Sand Fracture Mechanisms During High-Speed Sand Impacts

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Top-Level

- **GOAL:** Better understand the mechanics of crystalline, particulate media at high pressures (~GPa) and high rates (10^4 – 10^5 s^{-1})
- **ENVIRONMENT:** Hemispherical-nosed projectiles impacting confined sand targets

- High Speed Drag Law
- Document virgin & impacted sand grain morphology
- Identify fracture mechanisms as function of morphology

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Particulate Flows
&
Projectile Drag

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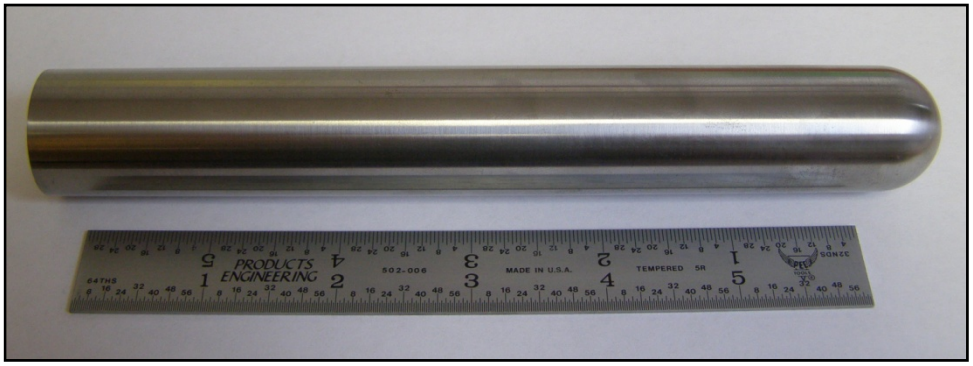
Sand Impact Test Conditions



- Hemispherical-nosed projectile
- 25.4 mm (1.00 in) diameter, L/D=7
- V_{impact} = 577 m/s (1,890 ft/s)
- “Eglin Sand” target (as-poured, not packed), ρ = 1.58 g/cc

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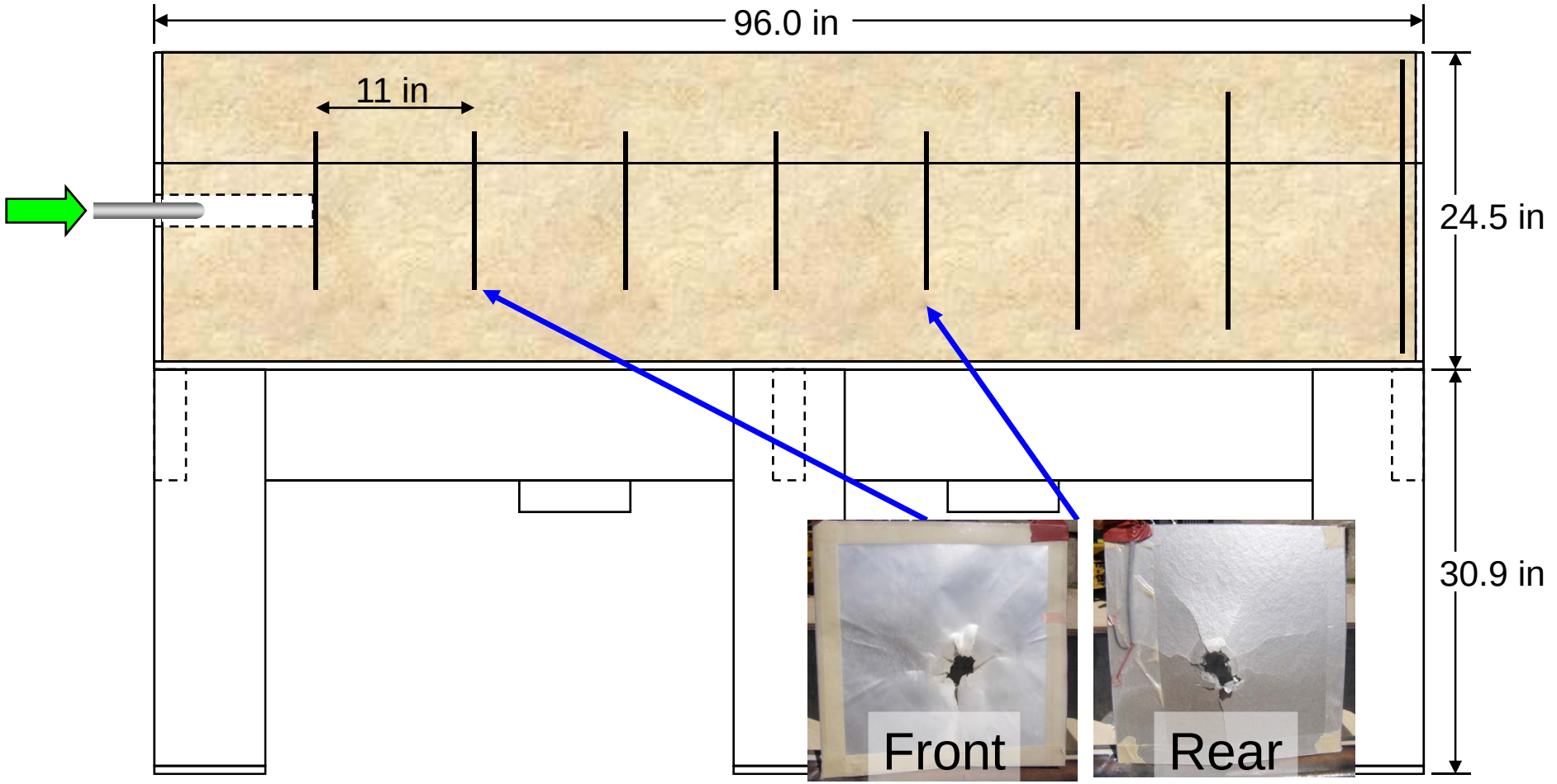
Target Layout



Make Screens

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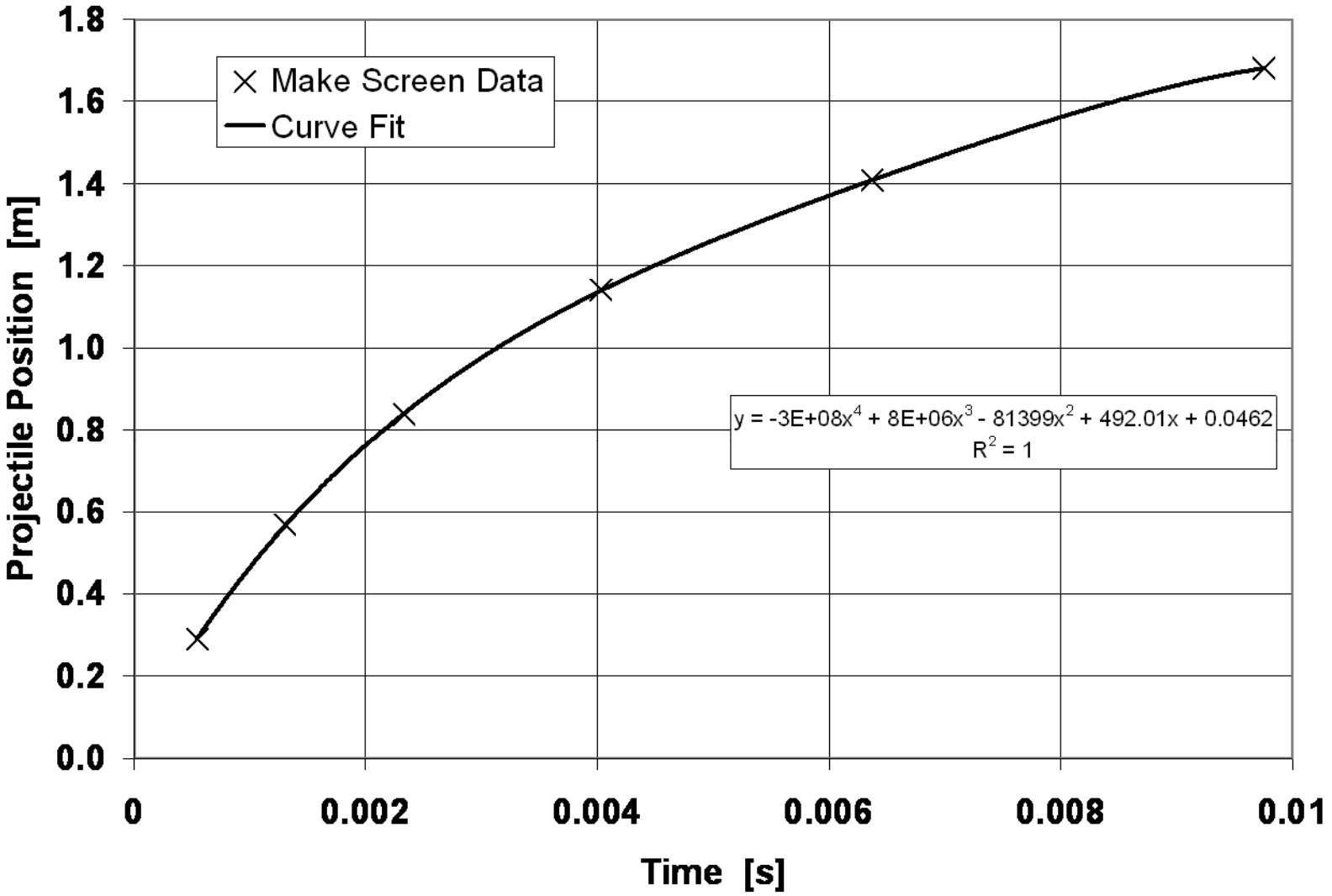
X - t



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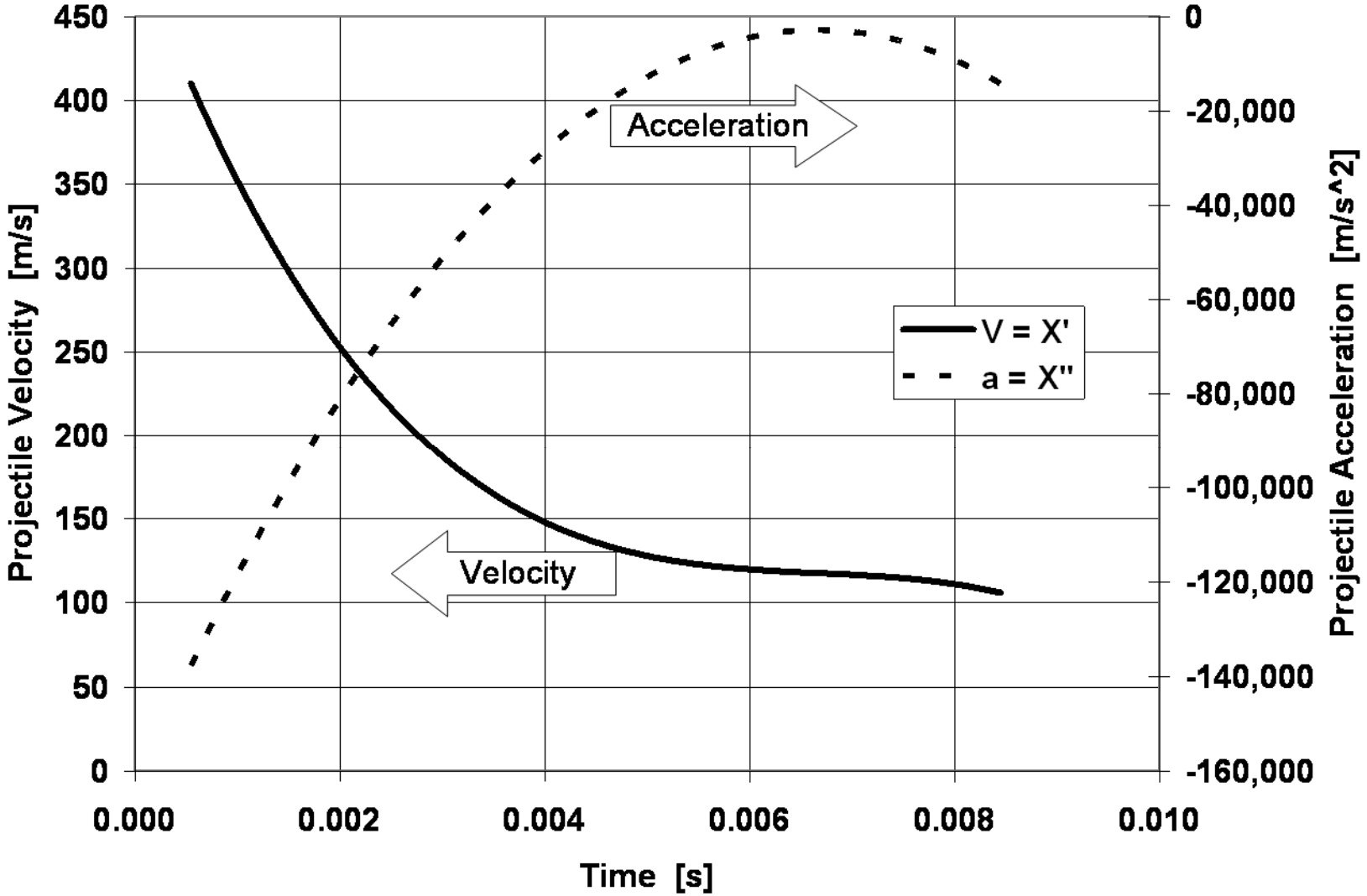
V, a - t



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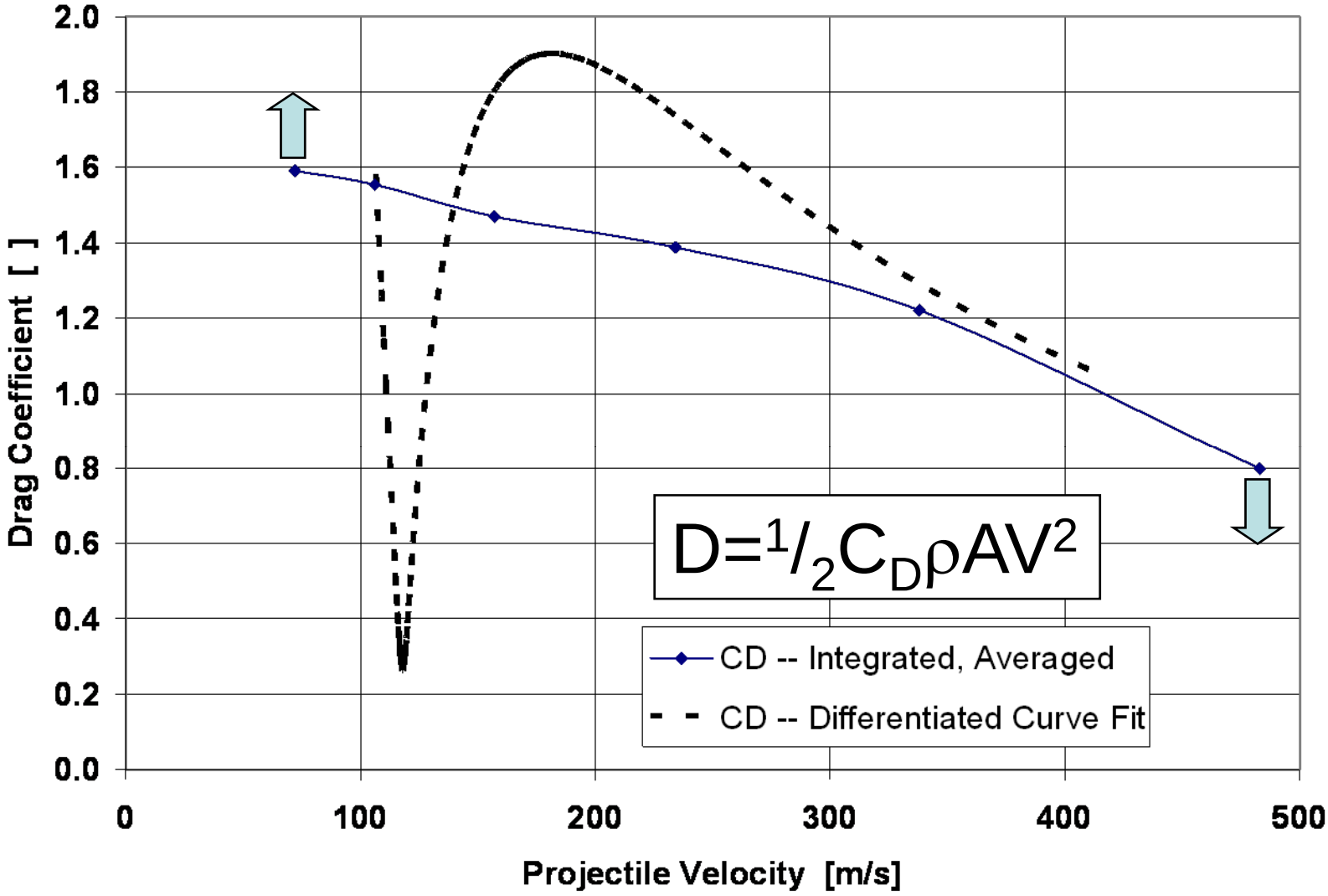
Drag Behavior



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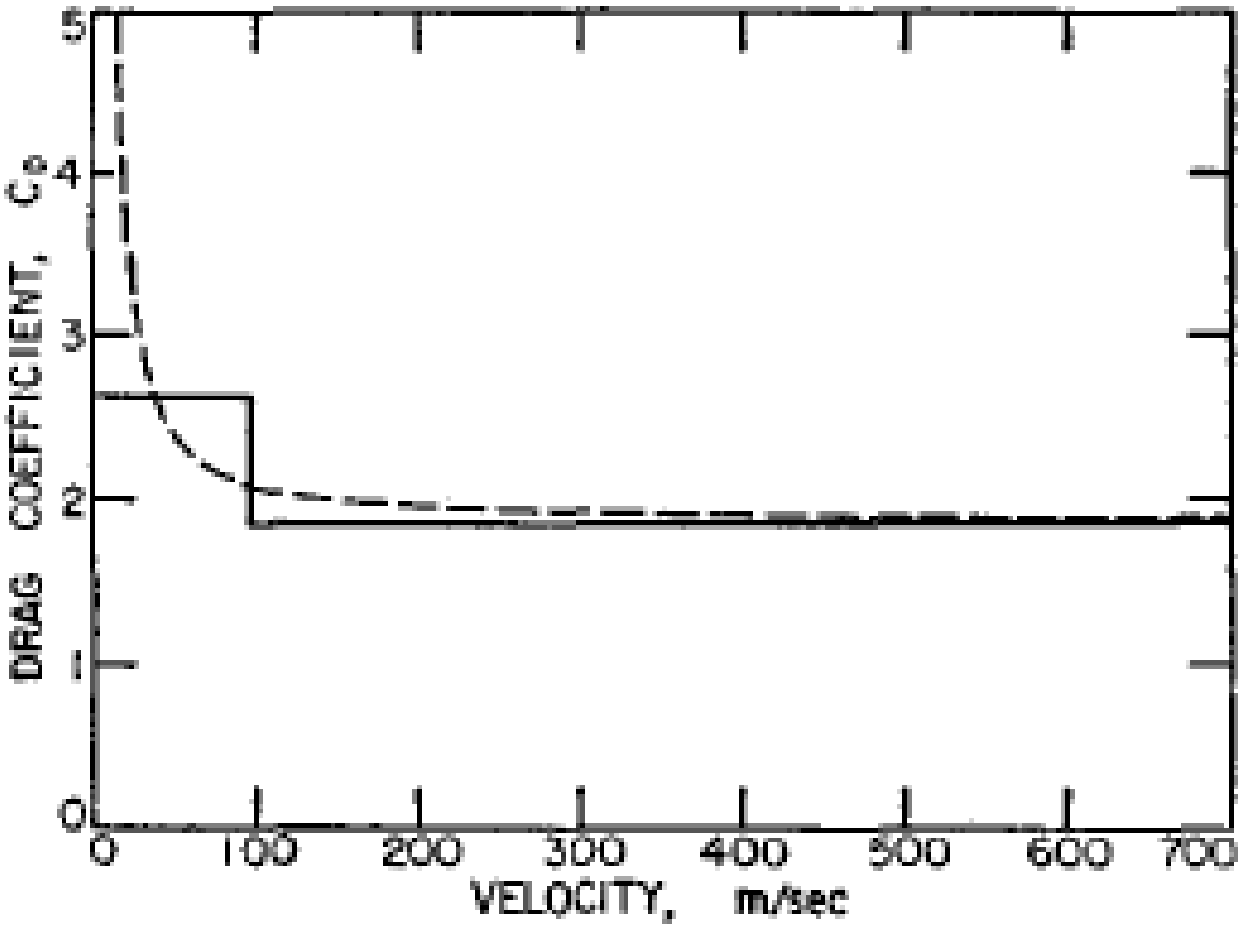
Prior Results in Literature



Ref: W.A. Allen, E. B. Mayfield, H.L. Morrison, Dynamics of a Projectile Penetrating Sand, J Appl Phys, 28 (3), 370-376, March 1957

Strong Axial Flow

Sand – as-poured, not packed

No confinement on upper surface

ρ = 1.58 [g/cc]

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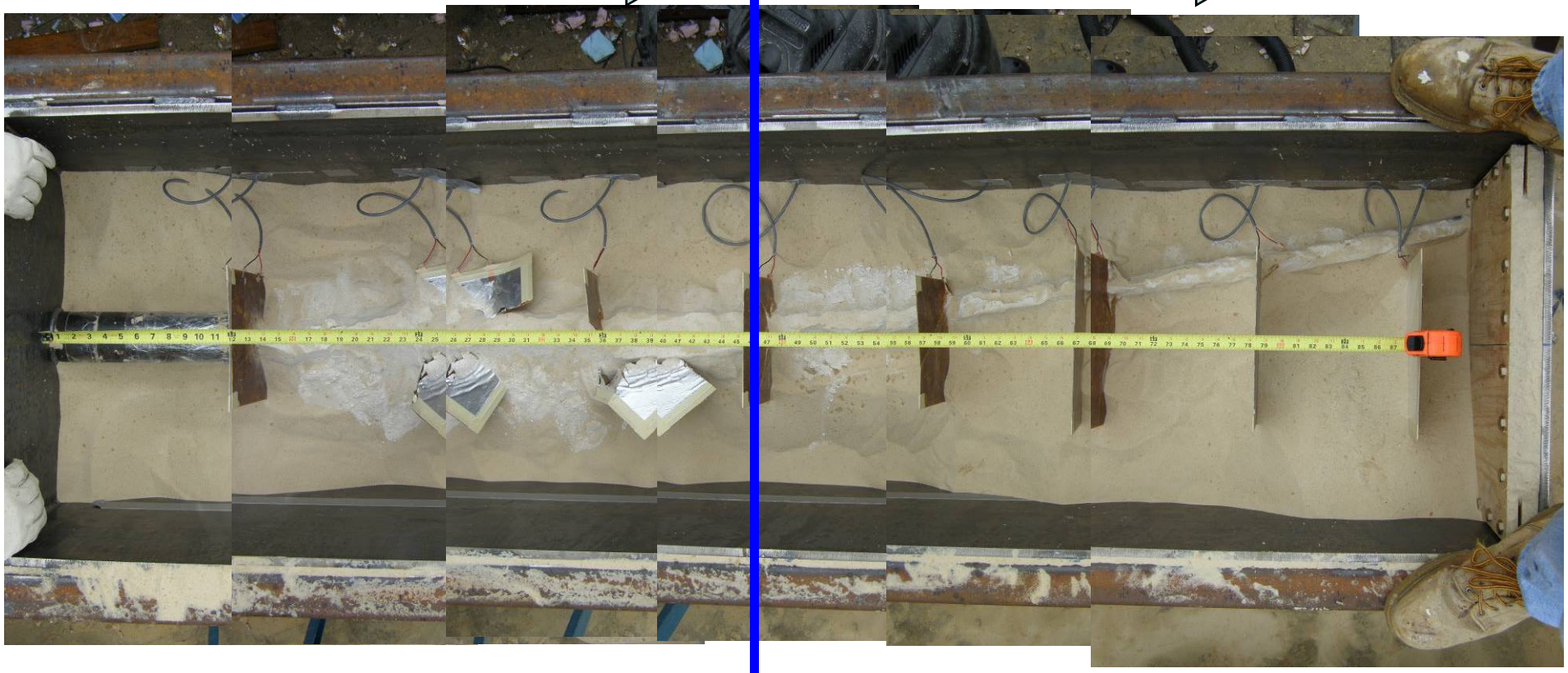
Strong Radial Flow

[better correlation with Allen *et al* result]

Cavitated, Diffuse

Non-Cavitated



V_{impact}=1,200 m/s

Packed Sand, ρ = 1.73 g/cc

Confined upper surface, Top Load=40 kPa (5.7 psi)

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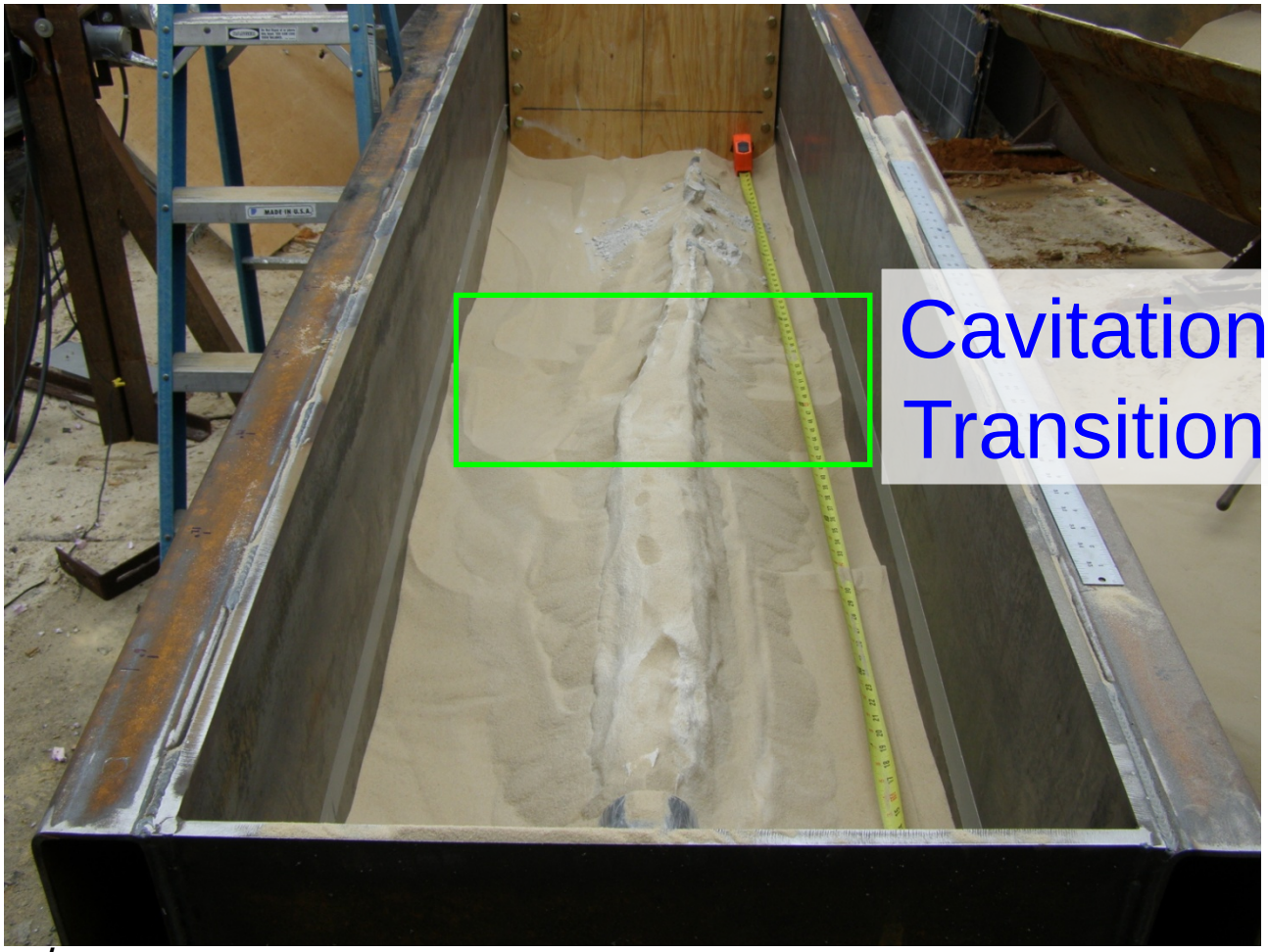
Strong Radial Flow



V_{impact}=1,200 m/s
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Particle Size Analysis

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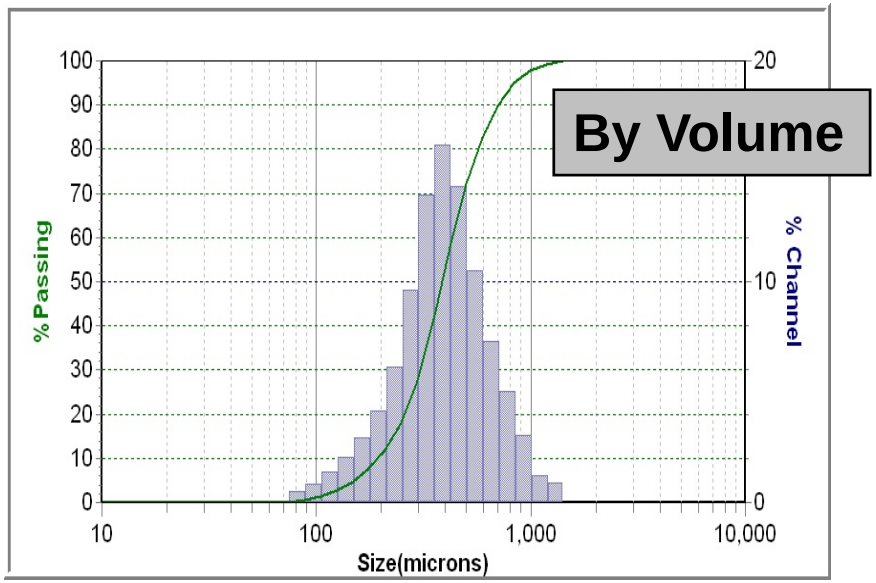
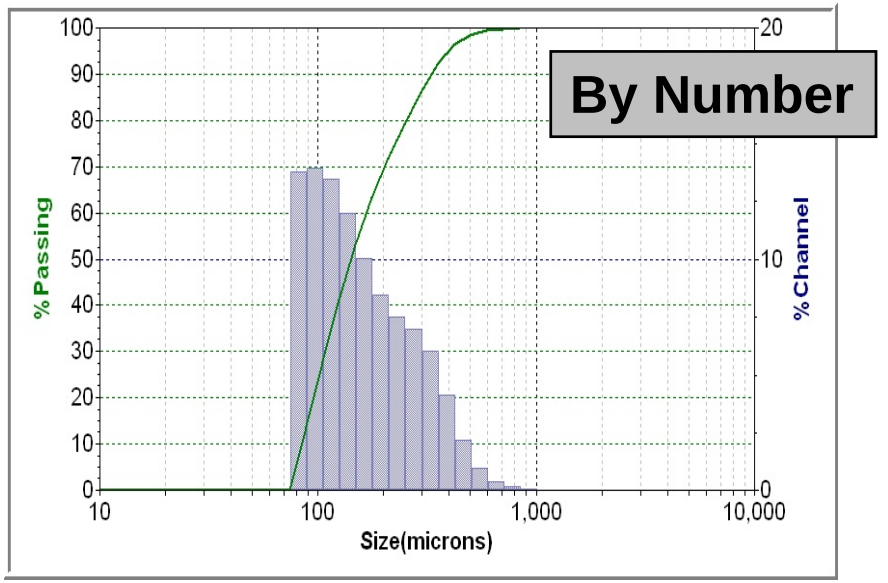
“Eglin Sand”





[Microtrac S-3500, dry-reflecting mode]

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Particle Size Analysis

[Microtrac S-3500, Laser Scattering, Spherical Particle Assumption]

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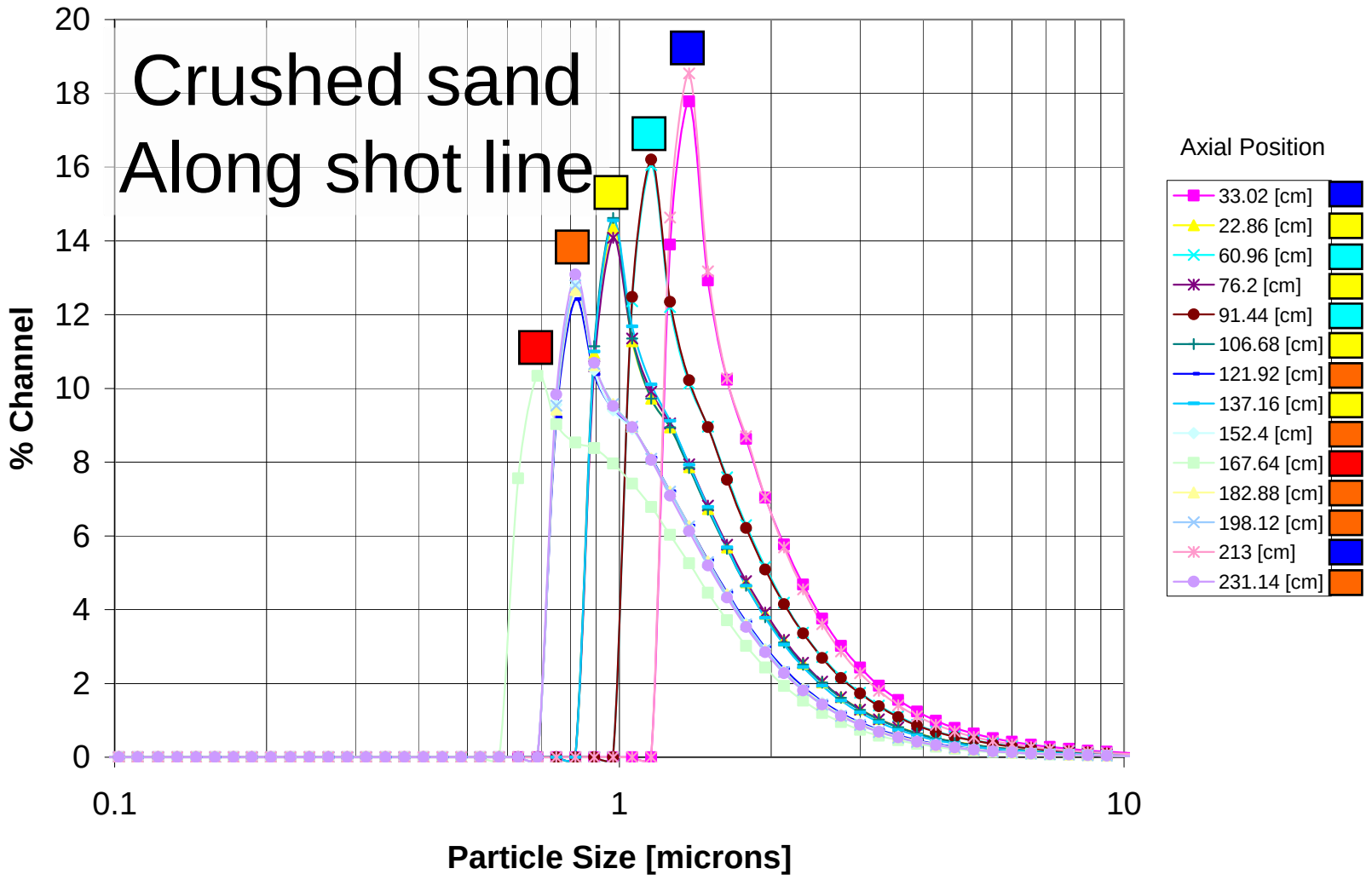

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Exp: 01242008002

Particle Size Analysis

[AnaTec Fine Particle Analyser, Collimated-light microscope]

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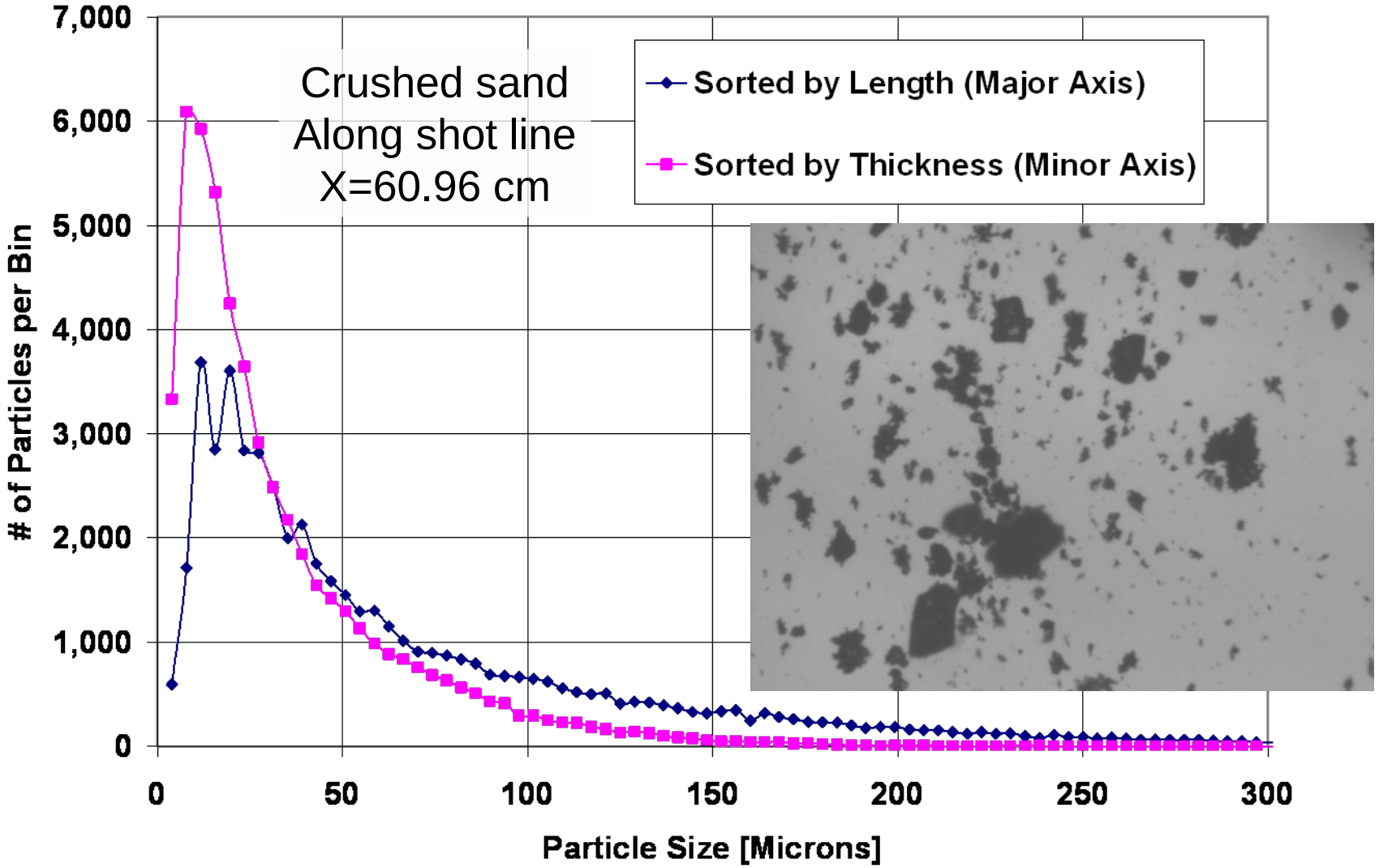

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Morphology
&
Fracture Mechanics

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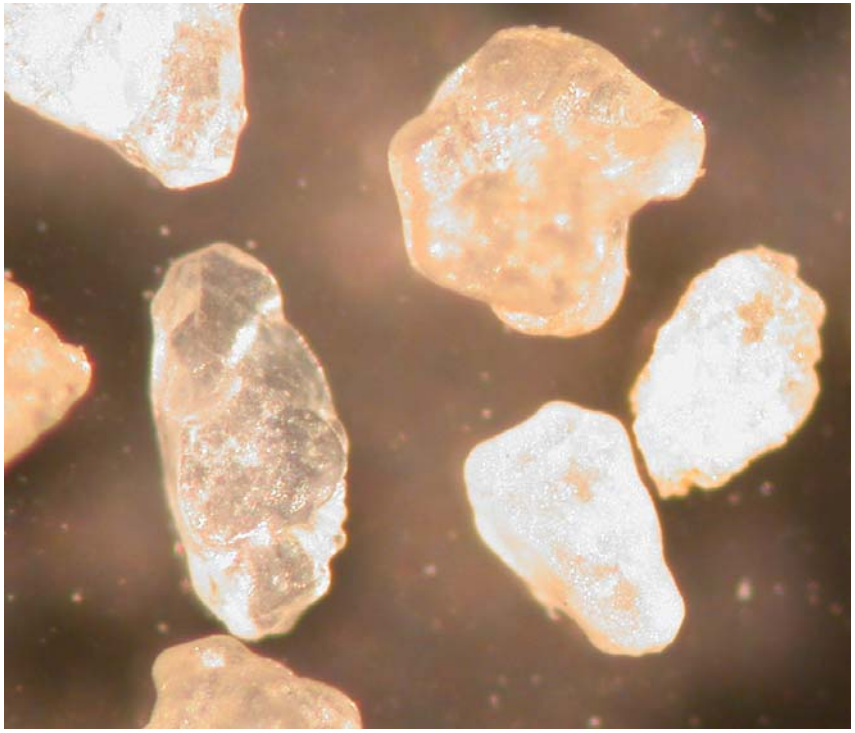
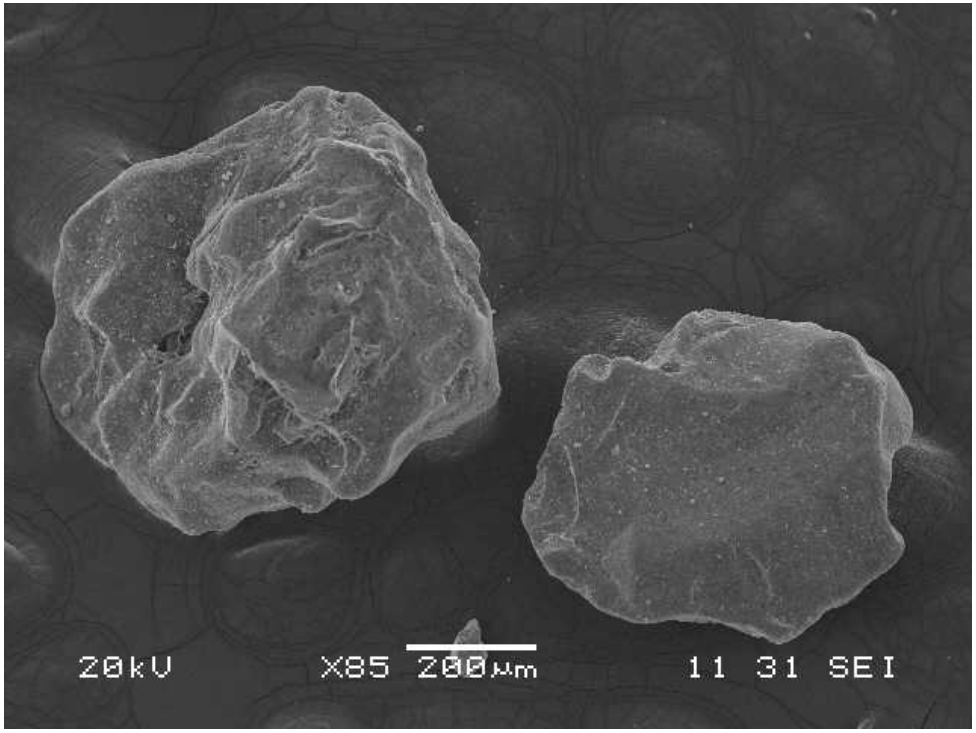
Typical Virgin “Eglin Sand”



Visible Light



SEM

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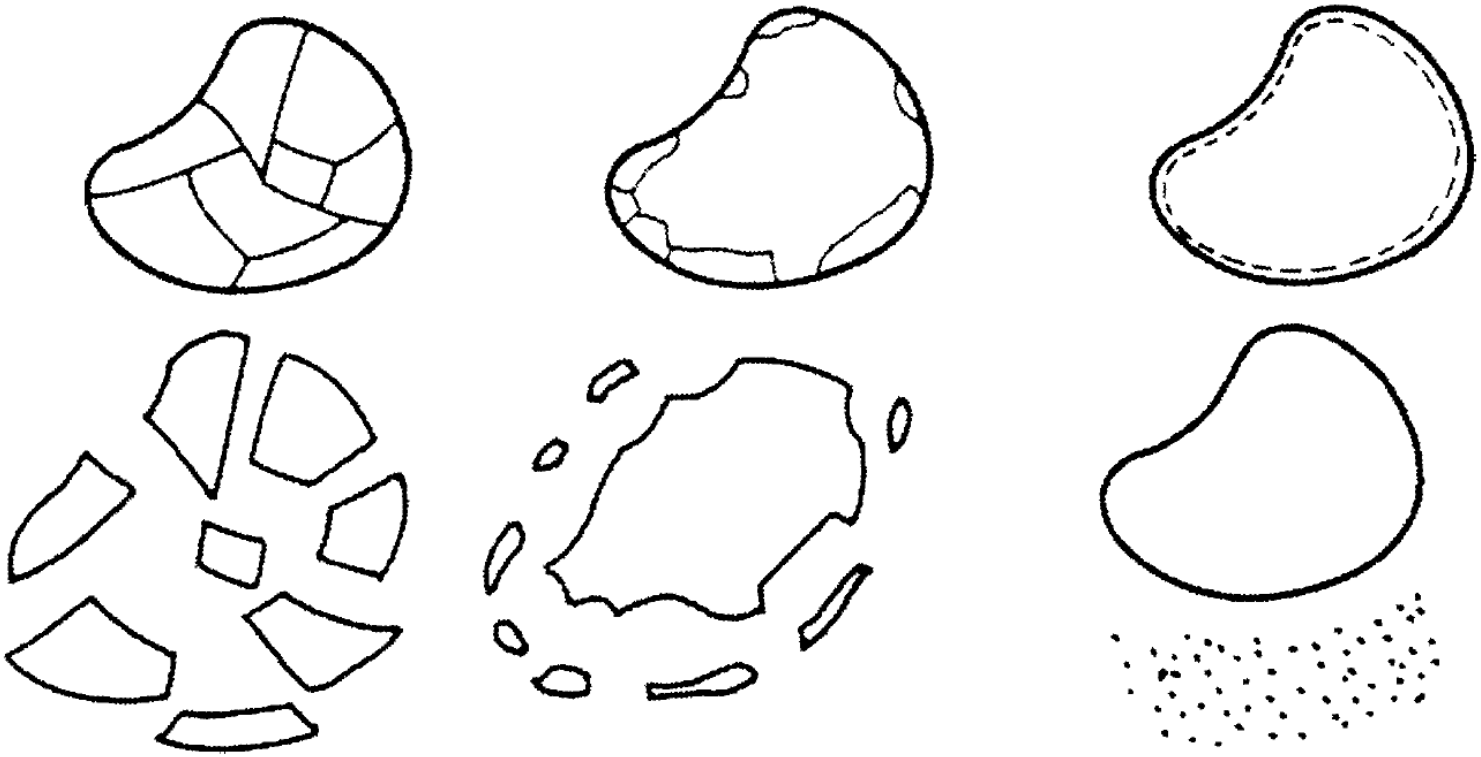
“Fracture” Modes



Fracture:
Grain breaks into smaller grains of similar sizes

Attrition:
Grain breaks into one grain of a slightly smaller size and several much smaller ones

Abrasion:
Granulometry remains almost constant but with a production of fine particles

Guyon E., Troadec J.-P., Du sac de billes au tas de sable, Editions Odile JACOB Sciences.

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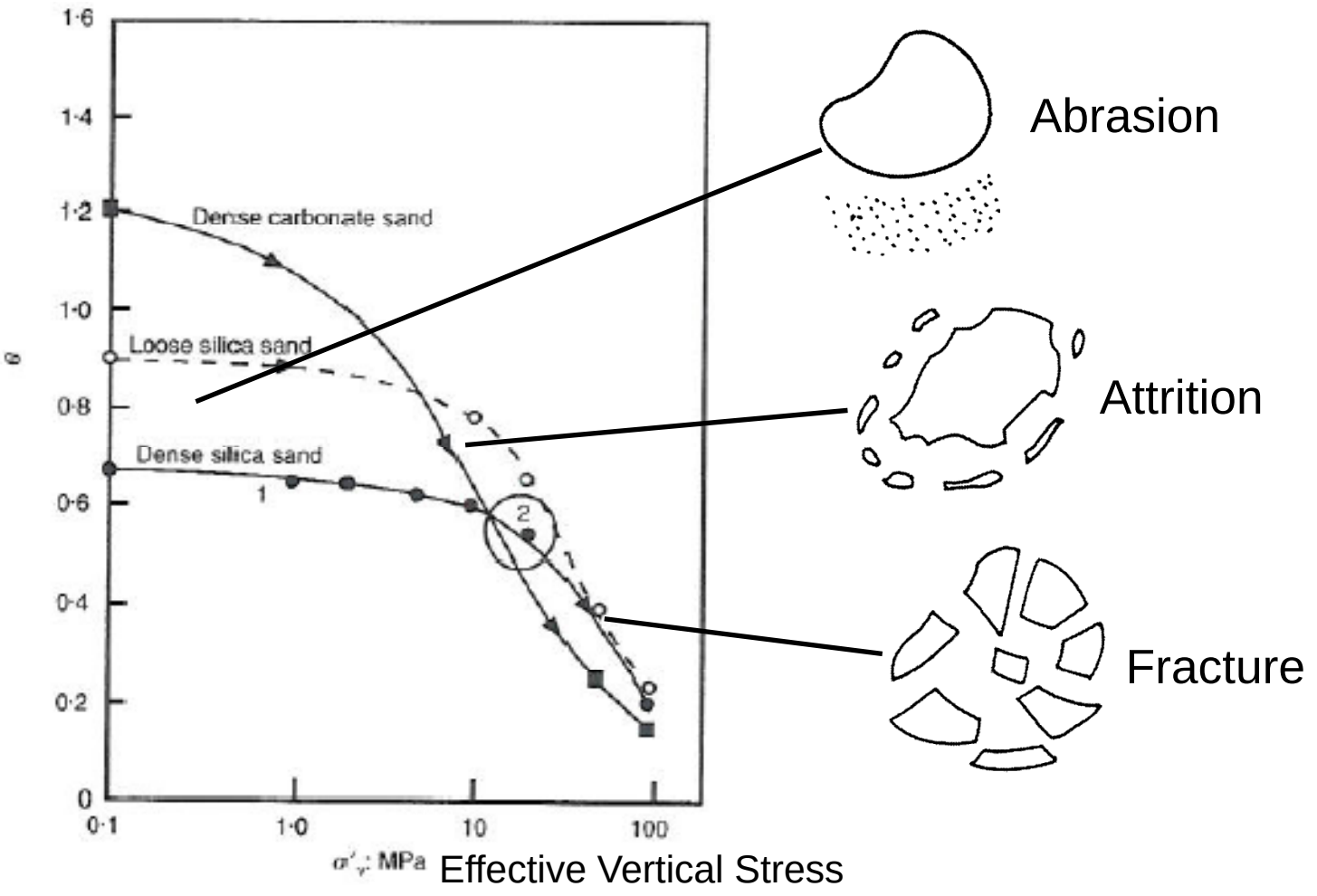
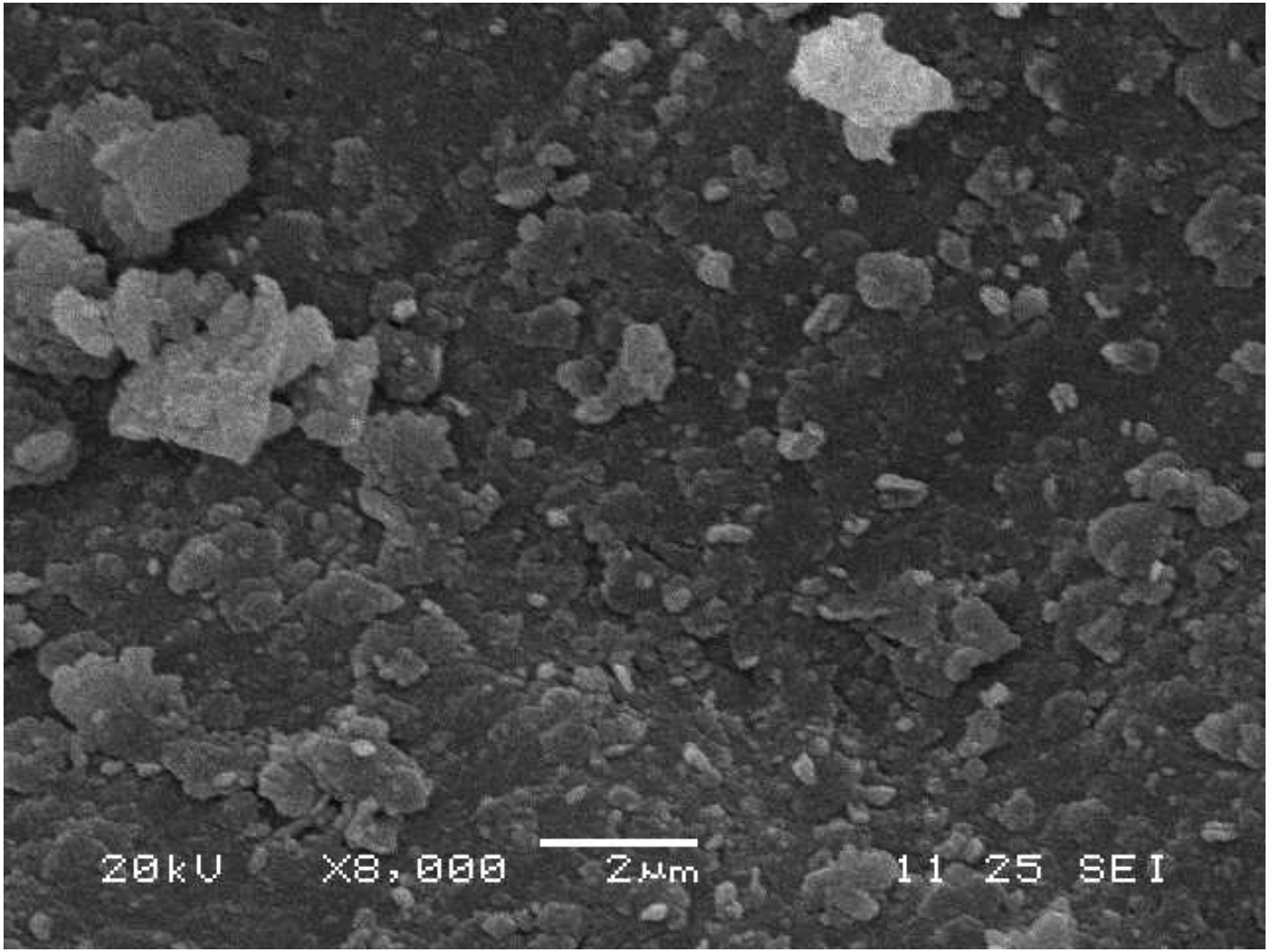
Evolution of Fracture?

$$e = \frac{V_{voids}}{V_{solids}}$$



Golightly, C.R., Engineering Properties of Carbonate Sands, PhD Dissertation (1990), Braford University

Nano-scopic Flakes in Crust



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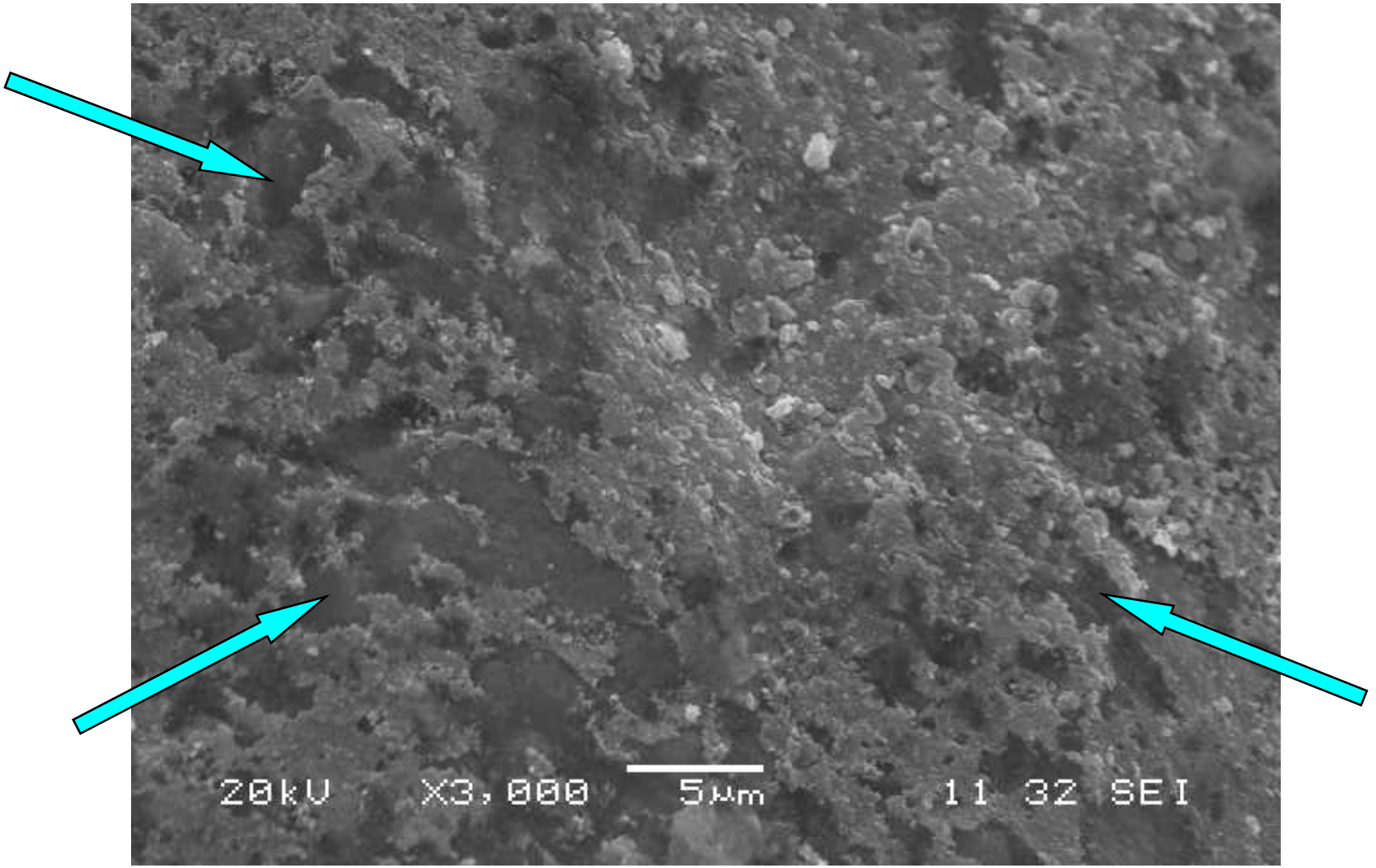
Pitting in Gaps in Crust



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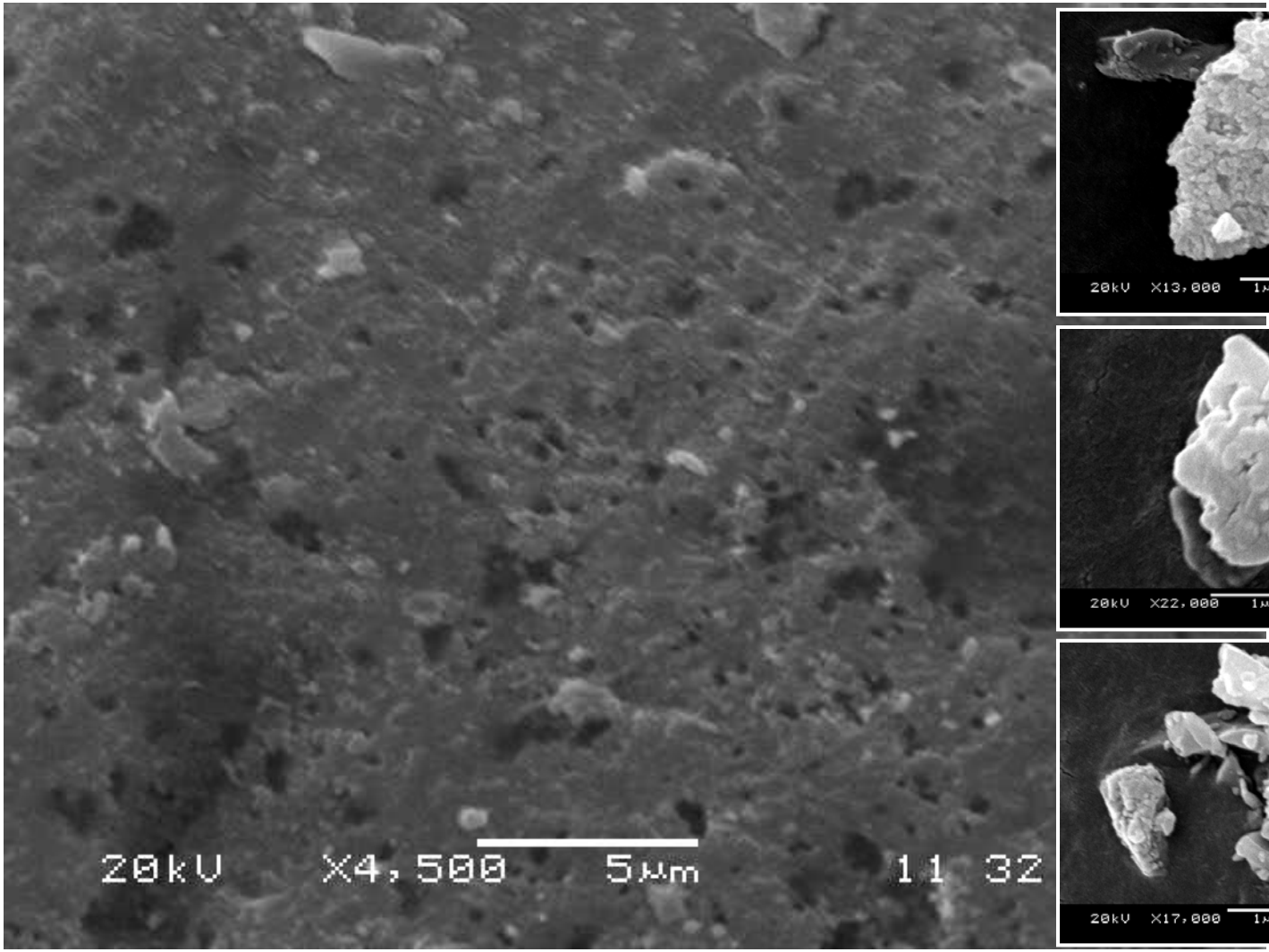
Post-Impact Surface with Crust Removed—Evidence of Pitting



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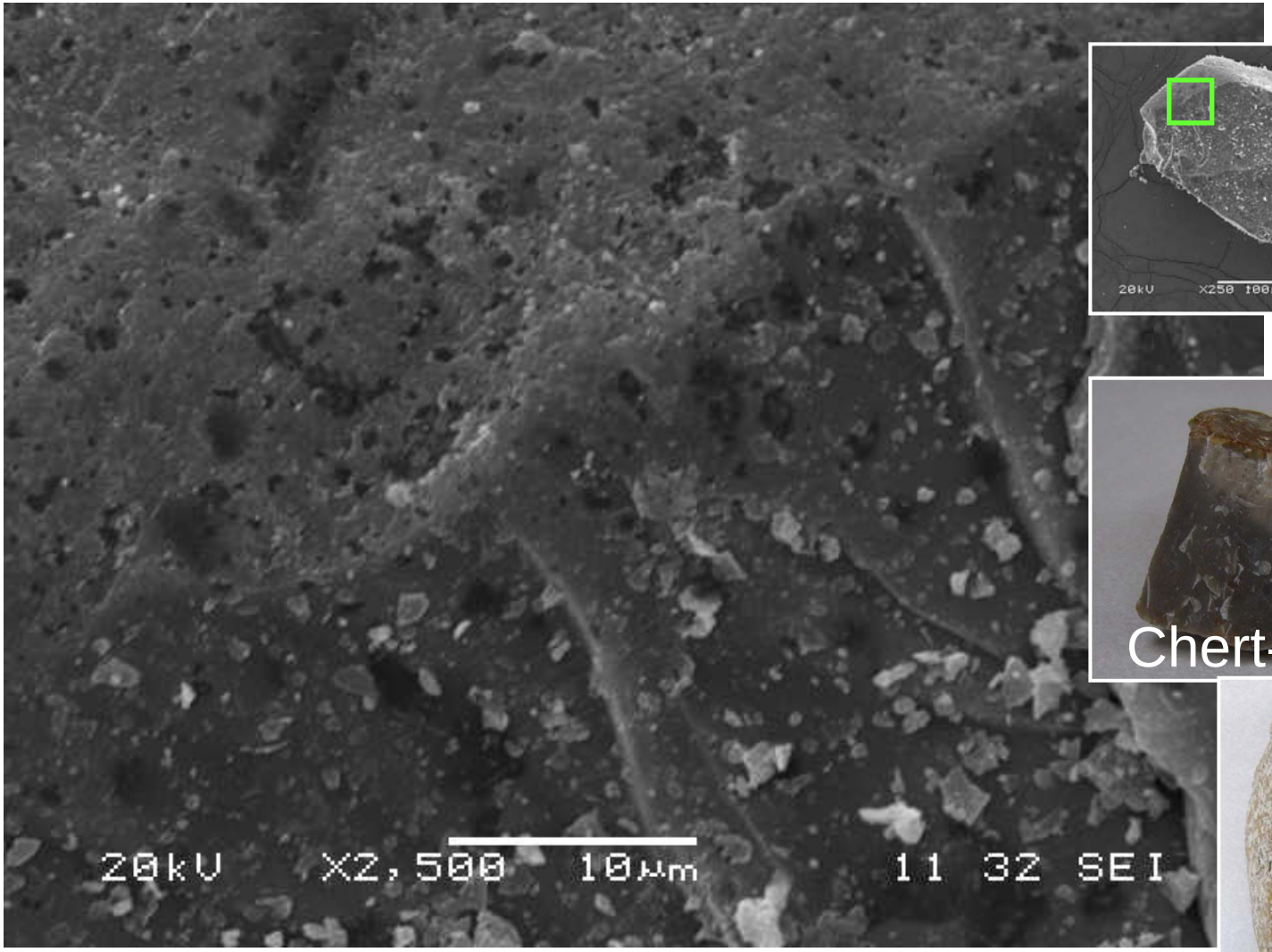
Sub-Surface Porosity



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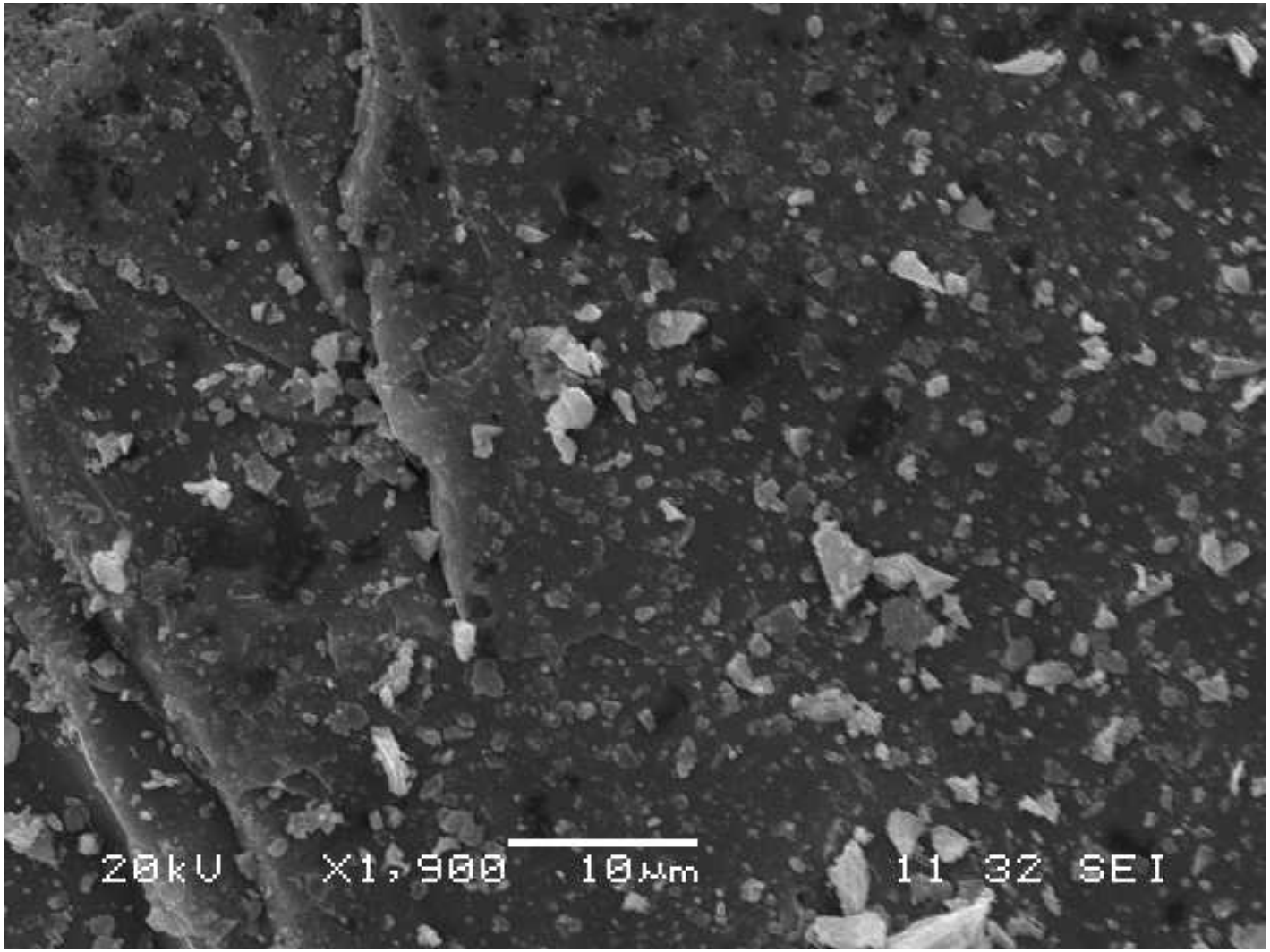
Pores Decrease with Distance from Surface



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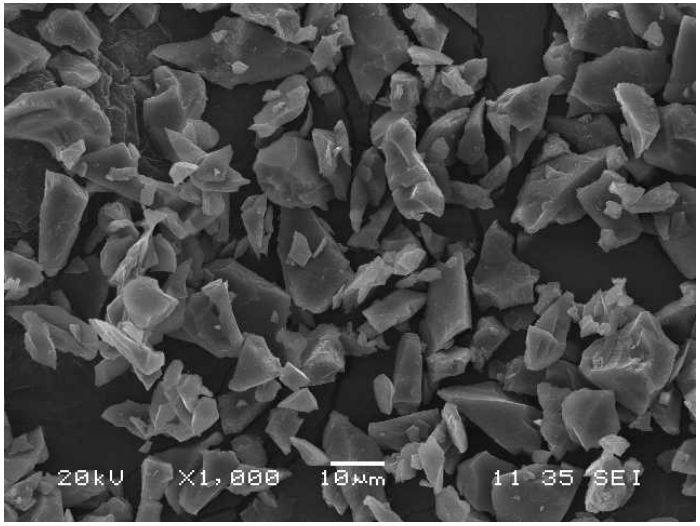
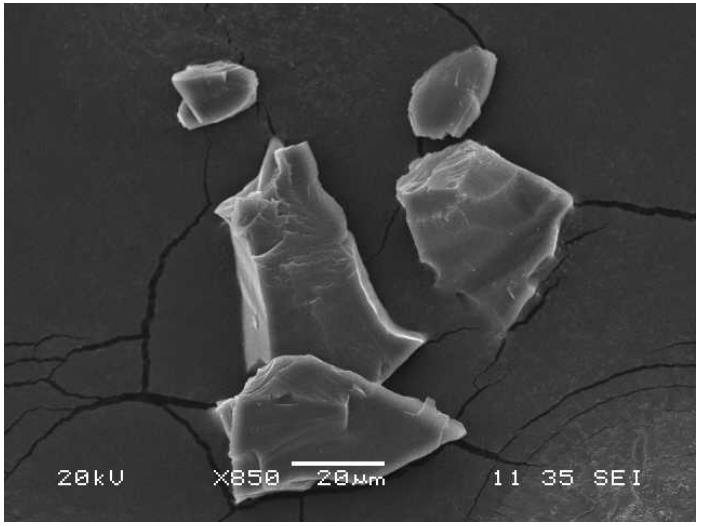
Sonicated, Washed, Sieved Self-Similar?

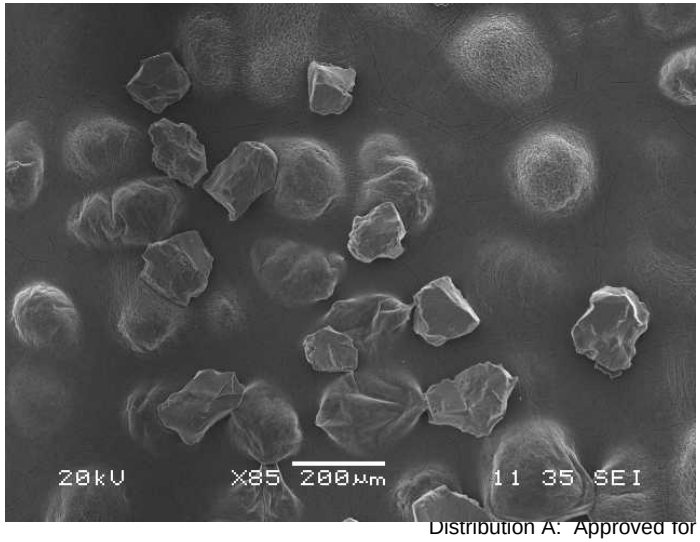
Fines

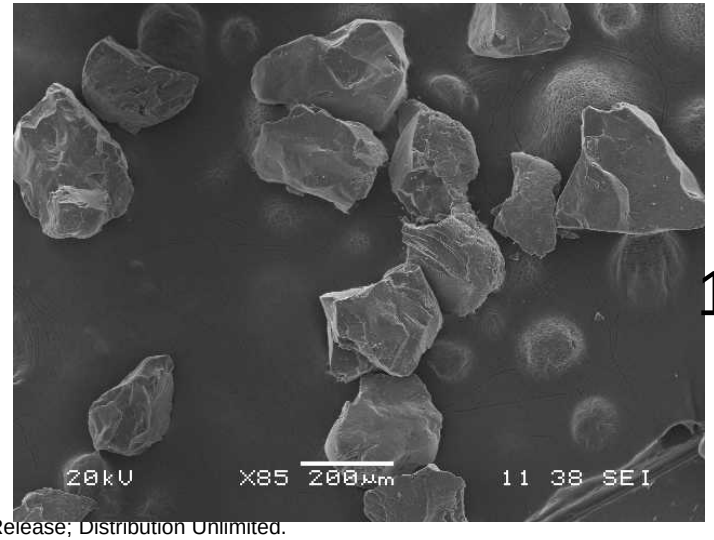




Sieve 20 µm

Sieve 53 µm





Sieve 150 µm

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Partial Fractures

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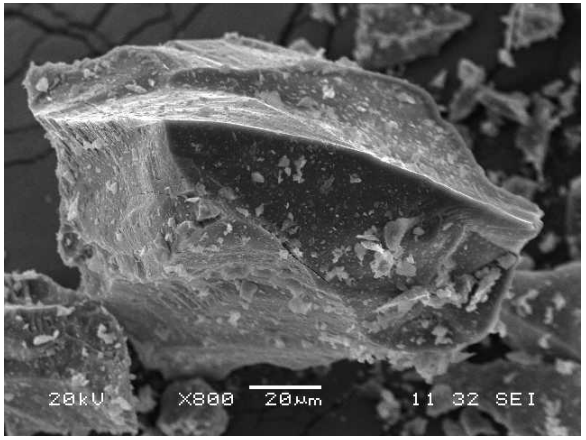

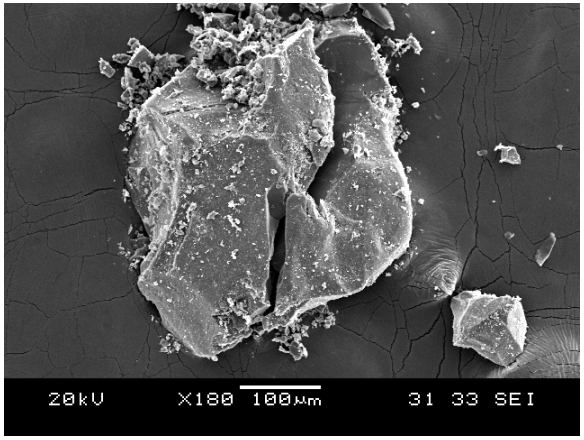

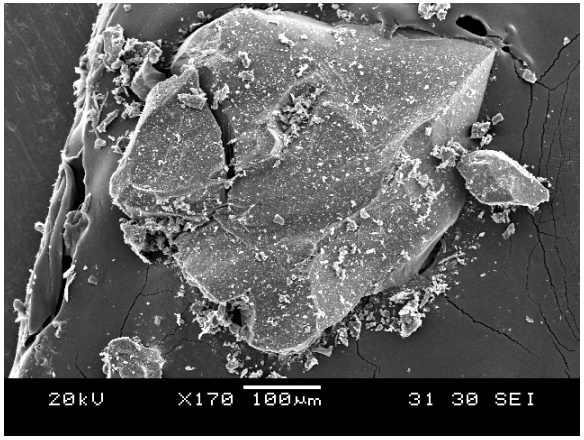

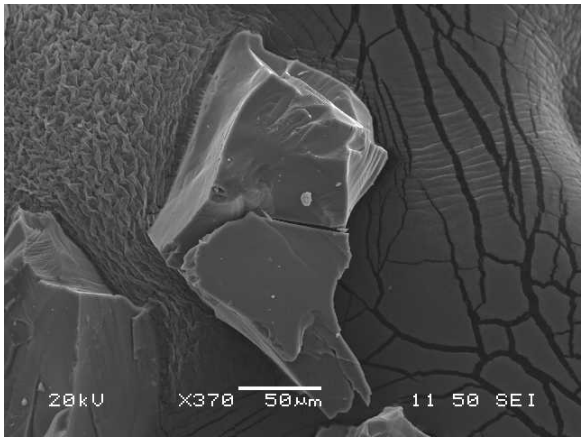

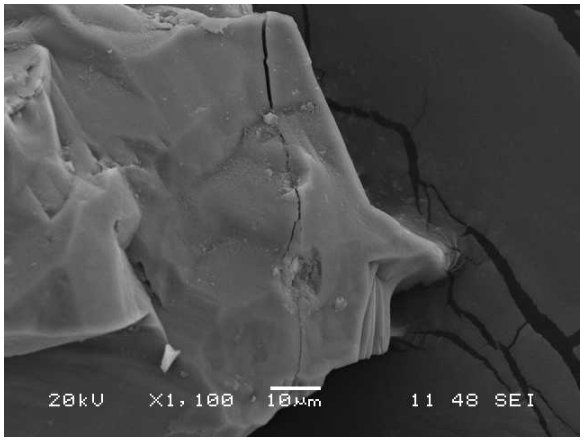

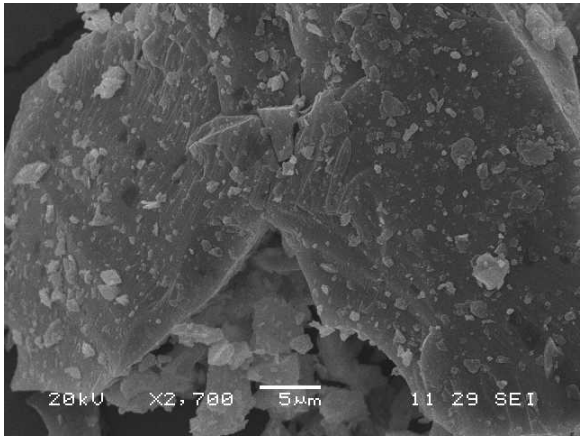

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