Beneficiated Fly Ash as a Micro Proppant for Oil and Gas Production from Fracking.

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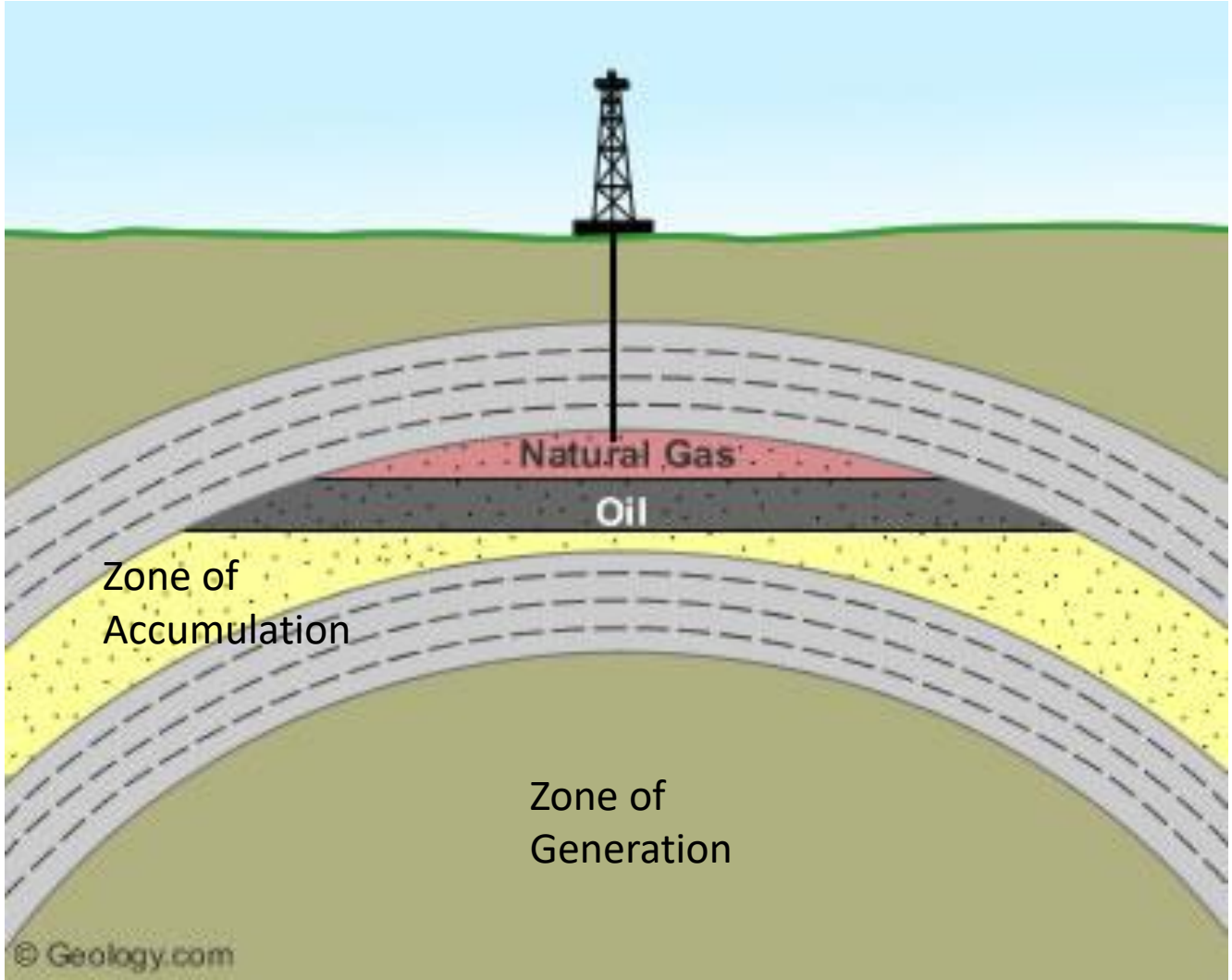
Happy Halloween

Outline of Presentation

1. Proppants: General Properties
2. Testing procedures
3. Proppants from fly ash
4. Field trials
5. Conclusions

Conventional Oil and Gas



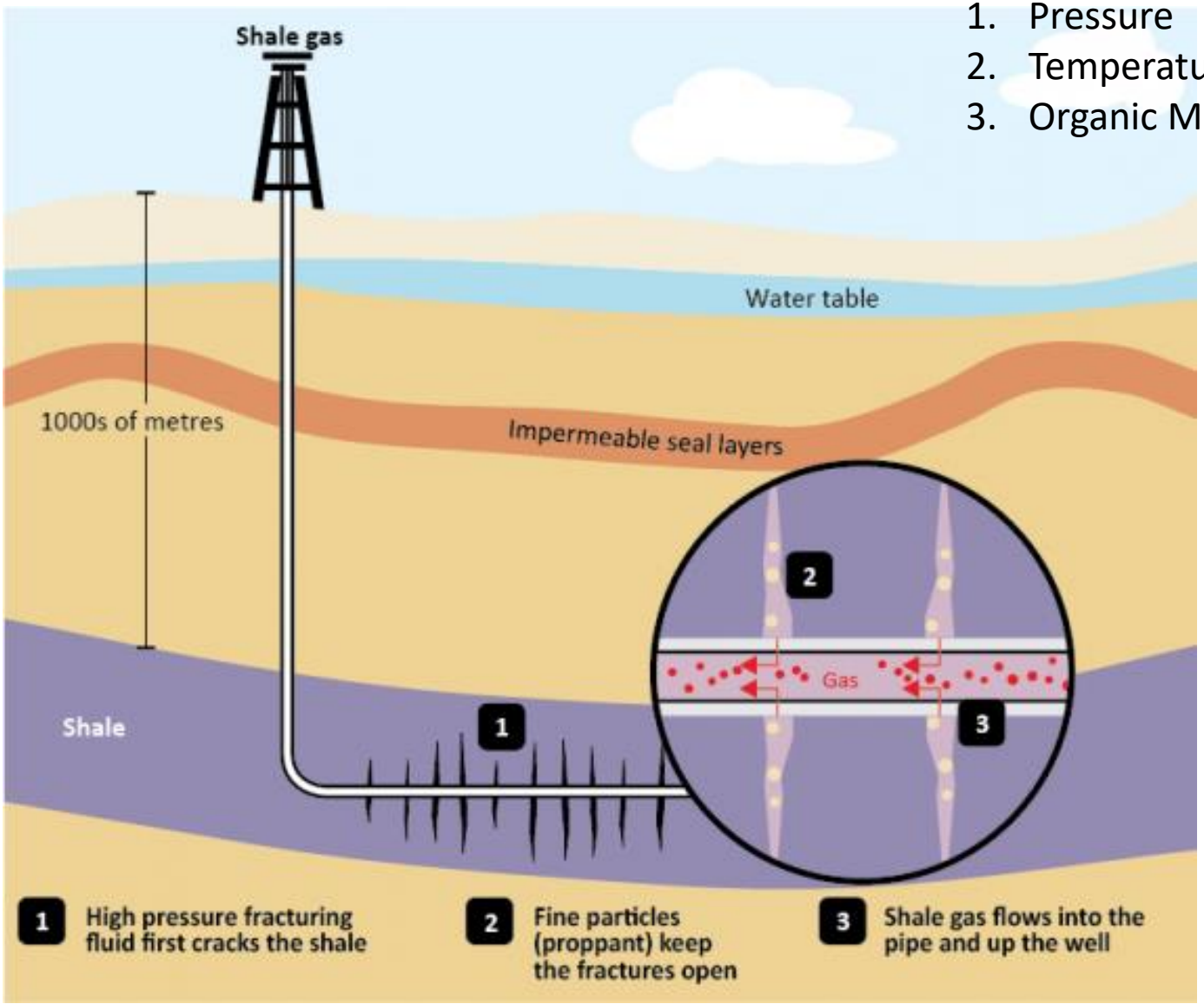
4 things Needed

1. Pressure
2. Temperature
3. Organic Matter
4. Someplace for the oil and gas to go

Fracking

3 Things Needed

1. Pressure
2. Temperature
3. Organic Matter



Fracking Proppants

- Proppants are used in Oil and Gas recovery via fracking.
  - “Props” the holes and fractures open.
  - Must be strong and have good permeability.
  - Needs to be pumpable great distances.
  - Frequently requires viscosity modifiers to keep suspensions viable.
- High Value Product, Large Market.
  - $80 to $500 per ton.
    - Largest cost in fracked well.
  - +$7 billion industry at peak, ~30 to 40 million tons.
    - Production is currently rebounding.
    - Fracking will produce the bulk of future energy in U.S.

Carman-Kozeny equation for flow through a packed bed

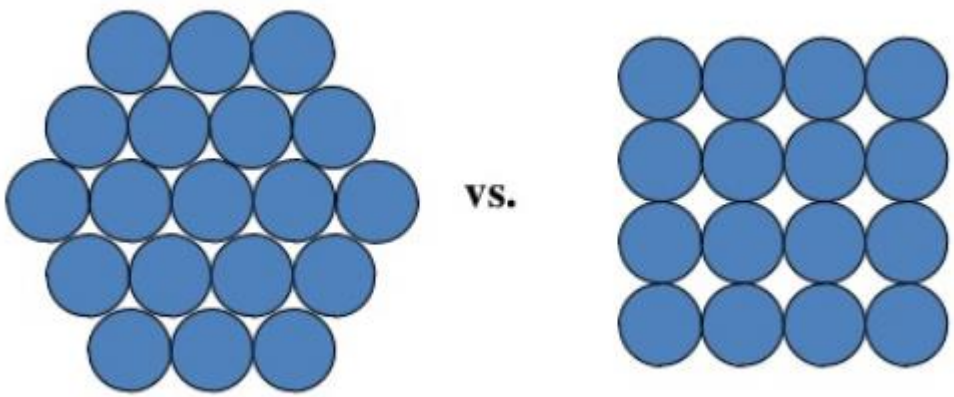
$$\frac{Q}{A} = \frac{\Delta p\ \epsilon^3}{\mu L\ 5(1-\epsilon)^2\ S^2}$$

Q is the volumetric flow rate
A is the face area of the bed
L is the depth of the bed,
Δp is the applied pressure drop
ϵ is the void volume of the bed
S is the volume specific surface of the bed
μ is the viscosity of the fluid

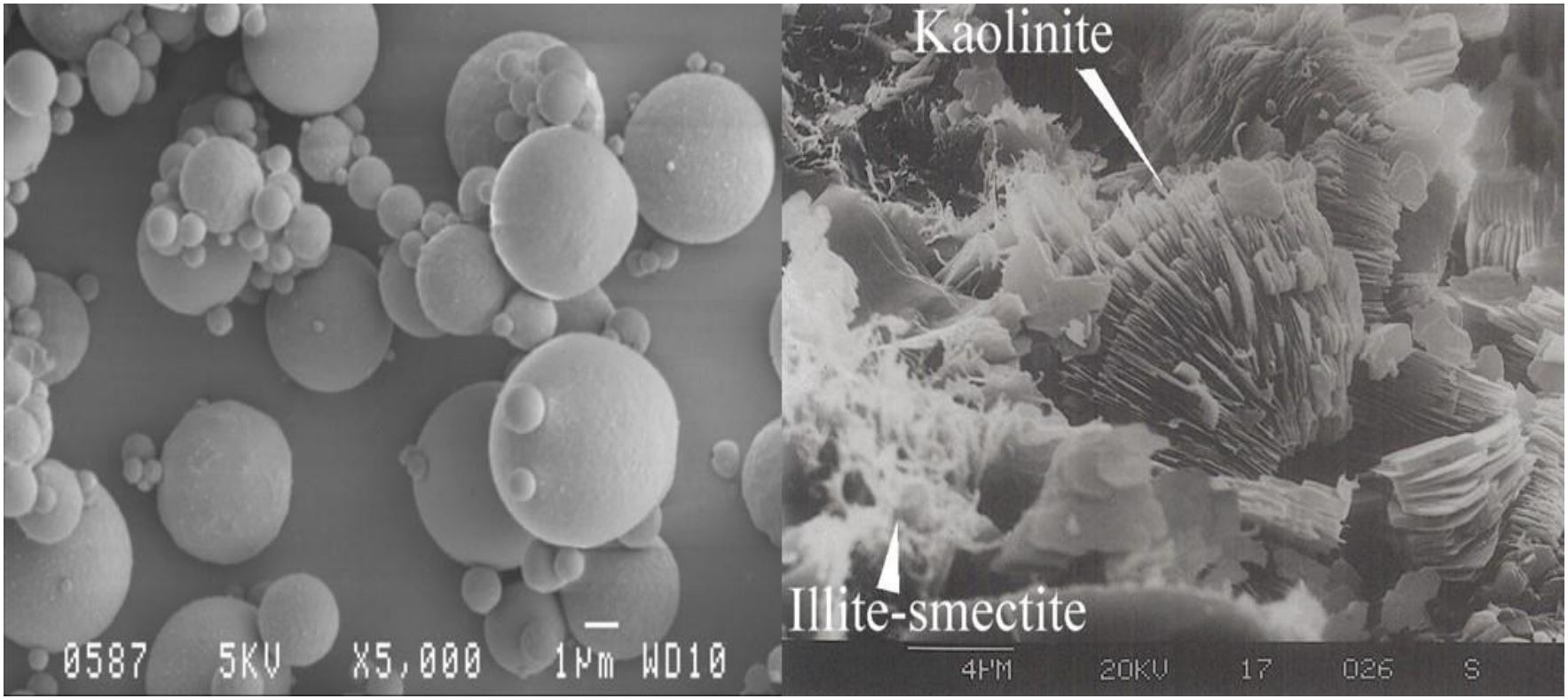
Void Volume (ϵ) and Packing

Hexagonal Close Packing D $= \pi\sqrt[2]{18} = 0.74$ ~26% ϵ

Cubic Close Packing D = π/6 = 0.52 ~48% ϵ



Ash Smooth Surface Low Drag



Internal Surface Area, S^2 Roughness factor

Pressure Differential Δp

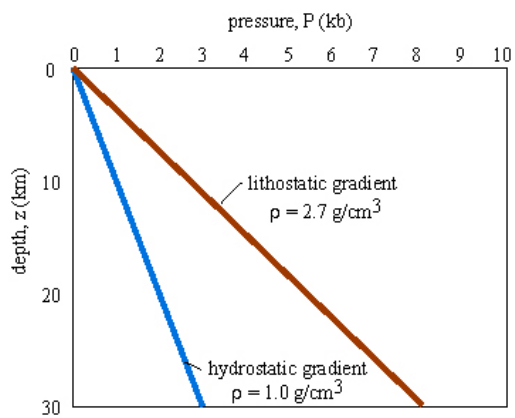
***p* = 9,360 psi lithostatic – 3,470 psi hydrostatic**

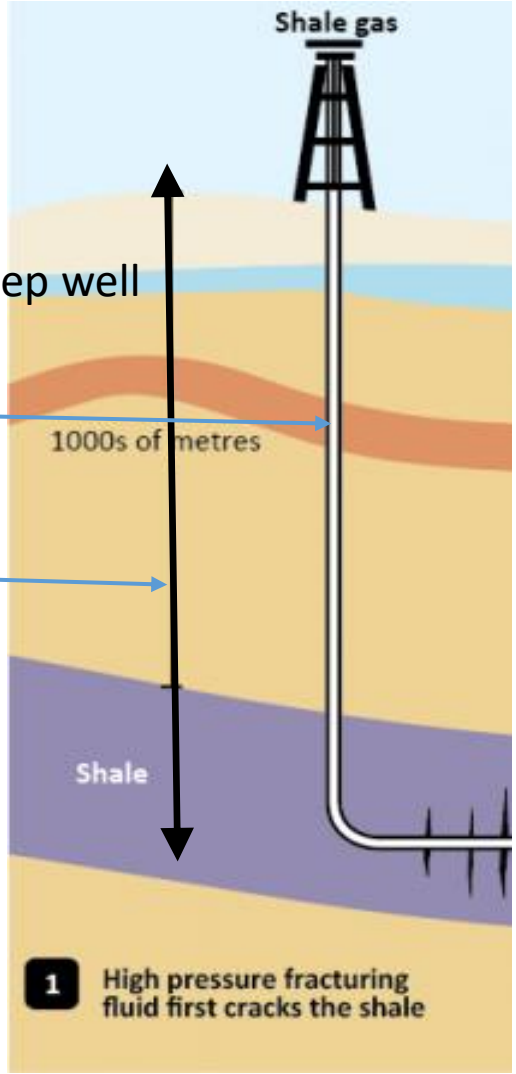
8,000 feet deep well

8,000 feet of water

Δ*p* = 5,890 psi packed bed differential

8,000 feet of rock

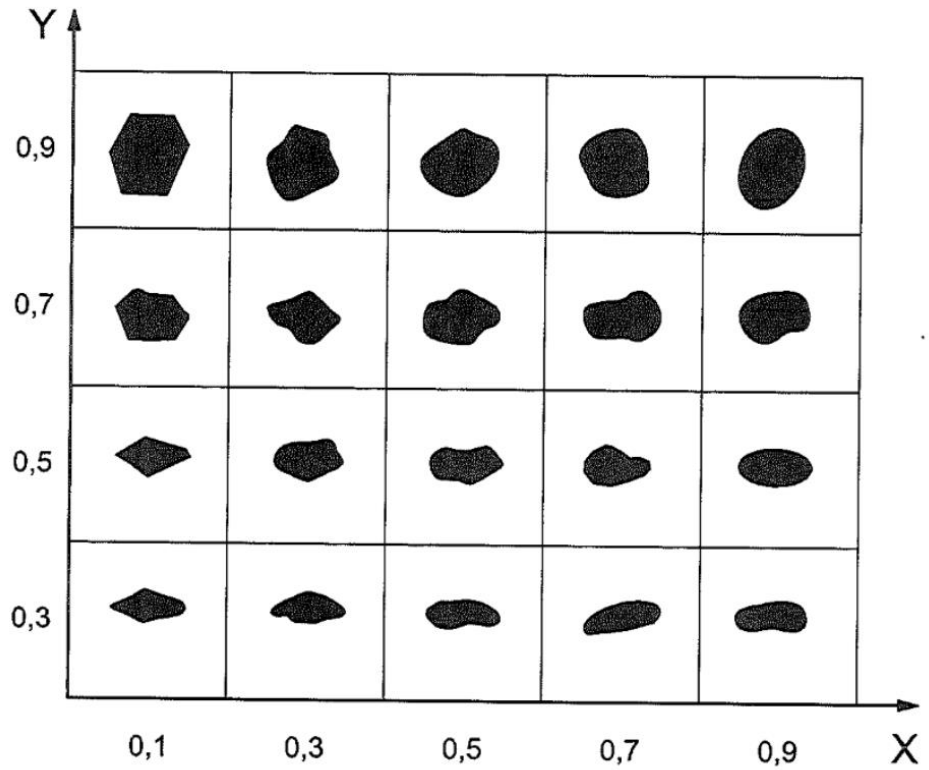




ISO 13503-2 Proppant Tests

- 4. Standard Sampling
- 5. Storage
- 6. Sieve Analysis
- 7. Proppant Sphericity and Roundness
- 8. Acid Solubility.
- 9. Turbidity.
- 10. Procedures for determining proppant bulk density, apparent density and absolute density.
- 11. Proppant crush-resistance test.
- 12. Loss on ignition of resin-coated proppant.

7. Sphericity and Roundness



Key

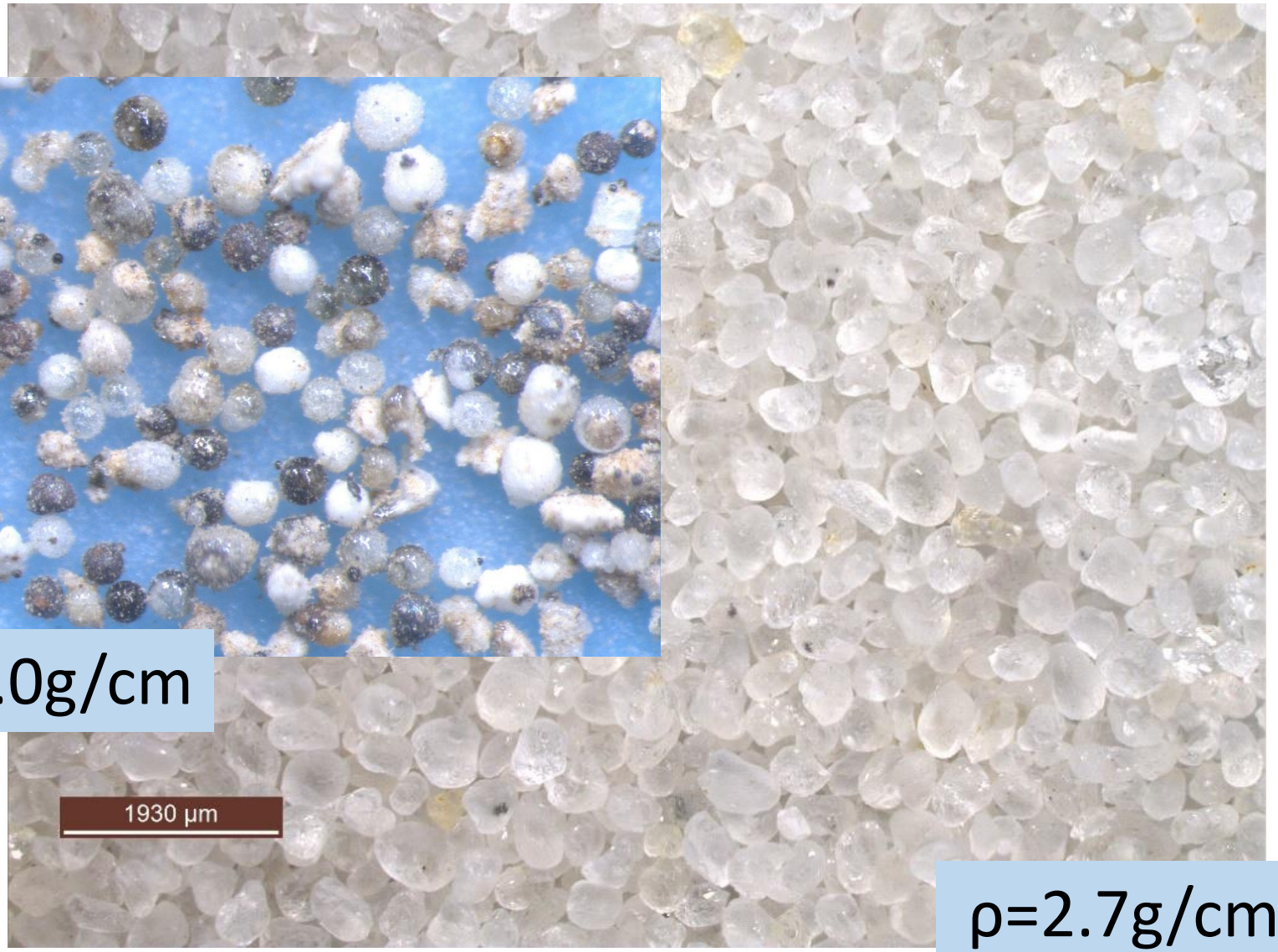
X roundness

Y sphericity

Figure B.1 — Chart for visual estimation of sphericity and roundness

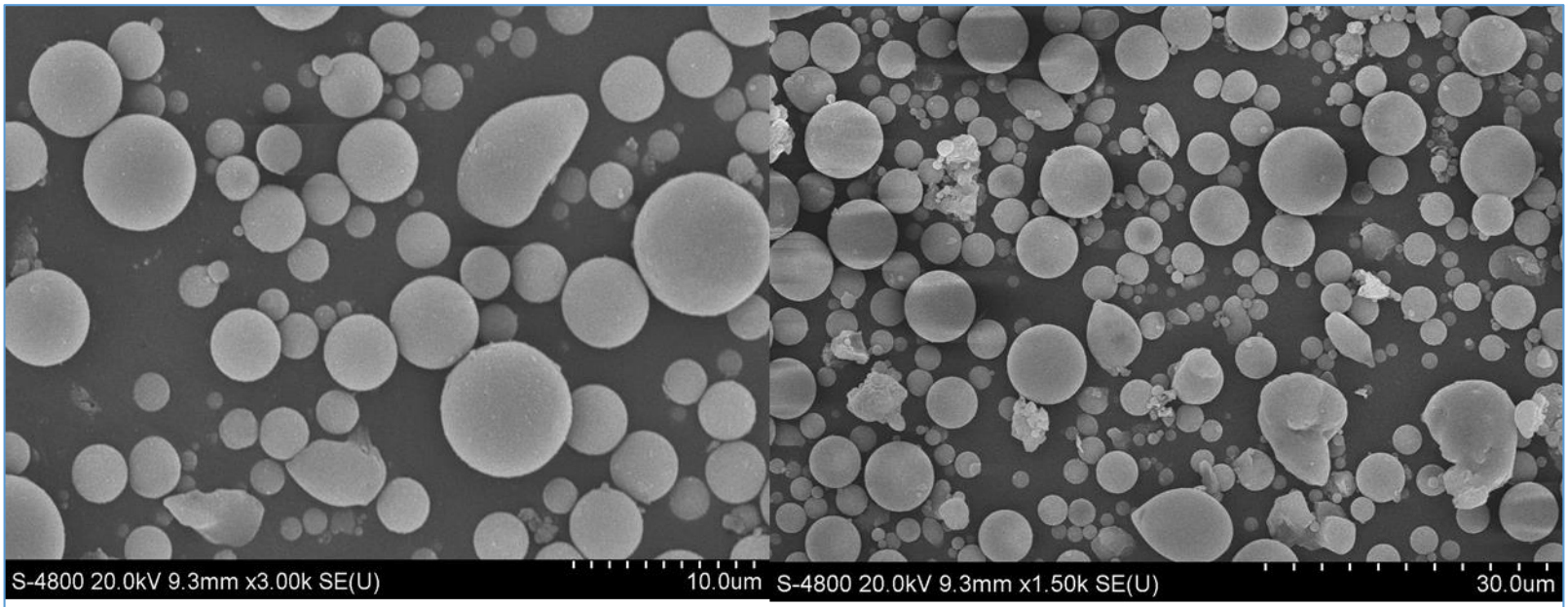
7. Sphericity and Roundness

ρ=2.0g/cm



ρ=2.7g/cm

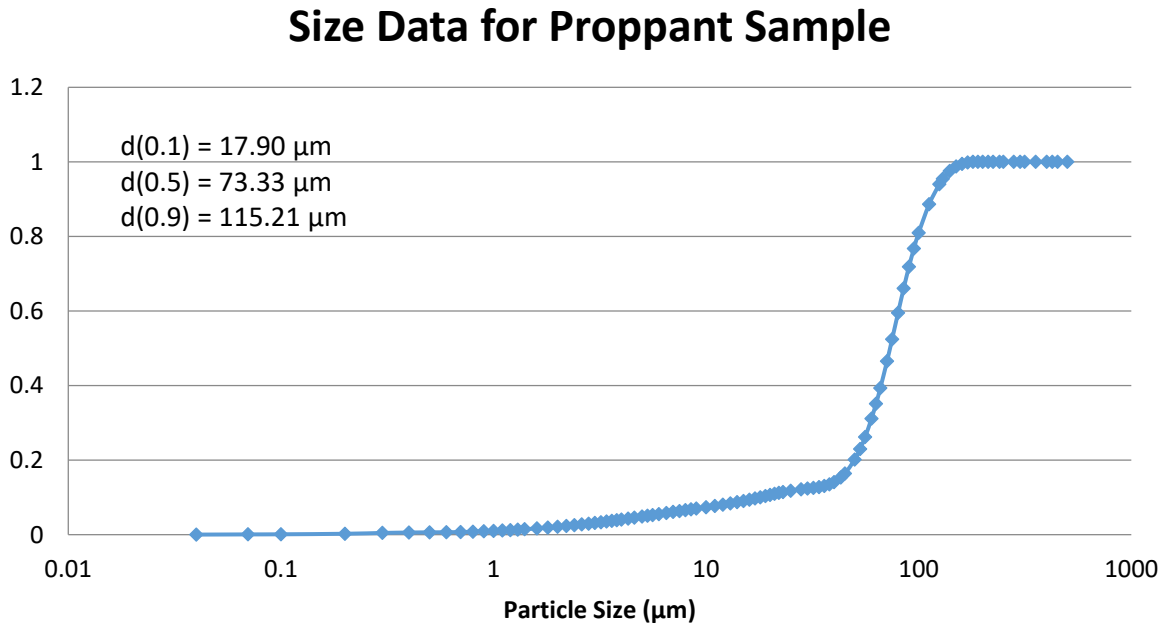
No Apparent Surface Changes for Ponded Ash with Depth or Age

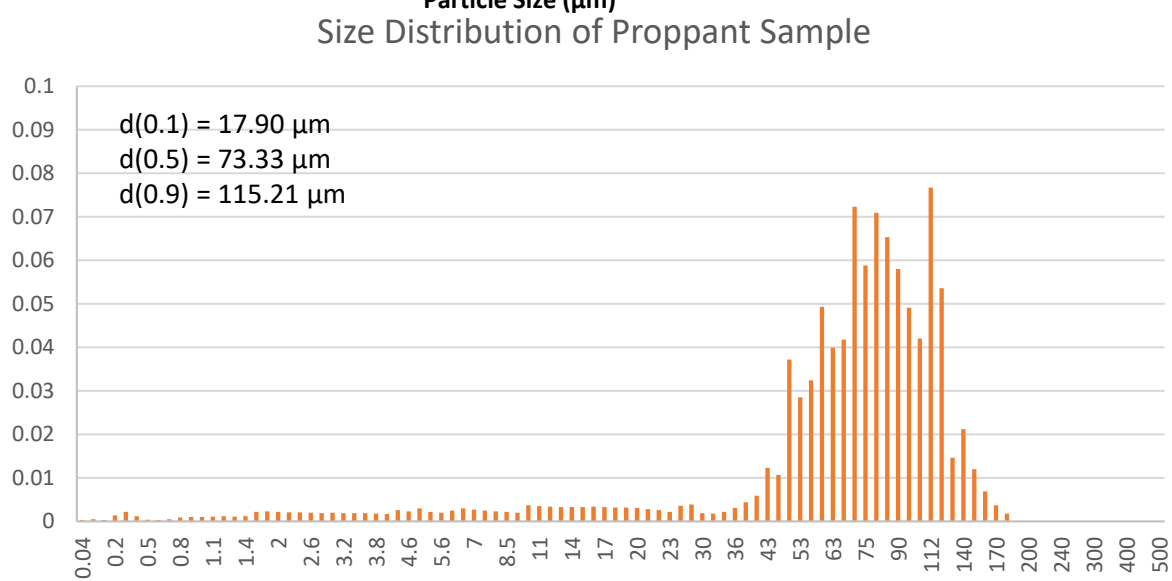


Depth 130 feet

Kingston Cell

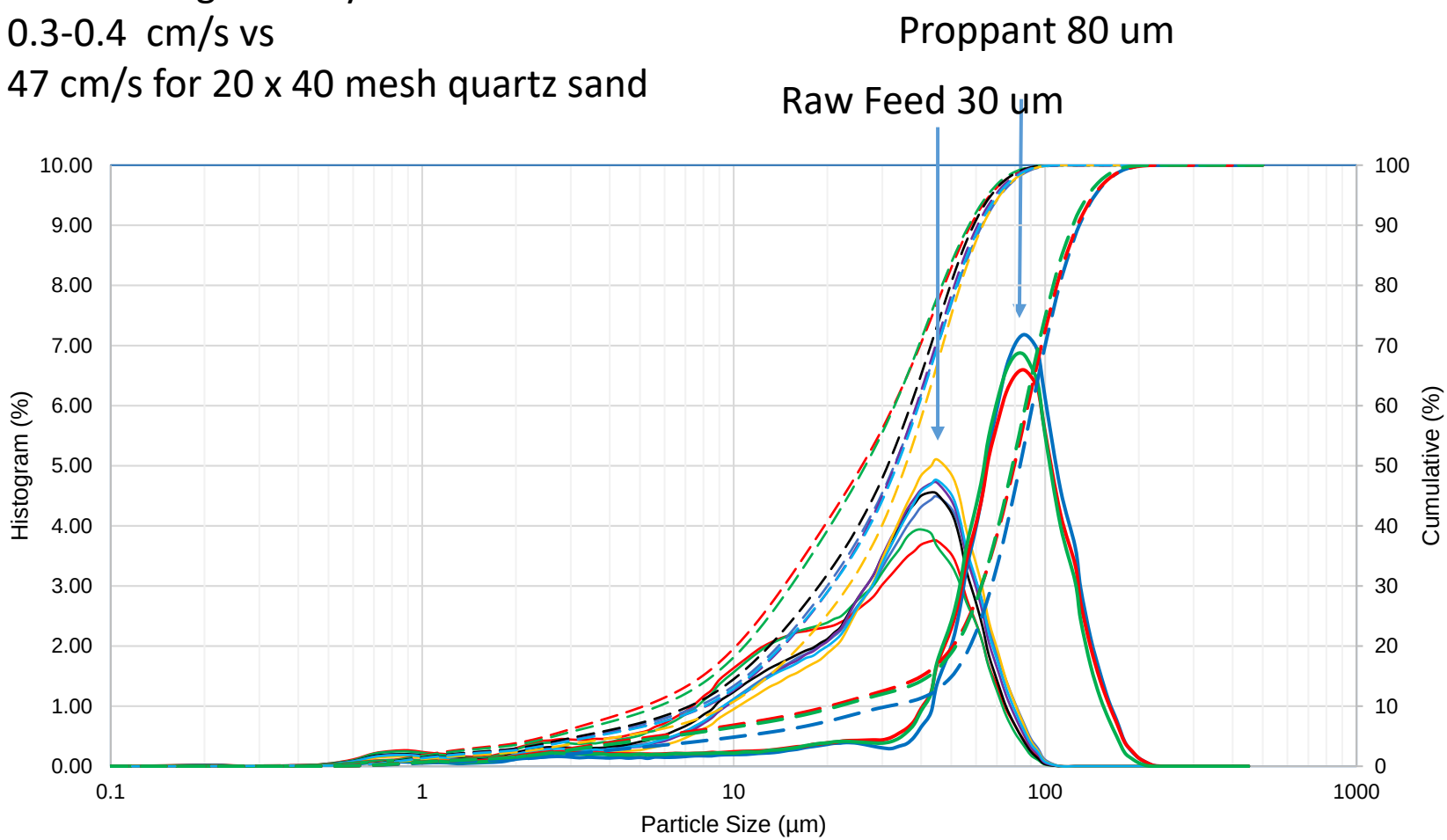
Size Distribution of Ash Proppants



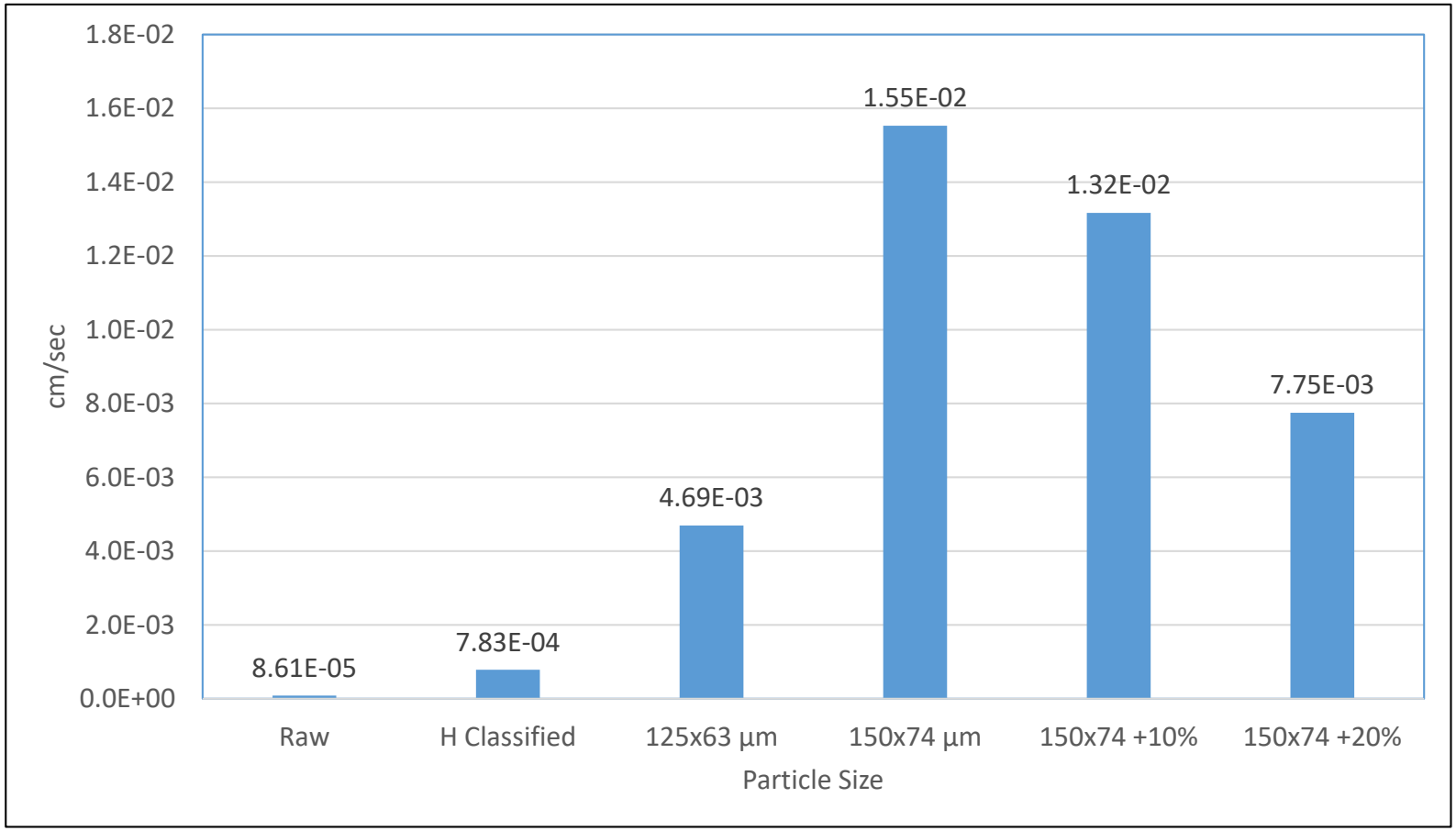


3. Particle Size From Cardinal

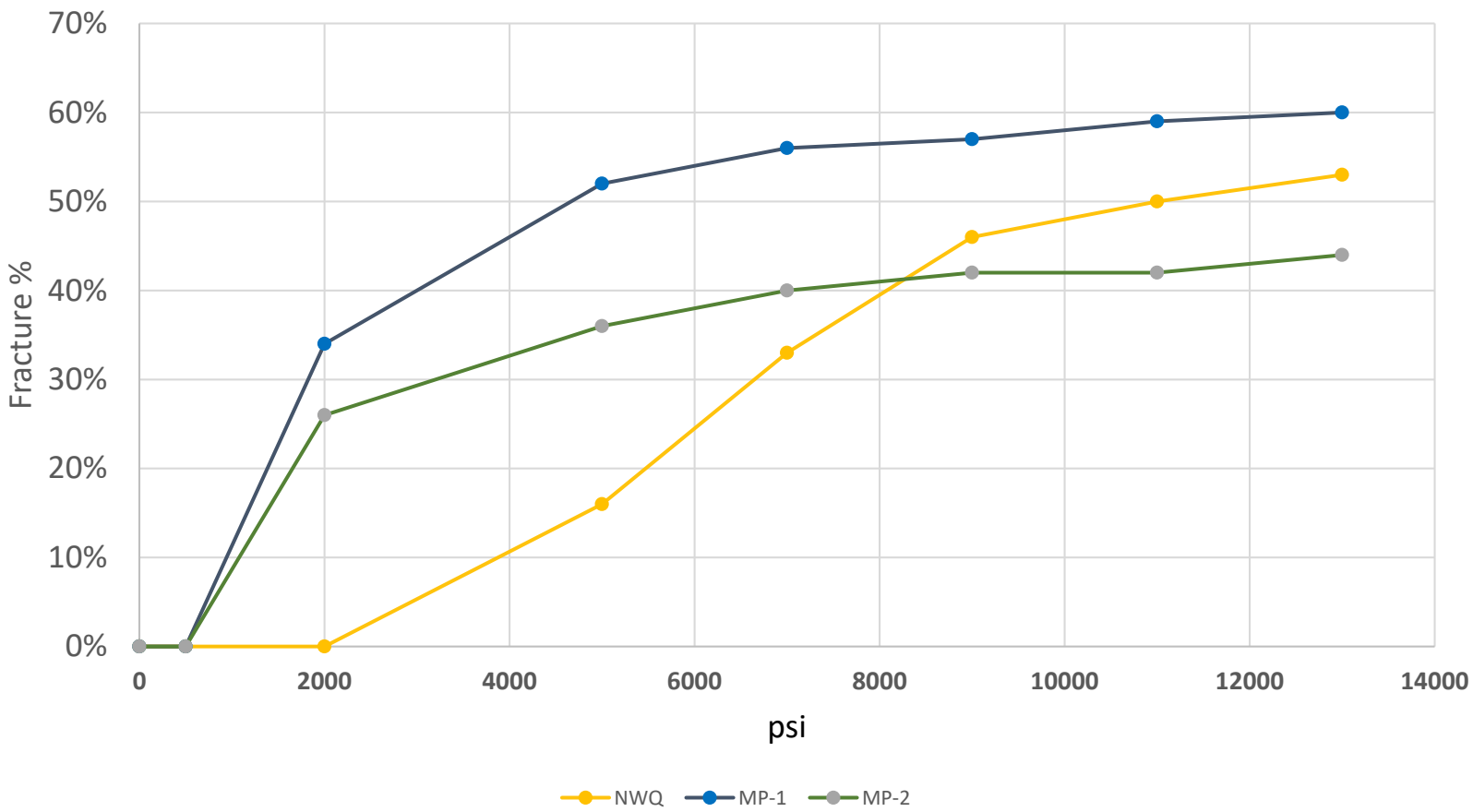
Low Settling Velocity
0.3-0.4 cm/s vs
47 cm/s for 20 x 40 mesh quartz sand



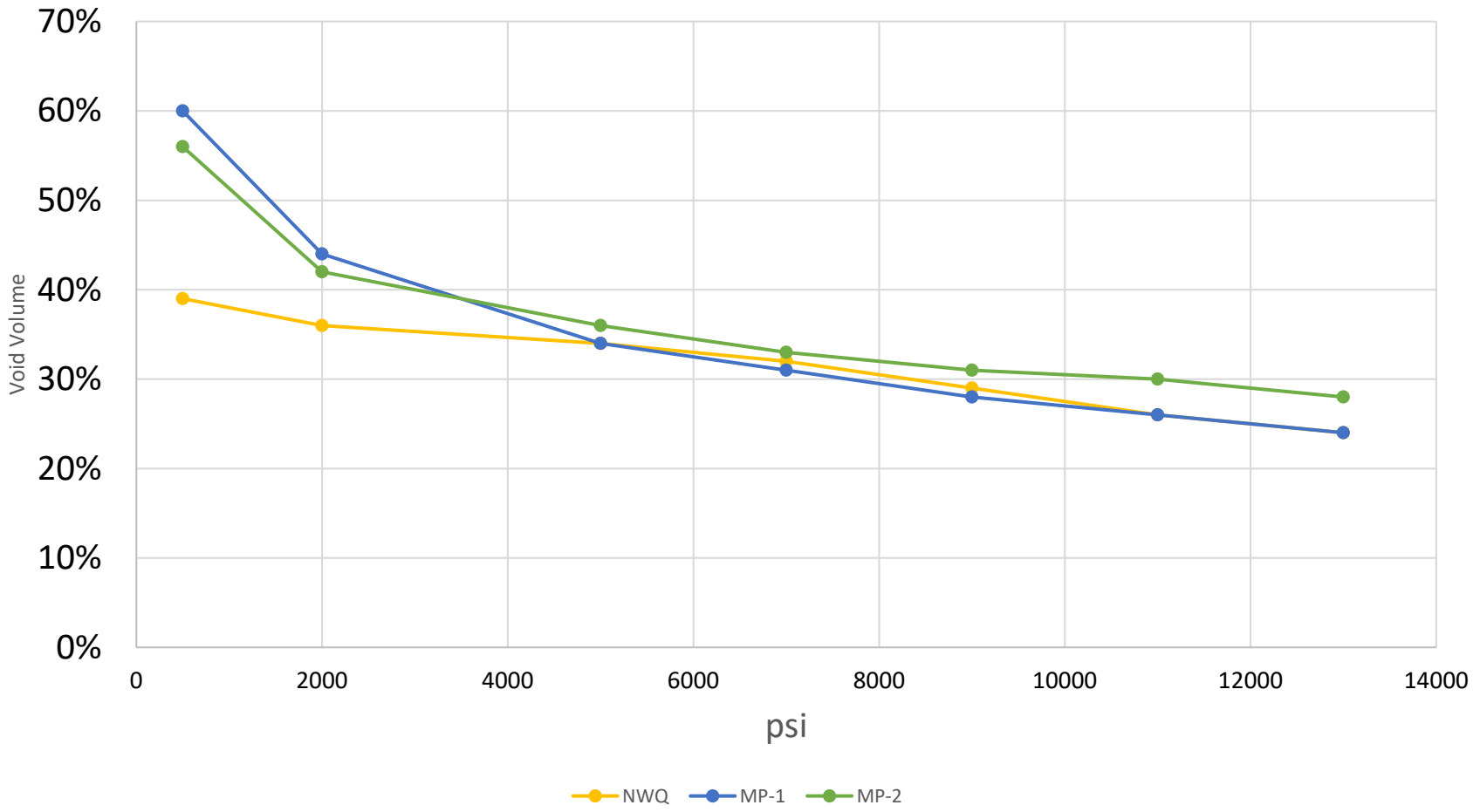
High Hydraulic Conductivity from Classified Ash



Fracture percent as function of pressure



Void volume as function of pressure



Trends in Proppant Properties, Finer is better, More is better

US 20130161003A1

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(12) **Patent Application Publication**

Makarychev-Mikhailov et al.

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(54) **PROPPANT PLACEMENT**

(75) Inventors: **Sergey Mikhailovich Makarychev-Mikhailov**, St. Petersburg (RU); **Christopher N. Fredd**, Westfield, NY (US); **Trevor Hughes**, Cambridge (GB); **Evgeny Borisovich Barmatov**, Cambridge (GB); **Jill F. Geddes**, Cambridge (GB)

(73) Assignee: **SCHLUMBERGER TECHNOLOGY**), TX

>90% <105 µm

>90% <37 µm

§ 371 (c)(1), (2), (4) Date: Mar. 12, 2013

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E21B 43/267 (2

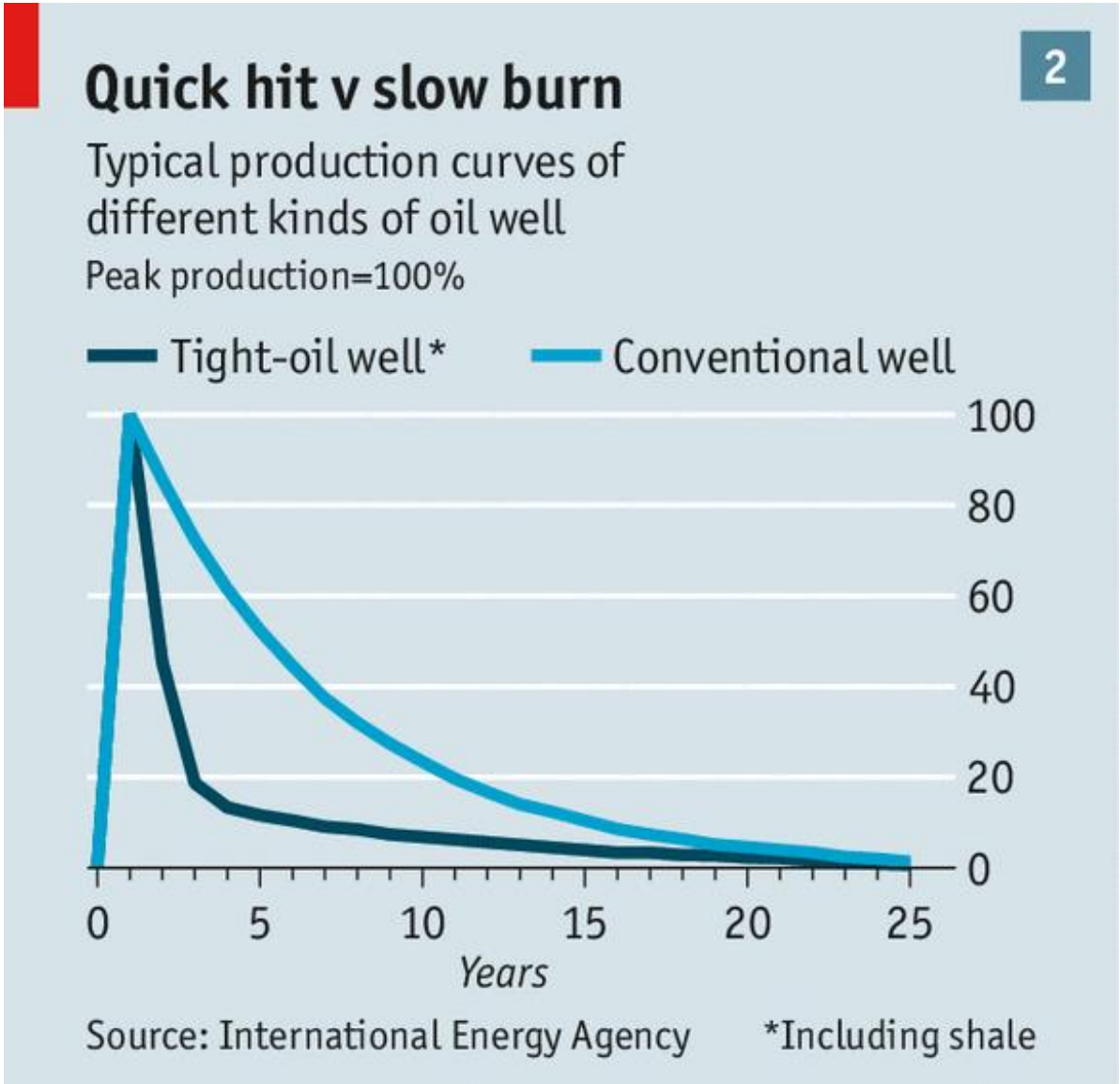
(52) **U.S. Cl.**
CPC .....
USPC .....

(57) **ABSTR.**

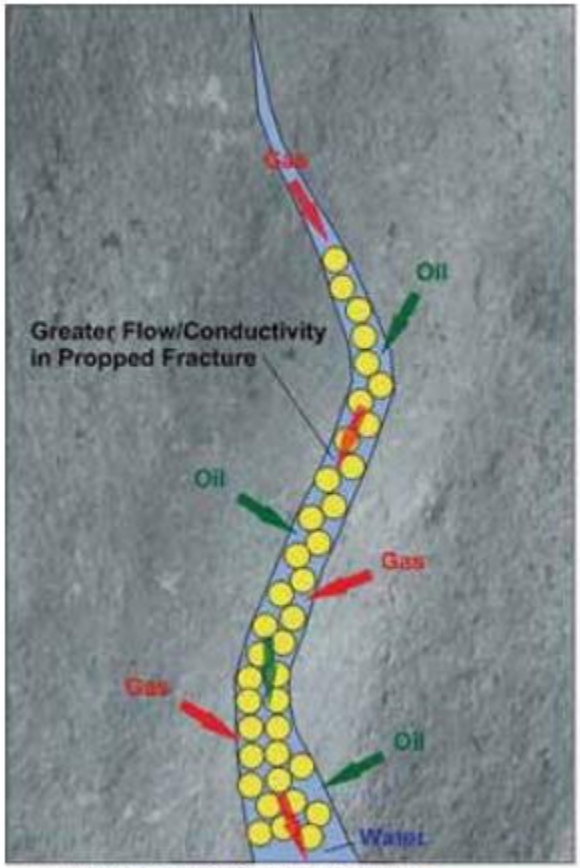
Embodiments of hydraulic fra herein use fine mesh proppan method is used to fracture a low one embodiment the method u conductivity of a fracture. In through the fine mesh proppant work of connected channels to i tivity.

Glass Beads
Plastic Beads
Bauxite
Muscovite
Nut shells
Wood chips

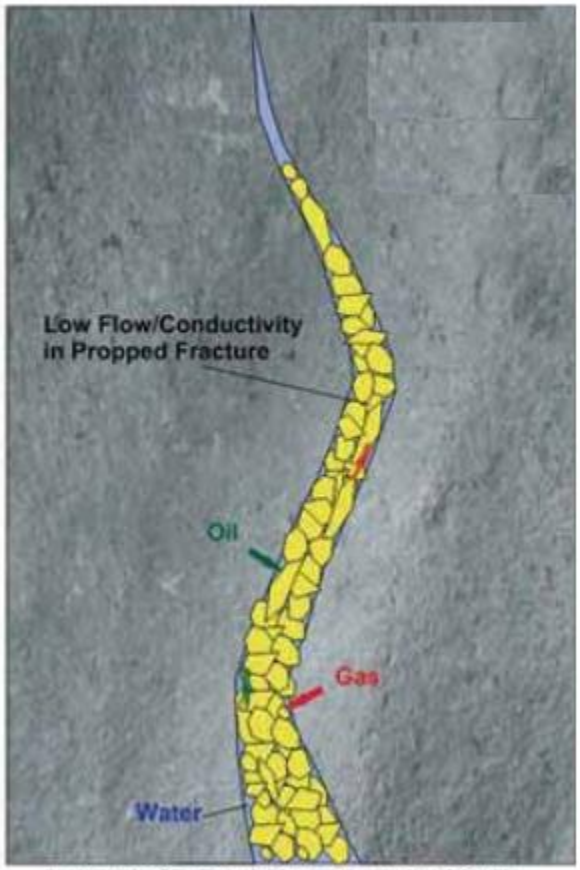
Oil Well production



Filling micro fractures is important



a. Well Rounded Ceramic Proppant



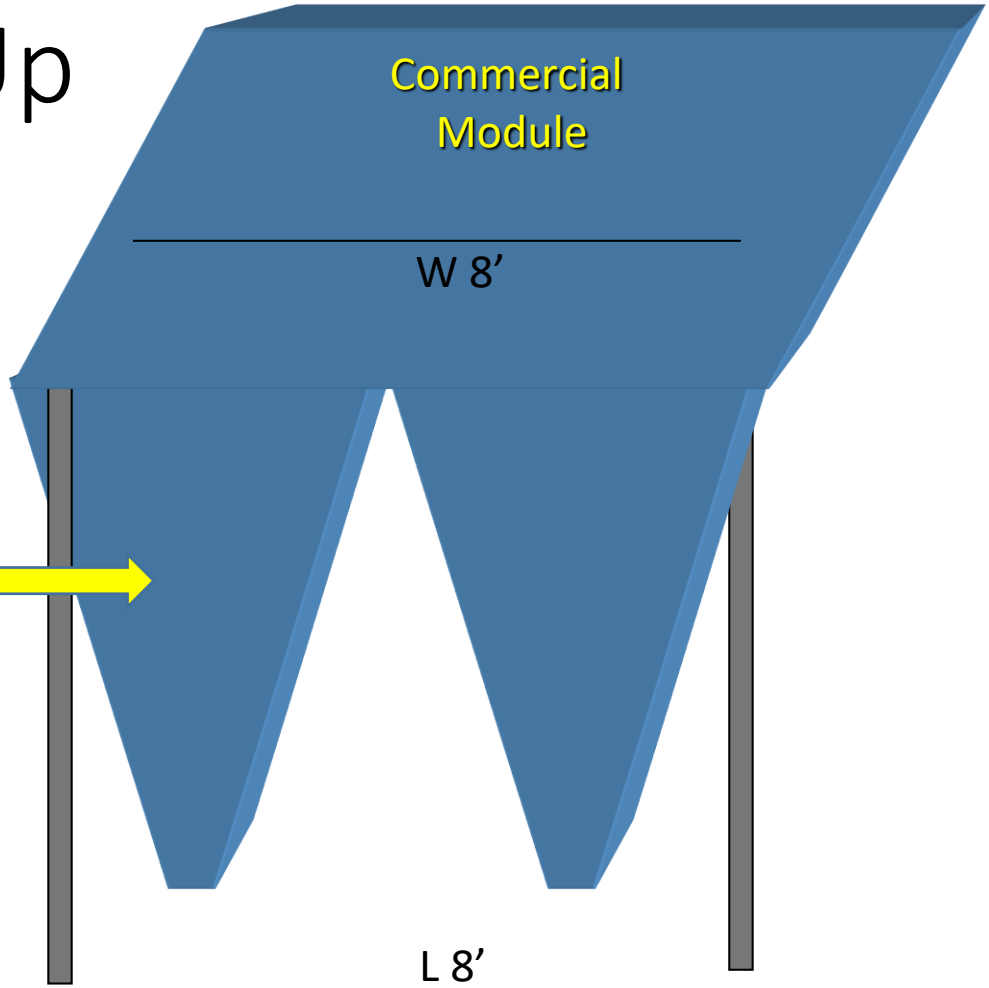
b. Poorly Sorted Angular Proppant Sand

Proppant Recovery Field Trials

The UK CAER/NuForm Materials Classifier/Thickener Technology

- Specifically for Ash Ponds.
  - 12 years in development from bench to demonstration.
  - Patented.
- Designed to be Fed from a Dredge.
  - High solid flows.
  - Only fast approach for rapid decommissioning.
  - Operates in saturated conditions.
- Simultaneously Recover Products and Thicken
  - Including High Performance Pozzolan
  - Proppants
  - Cenospheres
  - Fillers

Actual Scale Up



Redesigned to Improve Thickener Performance

The UK CAER/NuForm Materials Classifier/Thickener Technology

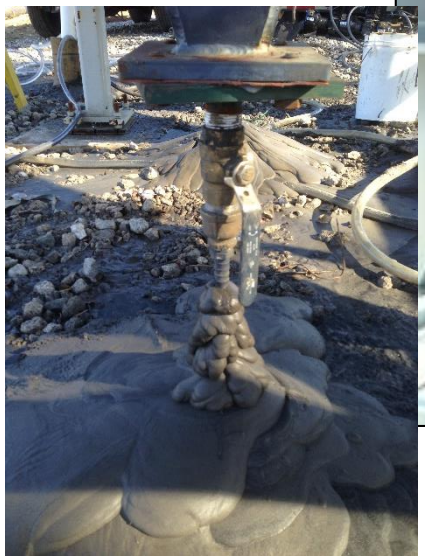
Cardinal Pond, Brilliant, Ohio

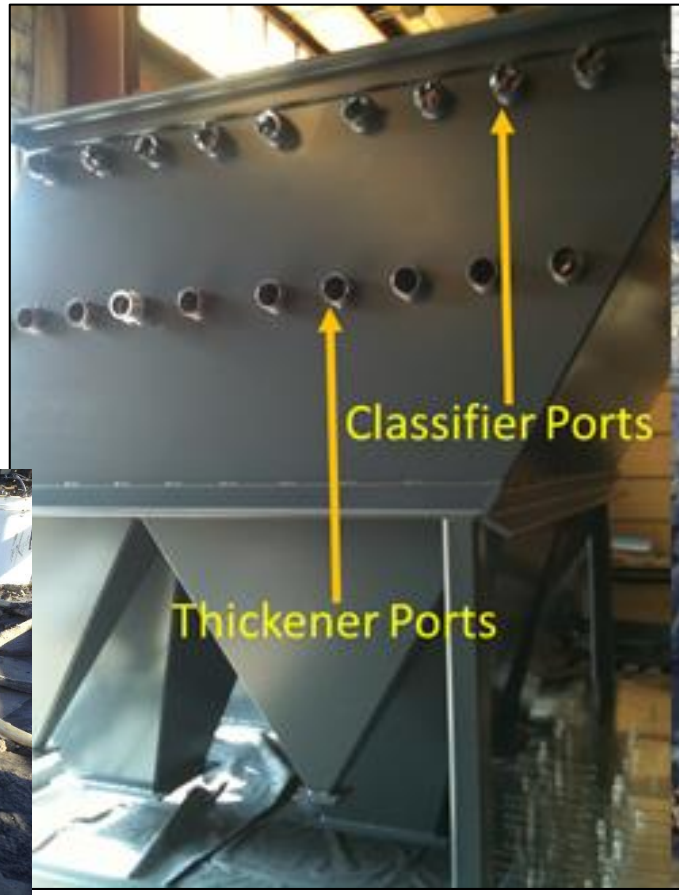
Classifier/Thickener Technology

AEP Cardinal Pond, Brilliant, Ohio

The UK CAER/NuForm Materials Classifier/Thickener Technology

Designed to be:
Simple
Inexpensive
Flexible
Transportable





Proppants from Ponded Ash

- Round Smooth Particles
  - Low surface drag.
- Classified Materials have High Hydraulic Conductivity.
  - Critical to Remove Fine Ash.
  - Values approaching 10^{-2} cm/sec achievable.
  - Highly Pumpable
- High Strength.
  - At low density and high void volume
  - Exceptional strength and stiffness at pressures in the 5,000 to 13,000 psi range.

Proppants from Ponded Ash

- Relatively low density.
  - Range of 1.97 to 2.2 g/cm^3,
  - low settling velocities, e.g. 0.3-0.4 cm/s compared to 47 cm/s for 20 x 40 mesh quartz sand.
- Simply modified smooth surfaces.
  - Polycarboxylate, sulfonates and silanes are useable
  - Works well with dispersants
- Chemically inert.
- Environmentally green material.
- High Value.
  - NWQ proppant is in the range of 60 to 80 dollars per ton.
  - A superior micro-proppant would be valued much higher.

Conclusions

- Recovery of high value proppants from most ash ponds is feasible.
- Siting facilities near high concrete value markets is not important.
- Recovery of proppants that are not sensitive to transportation costs increasing viable plant options.
- Ponded ash represents long term strategic resource worth billions in revenue and increased oil and gas production.

Thanks To:

Cardinal Pond Operators
Sphere One

Questions?