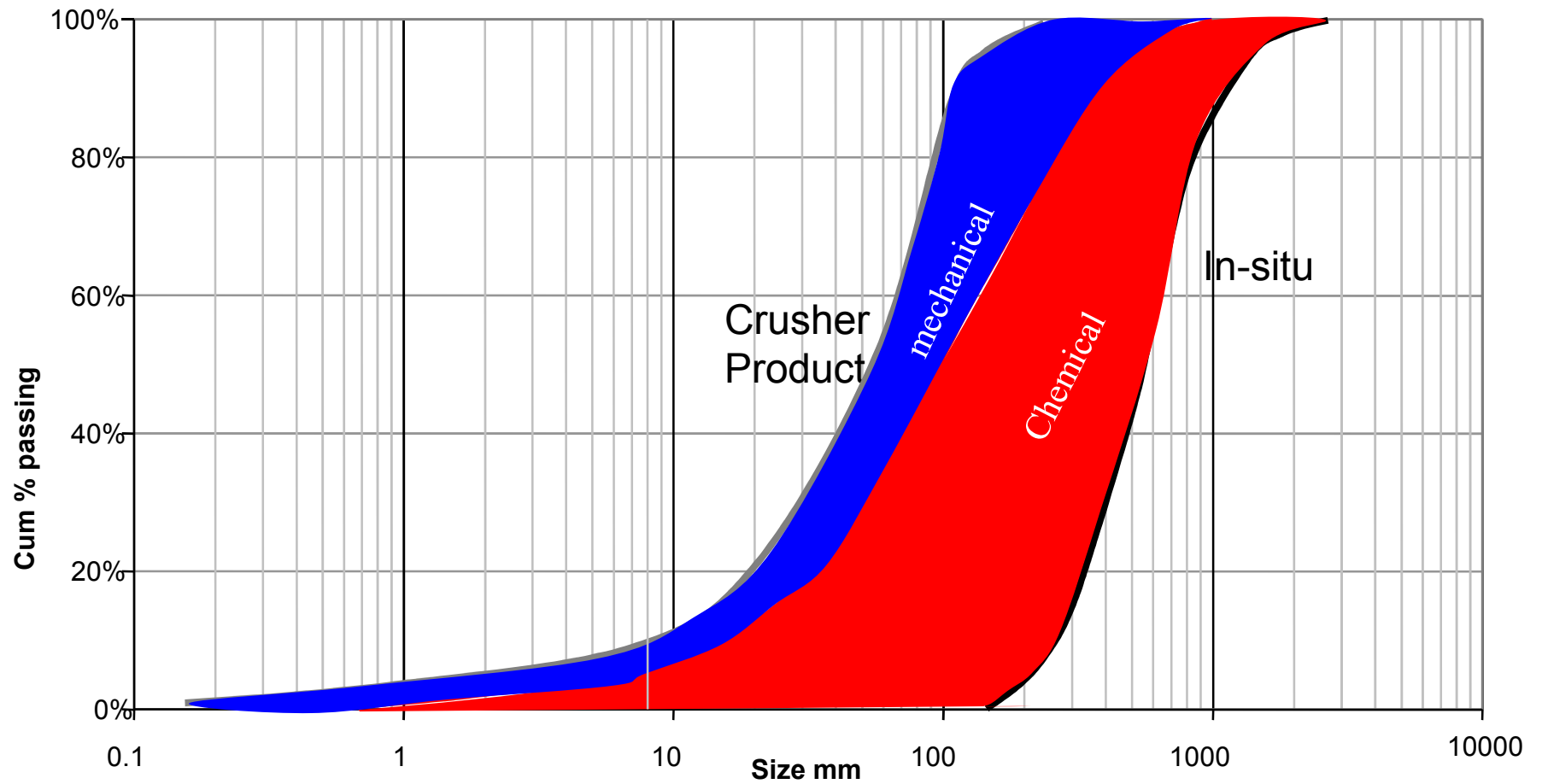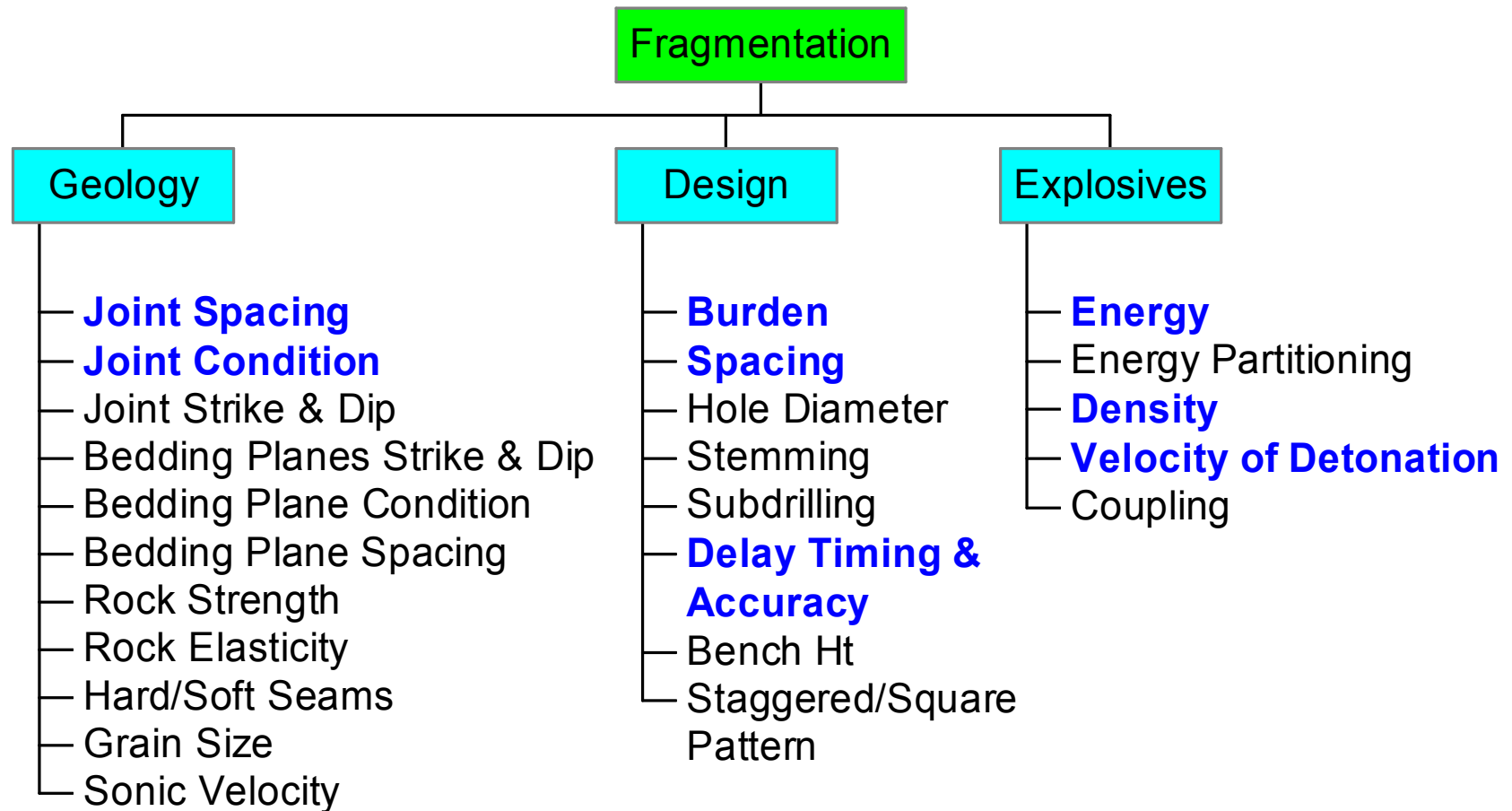
DYNO
Dyno Nobel

SANDVIK

Outline

- **Review of factors affecting fragmentation**
  - **Burden & Spacing**
  - **Powder factor**
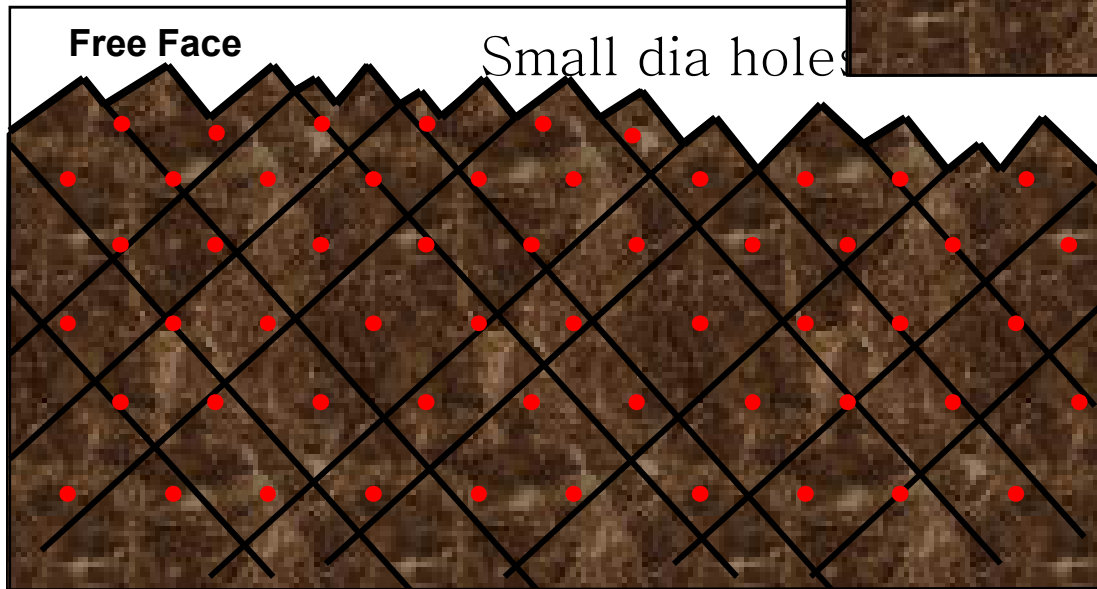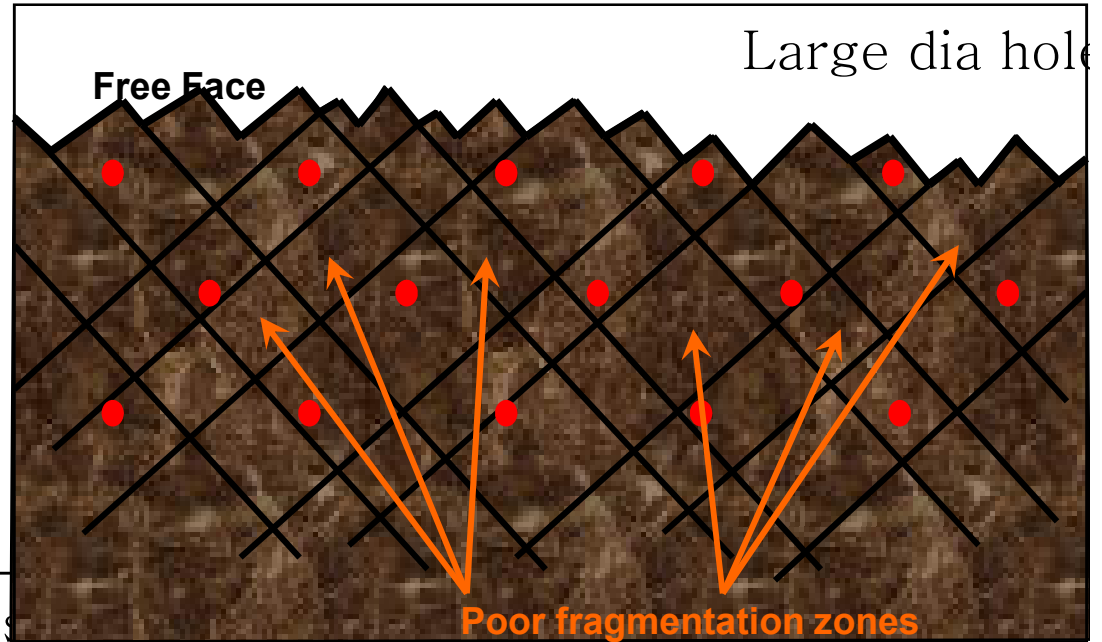 - **Delay time & accuracy**

- **Fragmentation modeling**

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Comminution or Breakage

Fragmentation Parameters

```
                          ┌──────────────────┐
                          │  Fragmentation   │
                          └──────────────────┘
        ┌──────────────────────────┼──────────────────────────┐
  ┌───────────┐              ┌───────────┐              ┌──────────────┐
  │  Geology  │              │  Design   │              │  Explosives  │
  └───────────┘              └───────────┘              └──────────────┘
```

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

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Burden & Spacing

Large dia hole

Free Face

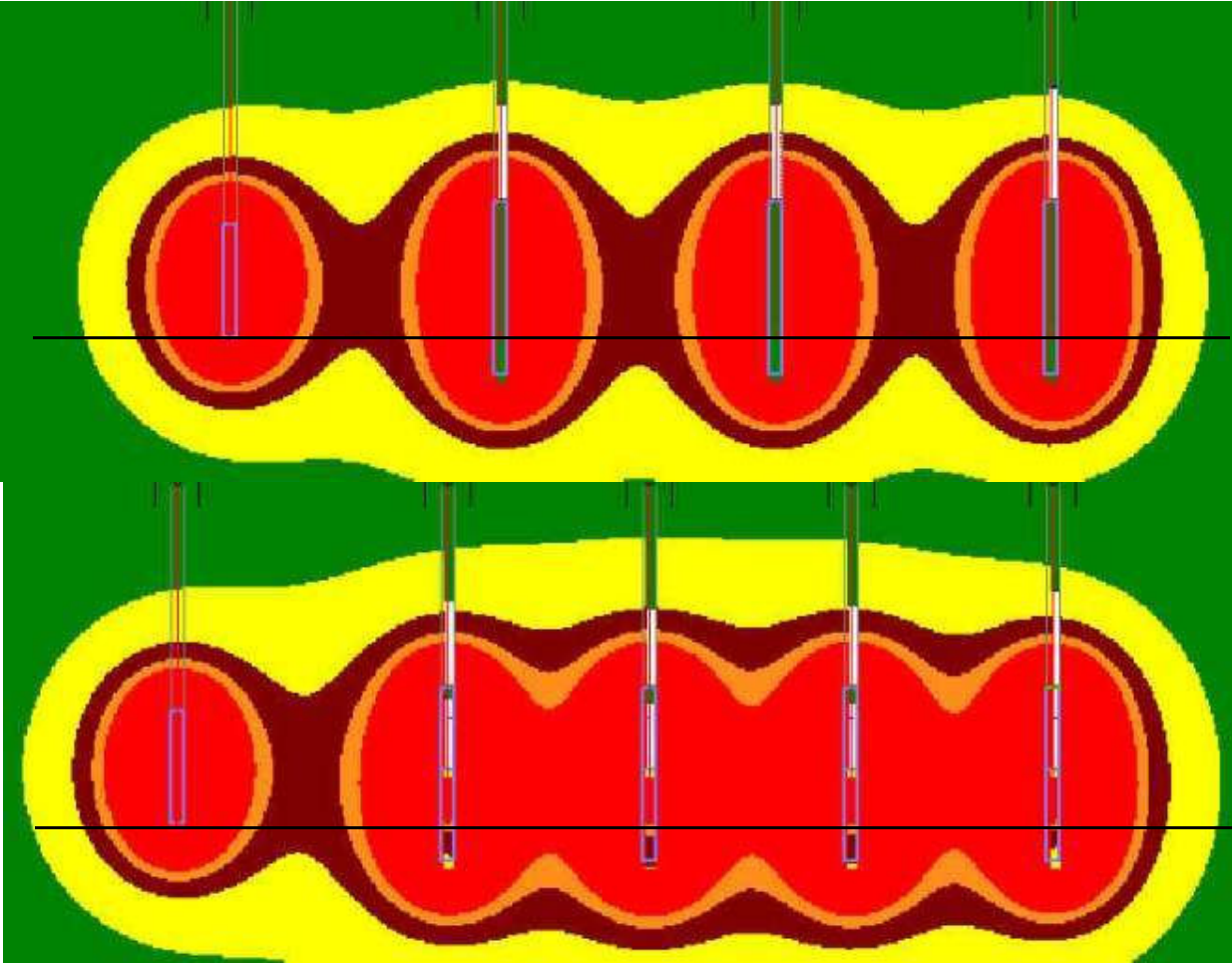Poor fragmentation zones
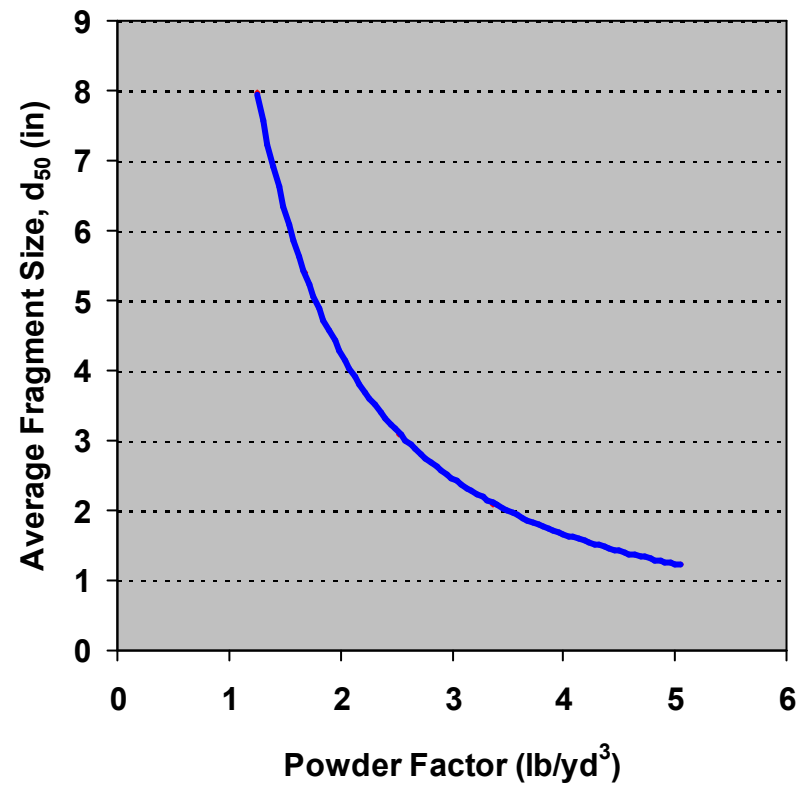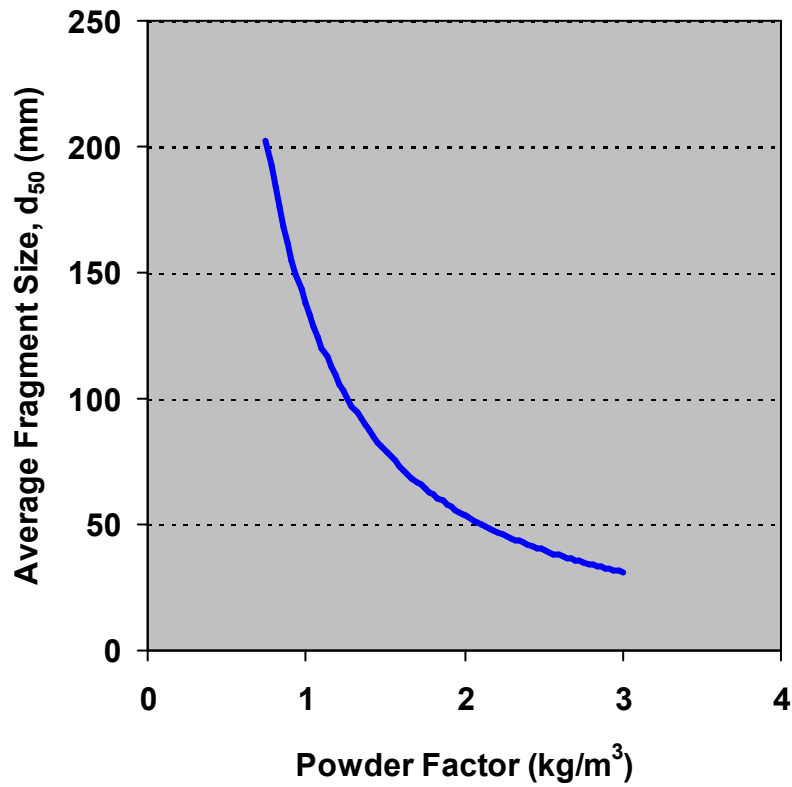
Free Face

Small dia holes

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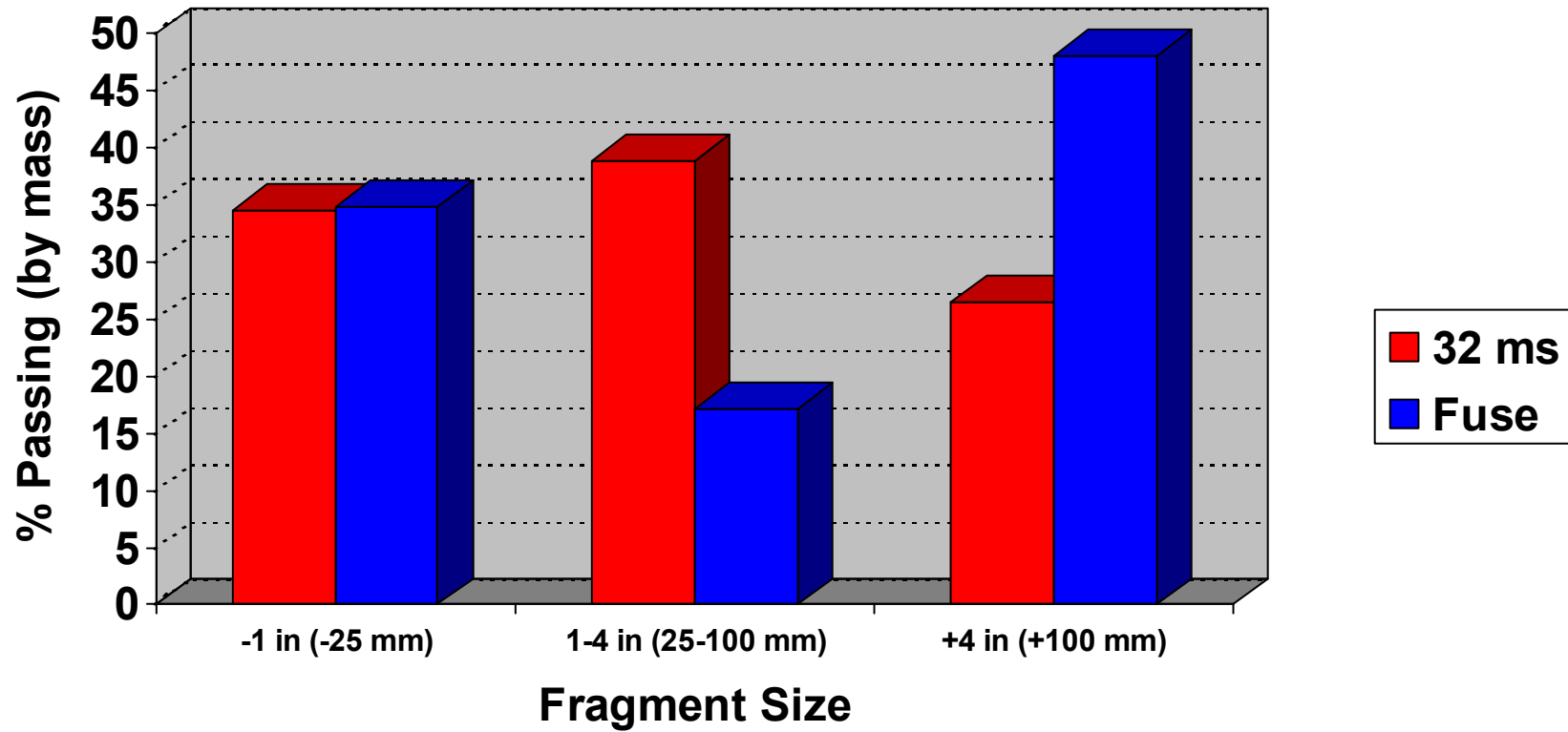# Geologically Defined Fragmentation

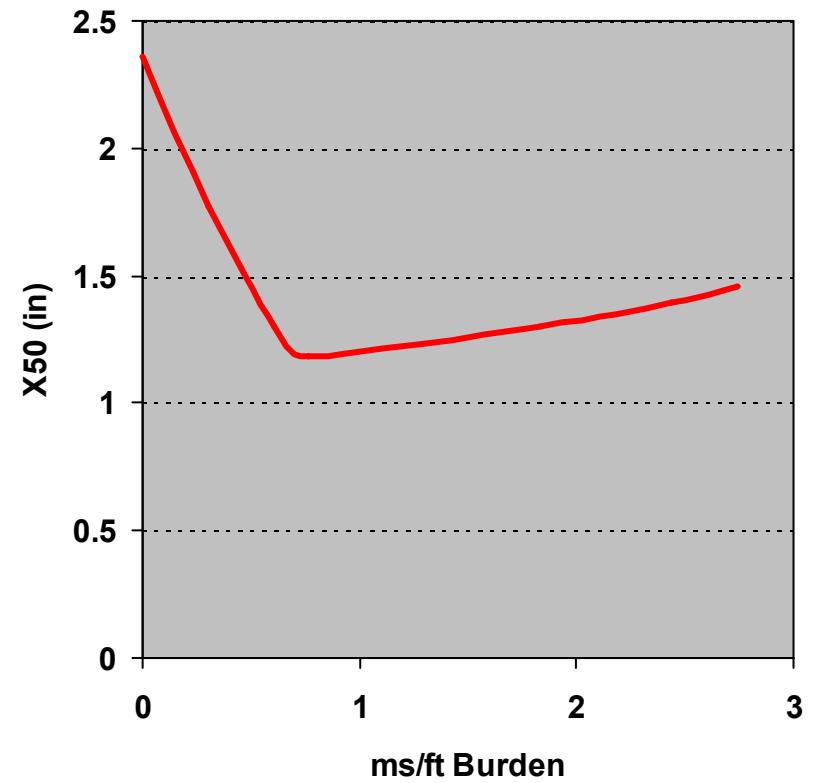# Burden & Spacing (Energy Distribution)
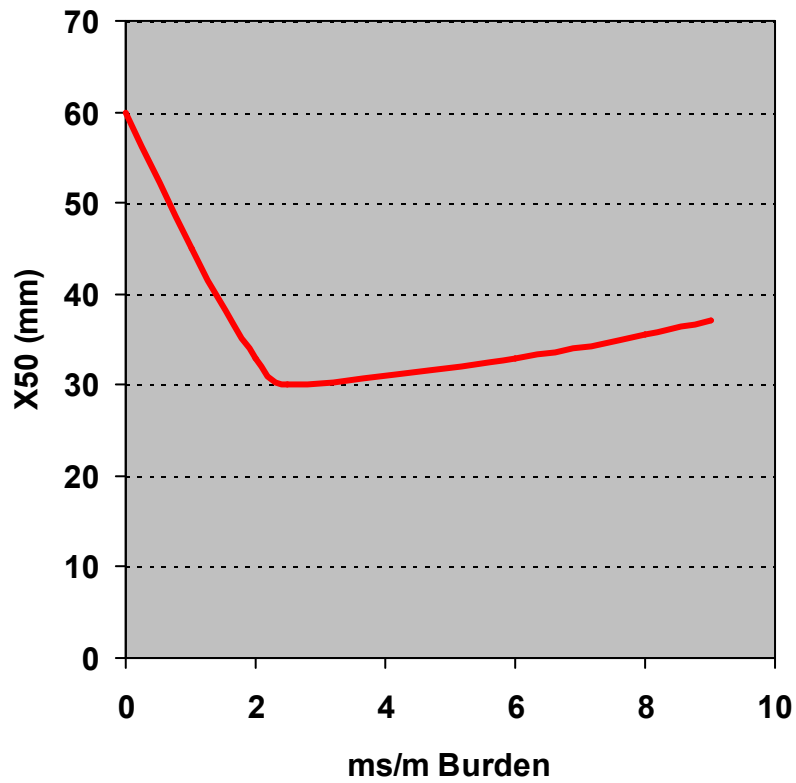
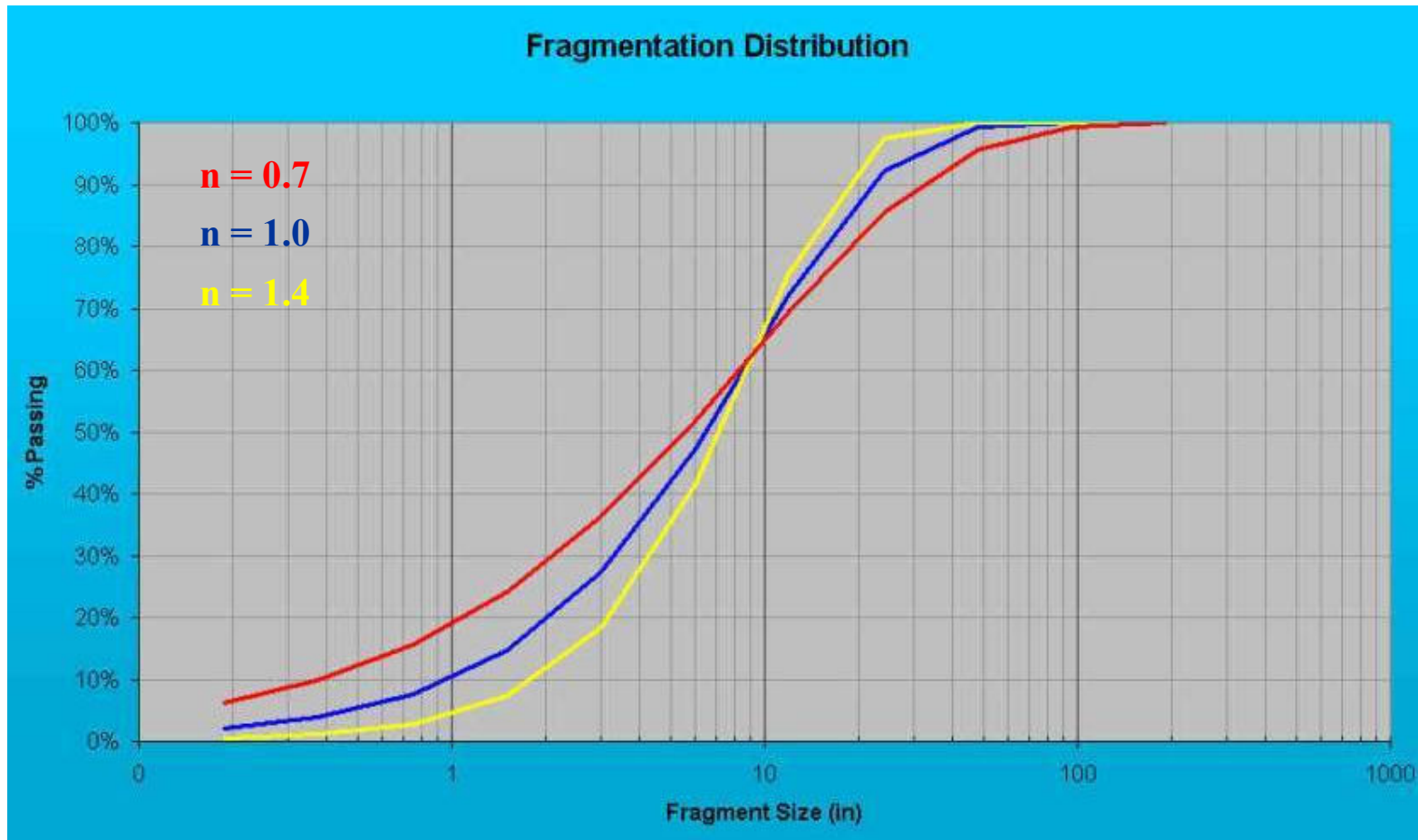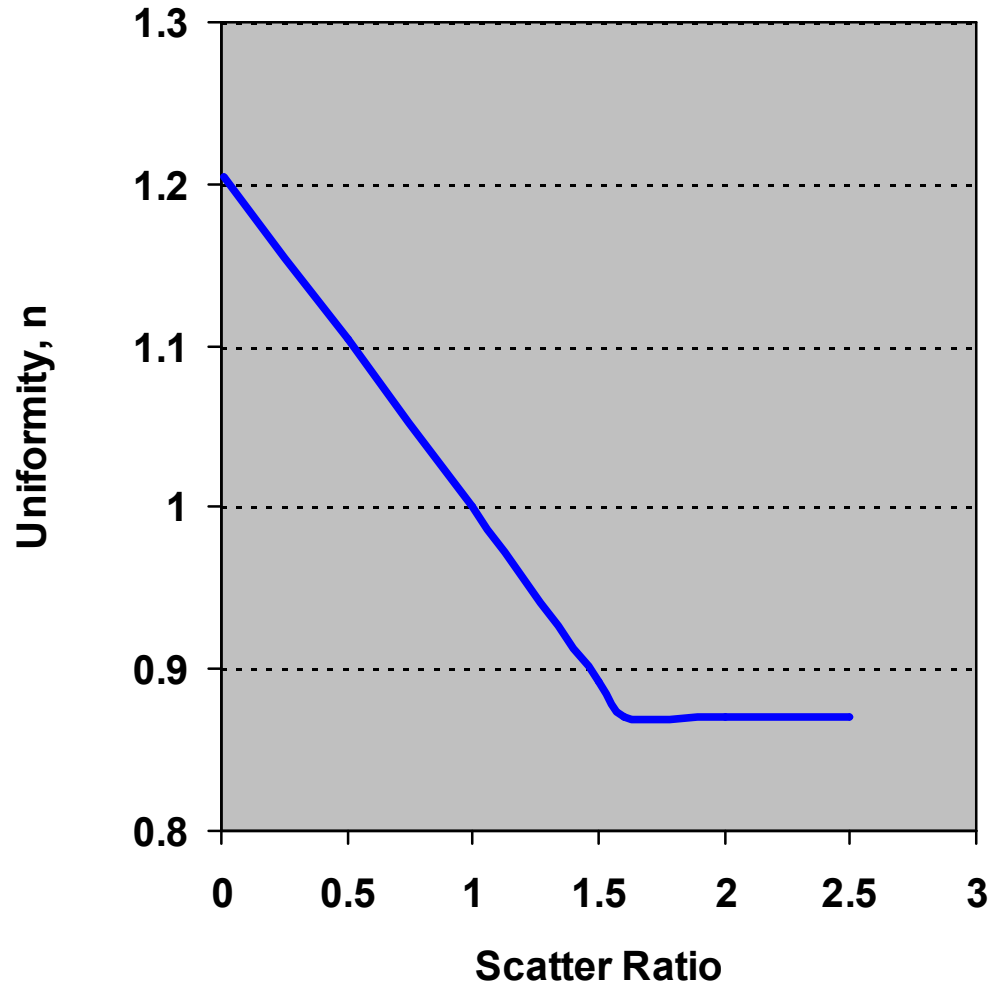# Powder Factor

(after Brinkman, 1985)

Delay Time

Delay Time

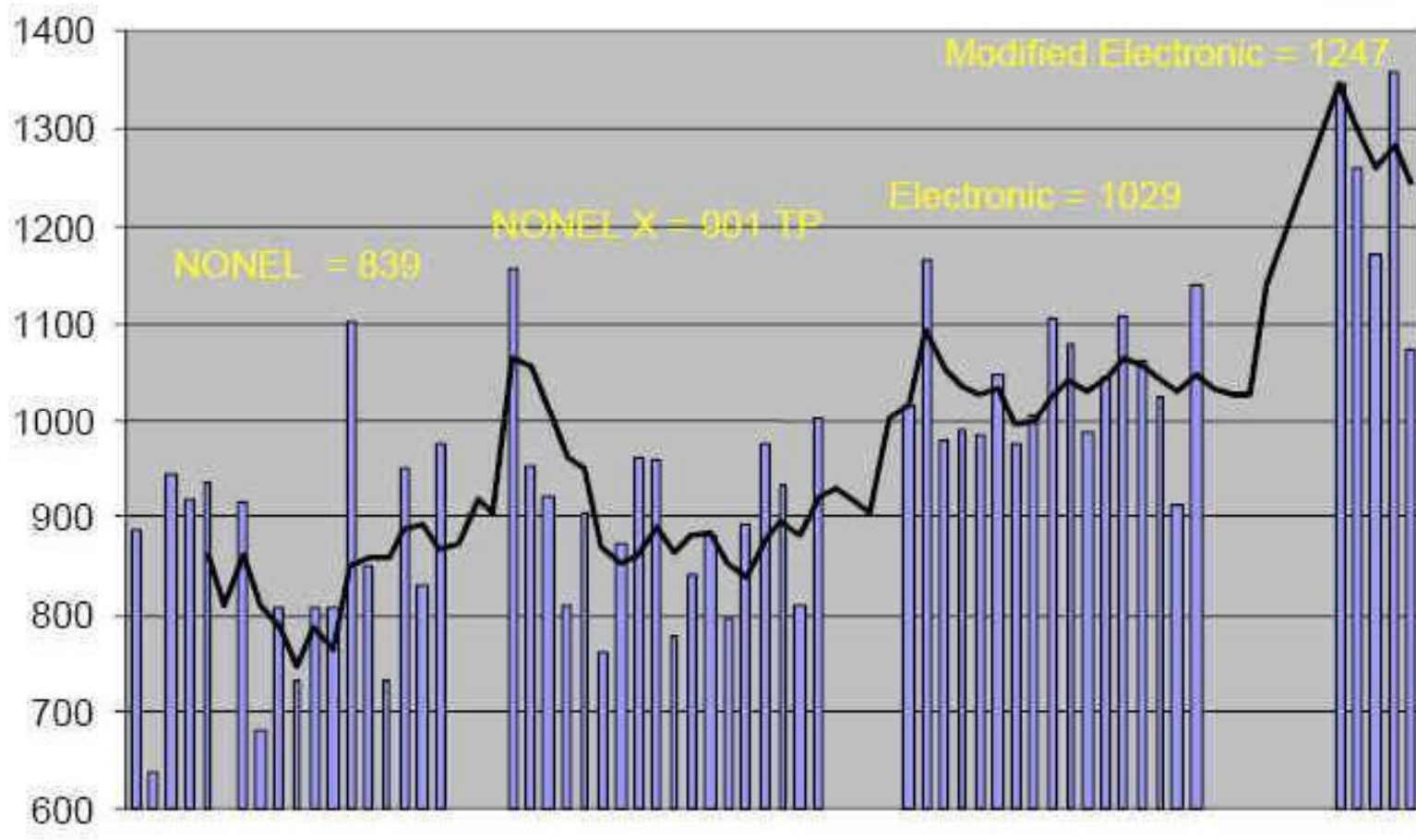*(after Cunningham, 2005)*
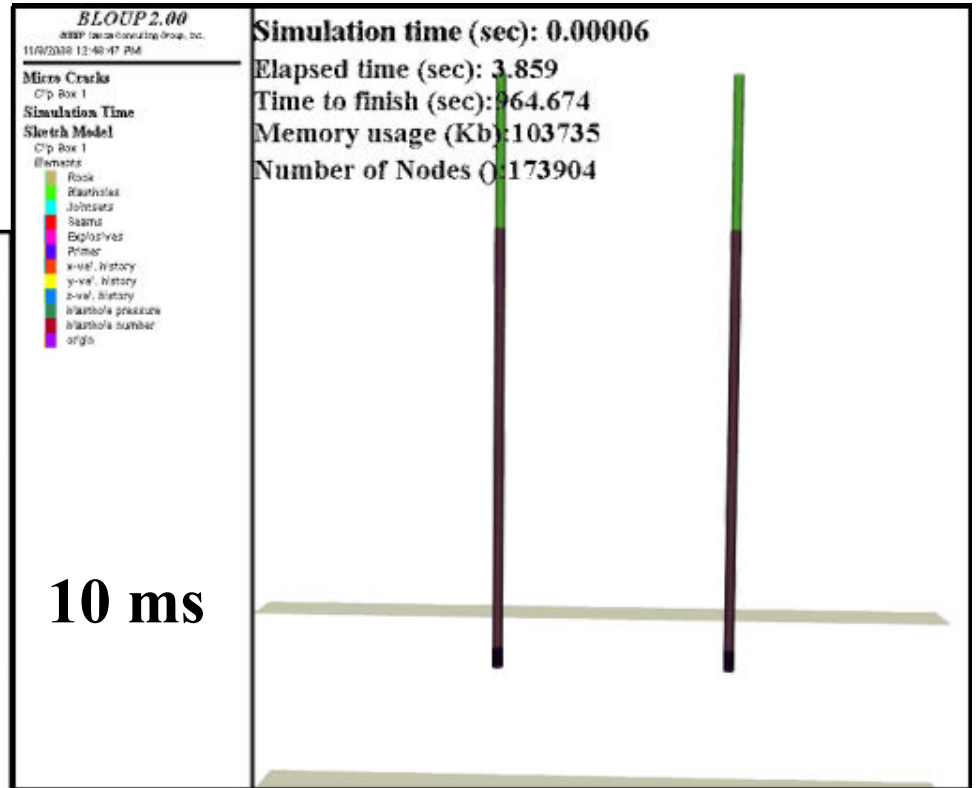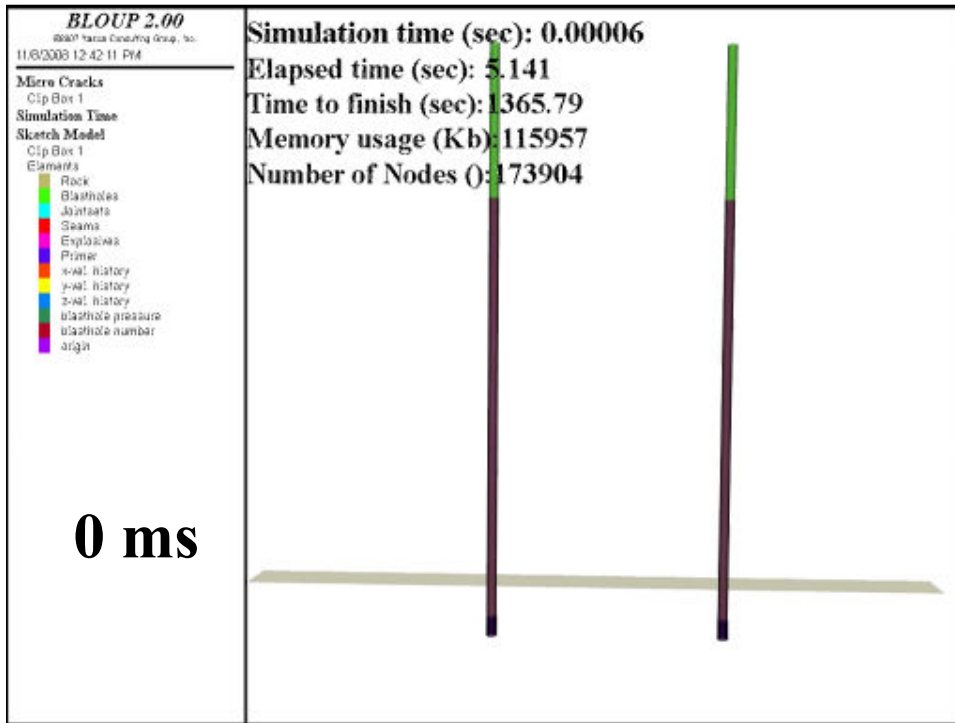
Description of Uniformity

Delay Scatter

Scatter Ratio = Scatter / Desired Delay

(after Cunningham,, 2005)

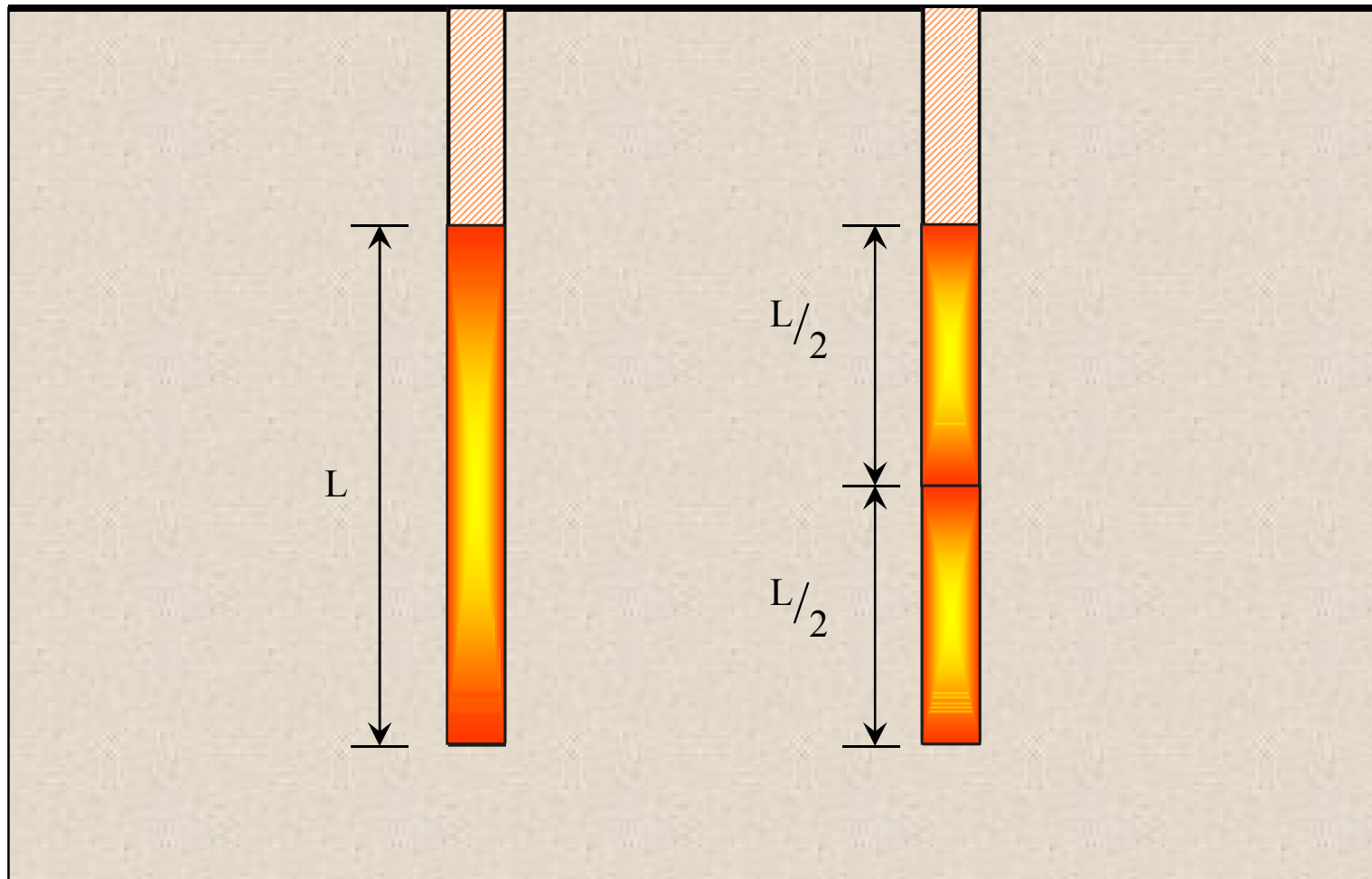# Effect of Accurate Timing & Improved Timing

Blast Model of Timing Effect

BLOUP 2.00
11/6/2008 12:42:11 PM

Micro Cracks
Clip Box 1
Simulation Time
Sketch Model
Clip Box 1
Elements
Rock
Blastholes
Jointsets
Seams
Explosives
Primer
x-vel. history
y-vel. history
z-vel. history
blasthole pressure
blasthole number
origin

Simulation time (sec): 0.00006
Elapsed time (sec): 5.141
Time to finish (sec): 1365.79
Memory usage (Kb): 115957
Number of Nodes (): 173904

0 ms

Quarry Academy Timing (0 ms).avi

BLOUP 2.00
11/6/2008 12:48:47 PM

Micro Cracks
Clip Box 1
Simulation Time
Sketch Model
Clip Box 1
Elements
Rock
Blastholes
Jointsets
Seams
Explosives
Primer
x-vel. history
y-vel. history
z-vel. history
blasthole pressure
blasthole number
origin

Simulation time (sec): 0.00006
Elapsed time (sec): 3.859
Time to finish (sec): 964.674
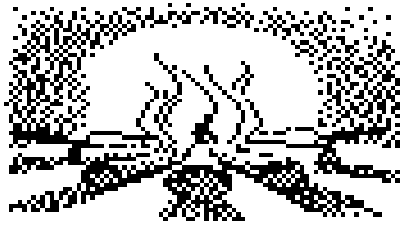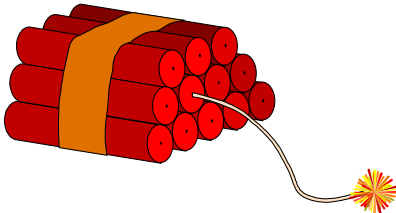Memory usage (Kb): 103735
Number of Nodes (): 173904

10 ms

Quarry Academy Timing (10 ms).avi

Reduction in Detonation Time

Reduction in Detonation Time

Energy Release

	Energy	Rate	Power
coal	~30 MJ/kg	minutes (hours) (10^3 secs)	~100 kW/kg
	4-6 MJ/kg	microseconds (10^{-6} secs)	~100,000,000 kW/kg

Reduction in Detonation Time

1) Time to complete detonation $= \dfrac{L}{VOD} = T$

2) Time to complete detonation $= \dfrac{L/2}{VOD} = T/2$

Power = Energy Released / Time

Fragmentation Improvements (Powder Factor & Delay Accuracy)

Loader Dig Rate

Dynamic Digging Rates for LT 1850 Loaders

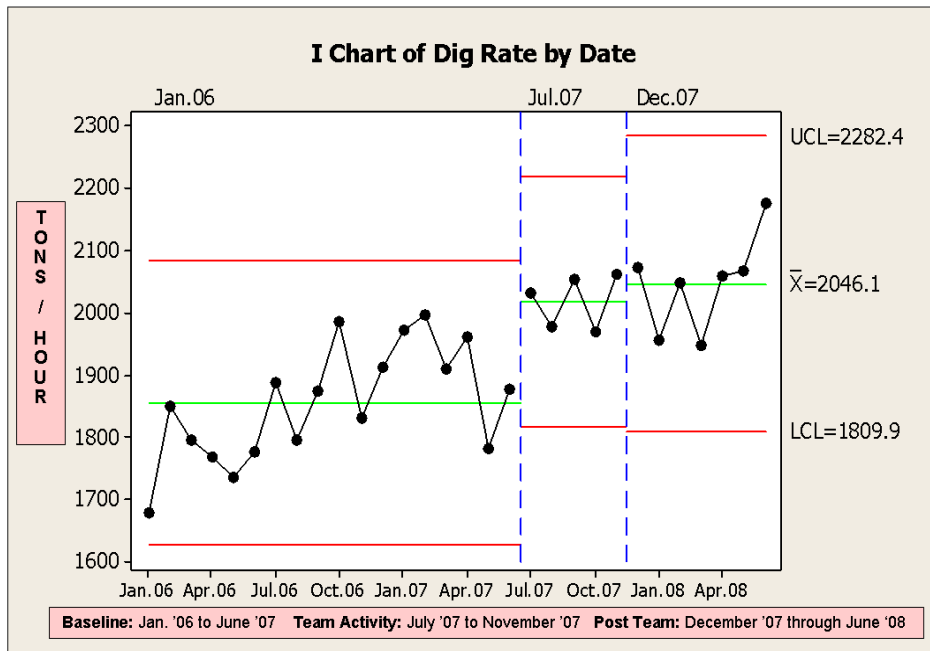I Chart of Dig Rate by Date

Baseline: Jan. '06 to June '07   Team Activity: July '07 to November '07   Post Team: December '07 through June '08
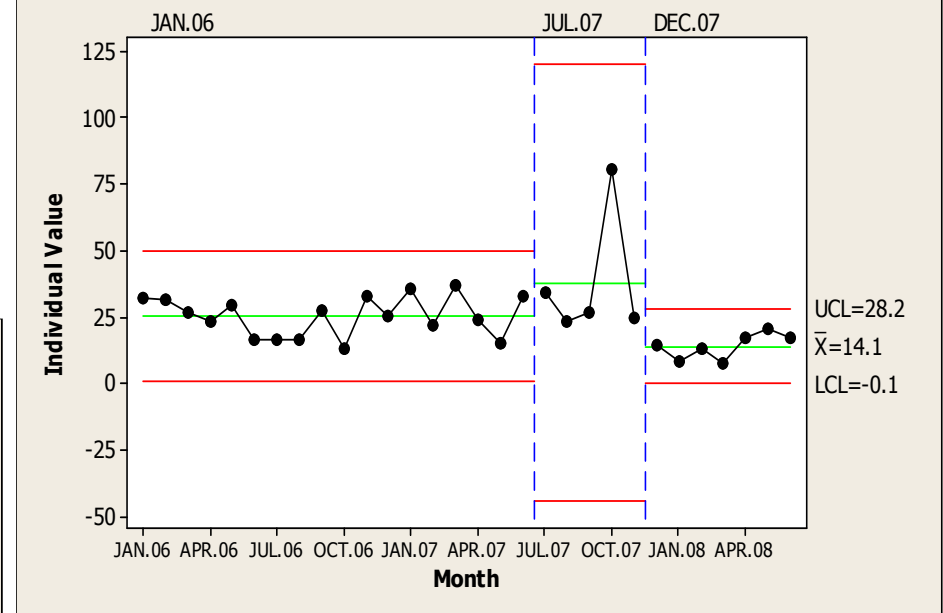

Chart for total hours lost/month for combined operations

Crusher 'Chunk' Delays

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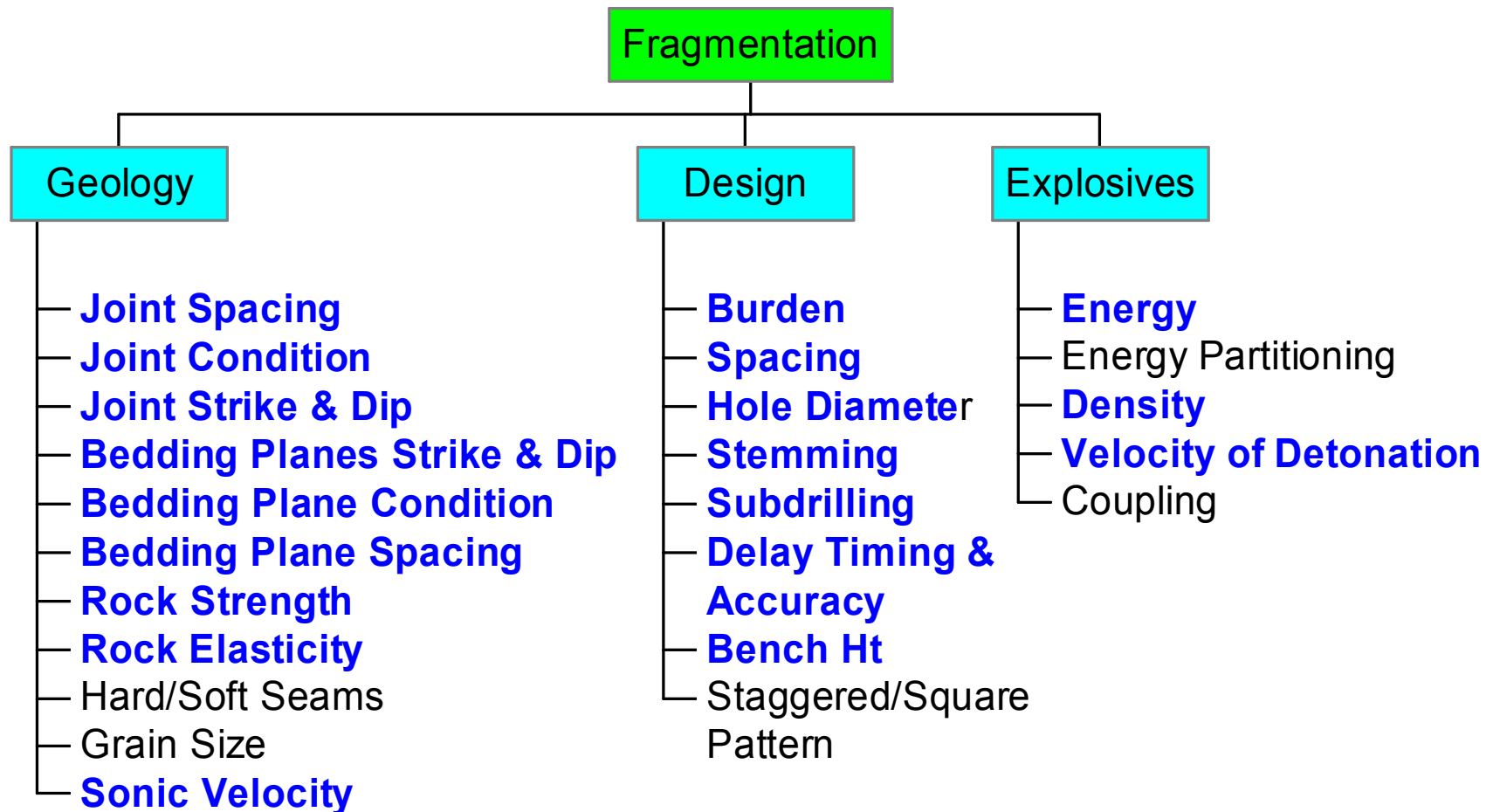# Fragmentation Models

- Used to determine trends in fragmentation due to changes in blast design

- Geologic factors have strong influence, however rarely known with any accuracy

- Can be calibrated if reliable fragmentation data is available

Fragmentation Models

- **Modified Kuz-Ram**
- **Includes timing between holes in same row**
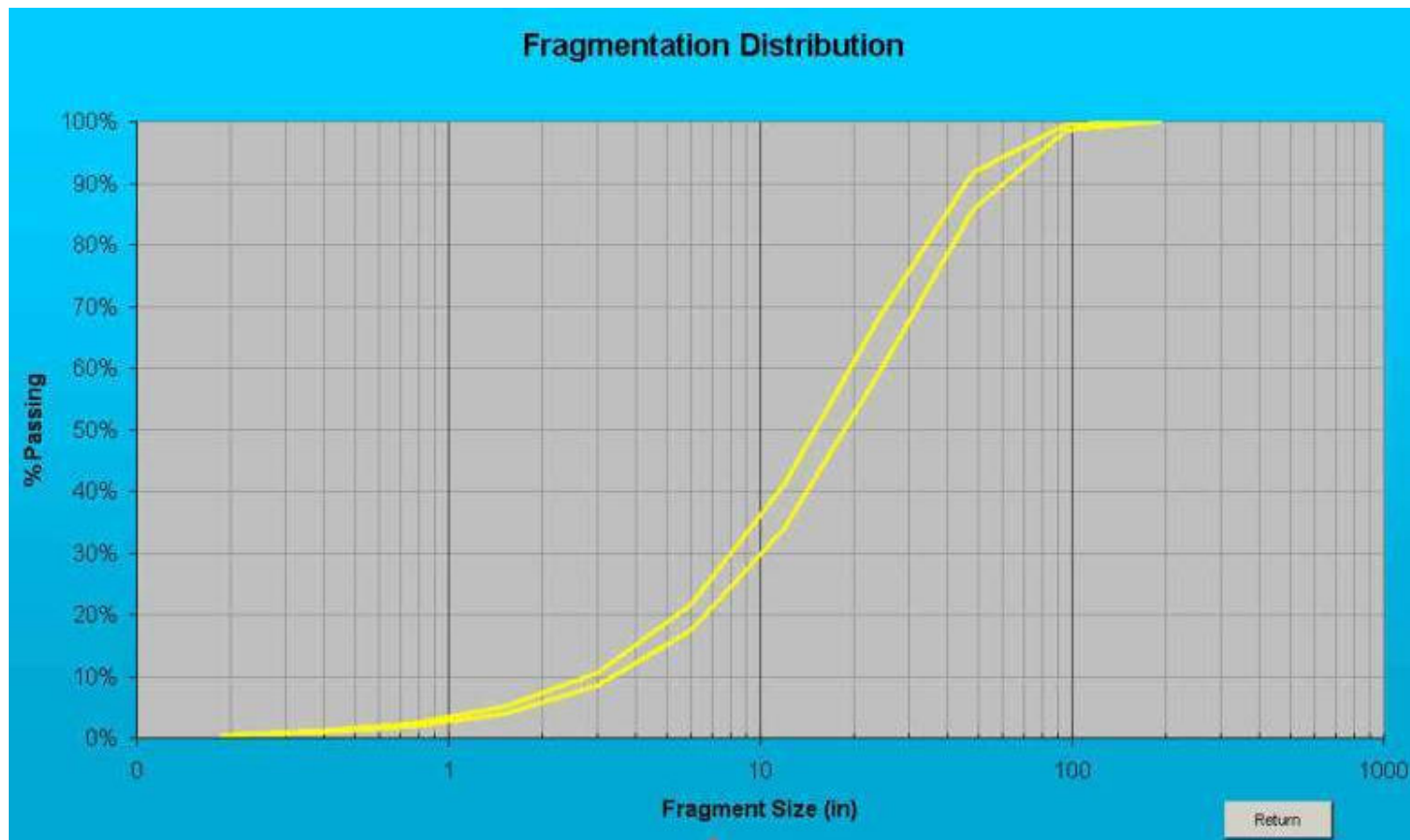
Fragmentation Modeling Inputs

Rock Properties (imperial)

Rock Type	Density (g/cc)	Compressive Strength (psi)	Tensile Strength (psi)	Young's Modulus (psi)	Poisson's Ratio	P Wave Velocity (ft/s)
Basalt	2.9	21,610	1,595	8,992,340	0.27	17,155
Dolomite	2.5	7,977	435	4,061,057	0.32	13,202
Gneiss	2.8	32,488	2,030	11,748,600	0.22	18,805
Granite	2.7	26,977	1,305	6,236,623	0.33	15,892
Limestone	2.7	23,061	725	7,977,076	0.25	16,404
Marble	3.1	36,404	2,175	16,374,000	0.28	21,998
Sandstone	2.5	19,435	145	1,015,264	-	12,903
Sandstone	1.8	1,595	0	870,226	0.31	6,873
Schist	2.9	24,076	1,305	11,167,910	0.2	17,985
Slate	2.6	12,328	870	9,572,491	0.17	16,955
Taconite	2.9	36,404	2,465	13,488,510	0.25	20,144

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Fragmentation Scenario #1

- **Current Blast Parameters**
  - **Bench ht – 100 ft**
  - **Granite**
  - **6" diameter hole**
  - **ANFO**
  - **17 ft x 17 ft pattern**
  - **8 ft stemming**
  - **5 ft sub-drill**
  - **Joint spacing of 16 ft (strike perpendicular to face)**
  - **25 ms delays between holes in row (2 ms S.D.)**

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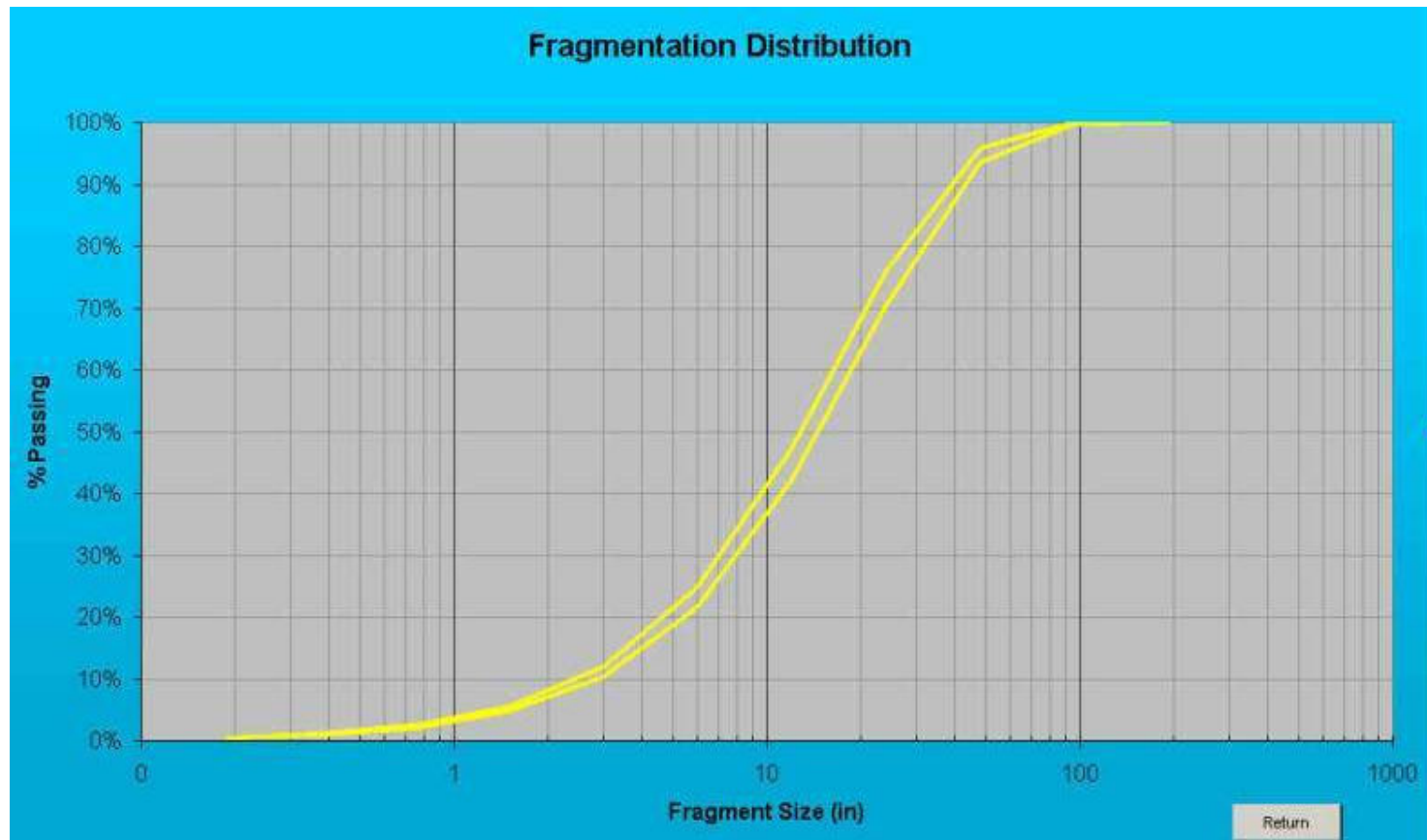# Fragmentation Scenario #1 (Current)

Fragmentation Scenario #1

- **Current Blast Parameters**
  - **Bench ht – 100 ft**
  - **Granite**
  - **6" diameter hole**
  - **ANFO**
  - **17 ft x 17 ft pattern**
  - **8 ft stemming**
  - **5 ft sub-drill**
  - **Joint spacing of 16 ft (strike perpendicular to face)**
  - **25 ms delays between holes in row (2 ms S.D.)**

- **Proposed Blast Parameters**
  - **Bench ht – 50 ft**

  - **14 ft x 14 ft pattern**
  - **7 ft stemming**
  - **4 ft sub-drill**

Fragmentation Scenario #2

- **Current Blast Parameters**
    - **Bench ht – 50 ft**
    - **Limestone**
    - **4" diameter hole**
    - **ANFO**
    - **11 ft x 13 ft pattern**
    - **8 ft stemming**
    - **5 ft sub-drill**
    - **Joint spacing of 12 ft (strike perpendicular to face)**
    - **25 ms delays between holes in row (2 ms S.D.)**

Scenario #2 Fragmentation (Current)

Fragmentation Scenario #2

Current Blast Parameters

- **Bench ht – 50 ft**
- **Limestone**
- **4" diameter hole**
- **ANFO**
- **11 ft x 13 ft pattern**
- **6 ft stemming**
- **3 ft sub-drill**
- **Joint spacing of 12 ft (strike perpendicular to face)**
- **25 ms delays between holes in row (2 ms S.D.)**

Proposed Blast Parameters

- **6" diameter hole**

- **15 ft x 18 ft pattern**
- **8 ft stemming**
- **5 ft sub-drill**

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