Colloid-Facilitated Contaminant Transport in Subsurface Environments

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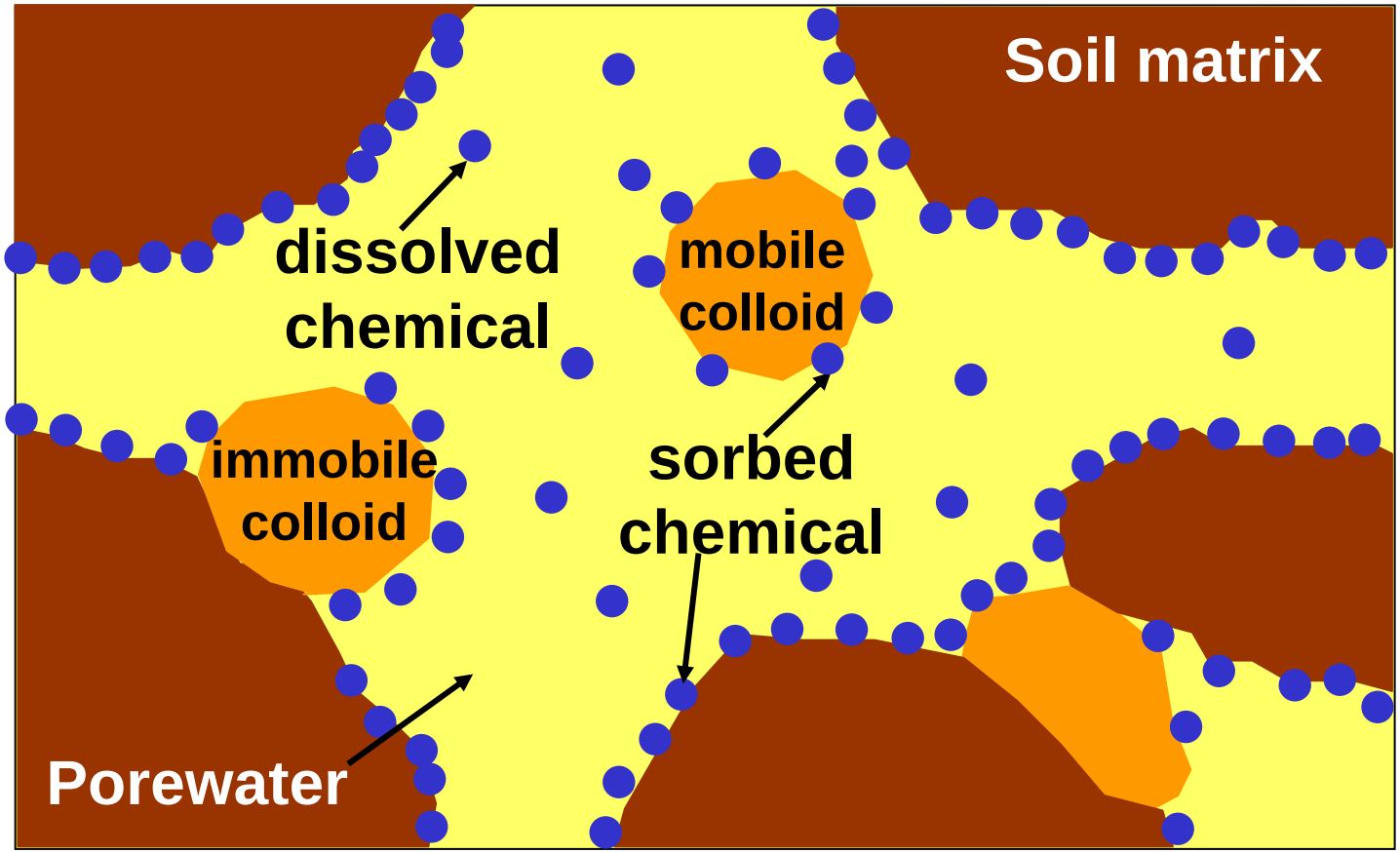
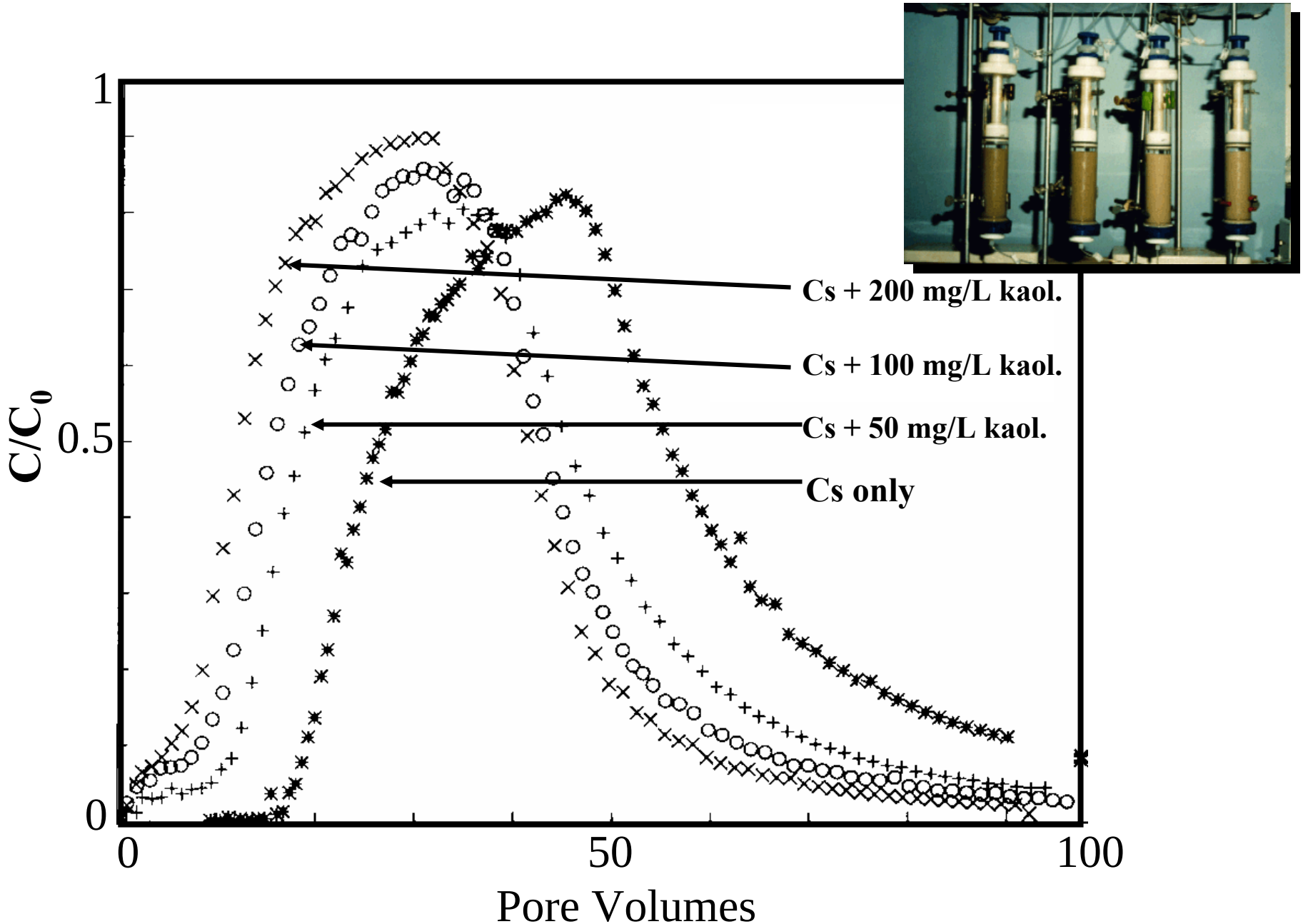
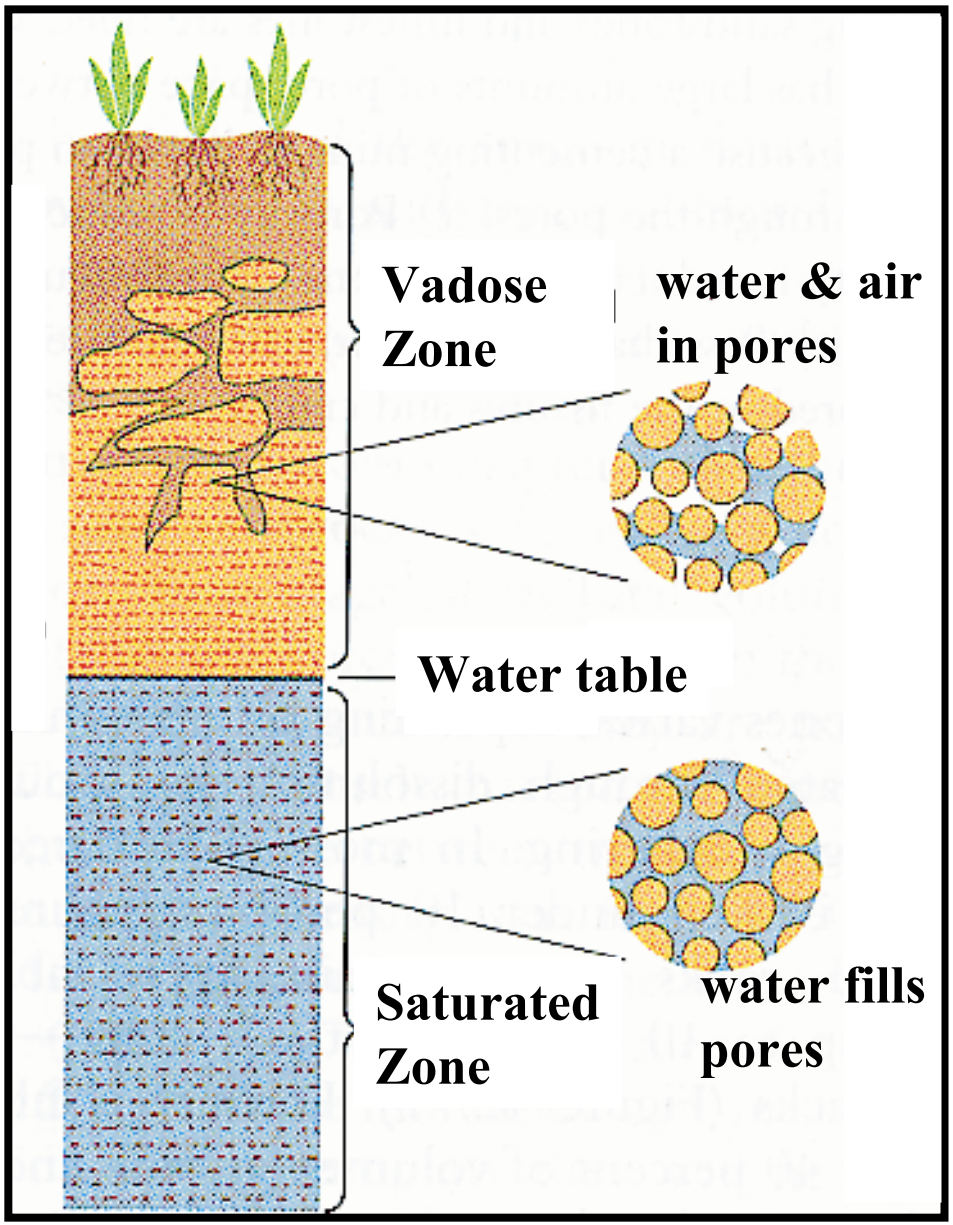
Colloids Affect Contaminant Mobility



Colloid-Facilitated Cesium Transport



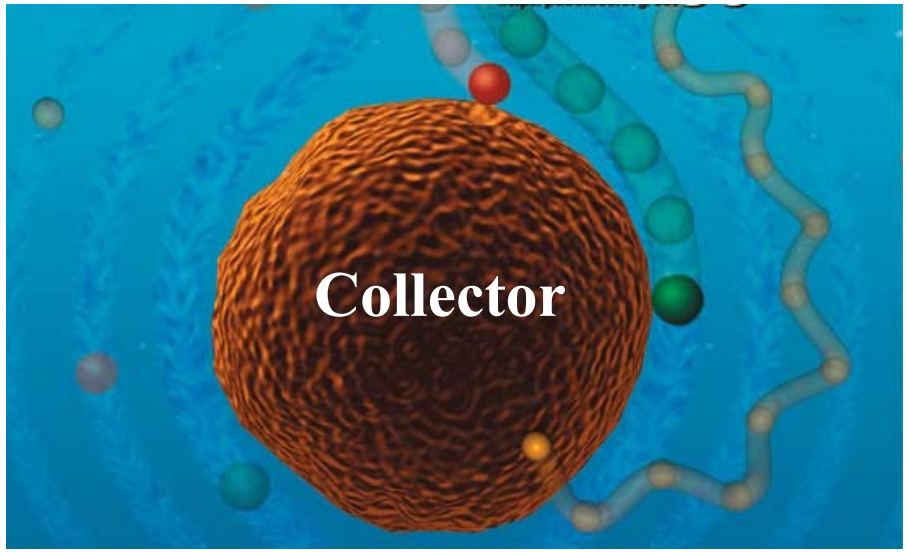
Controls on Colloid Movement



- **Mobilization: processes that release colloids into porewater**
- **Advection: transport due to bulk motion of the porewater**
- **Dispersion: spreading arising from velocity variations**
- **Deposition: processes that immobilize porewater colloids**

Colloid-Filtration Theory

Single-Collector Model



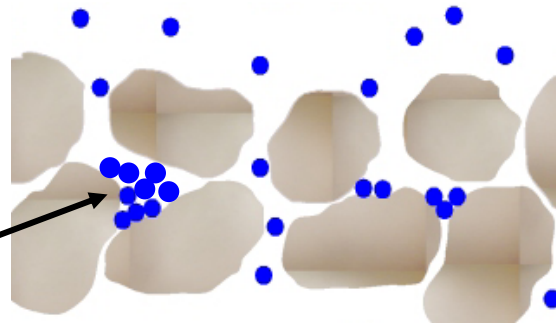
Filtration Rate = Contact Efficiency x Sticking Efficiency

$$\text{Contact Efficiency} = \frac{\text{rate at which colloids contact collector}}{\text{rate at which colloids approach collector}}$$

$$\text{Sticking Efficiency} = \frac{\text{rate at which colloids stick to collector}}{\text{rate at which colloids contact collector}}$$

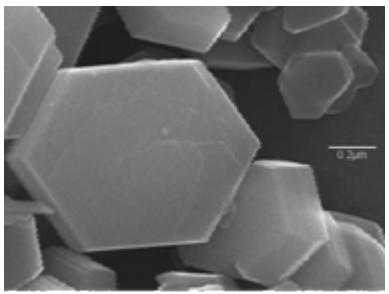
Research Questions

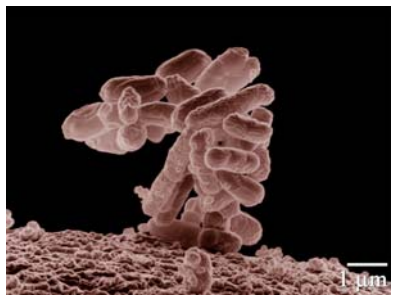
- **How do straining rates respond to changes in the physical properties of the colloids and porous media?**



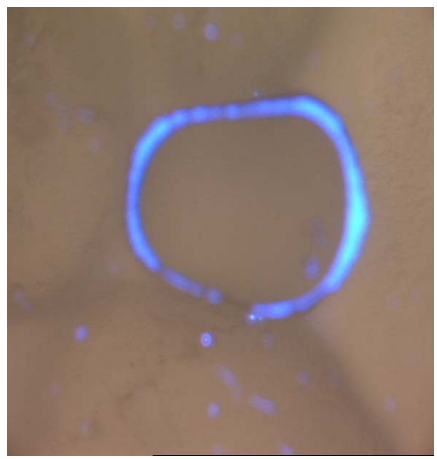
strained colloids

- **Are deposition rates sensitive to changes in colloid shape?**

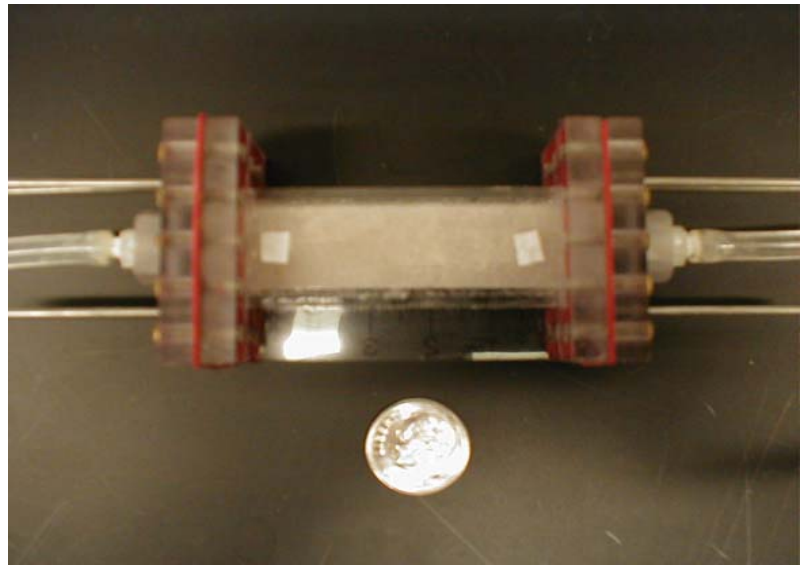




- **What role does the air phase have in deposition?**



Laboratory Experiments

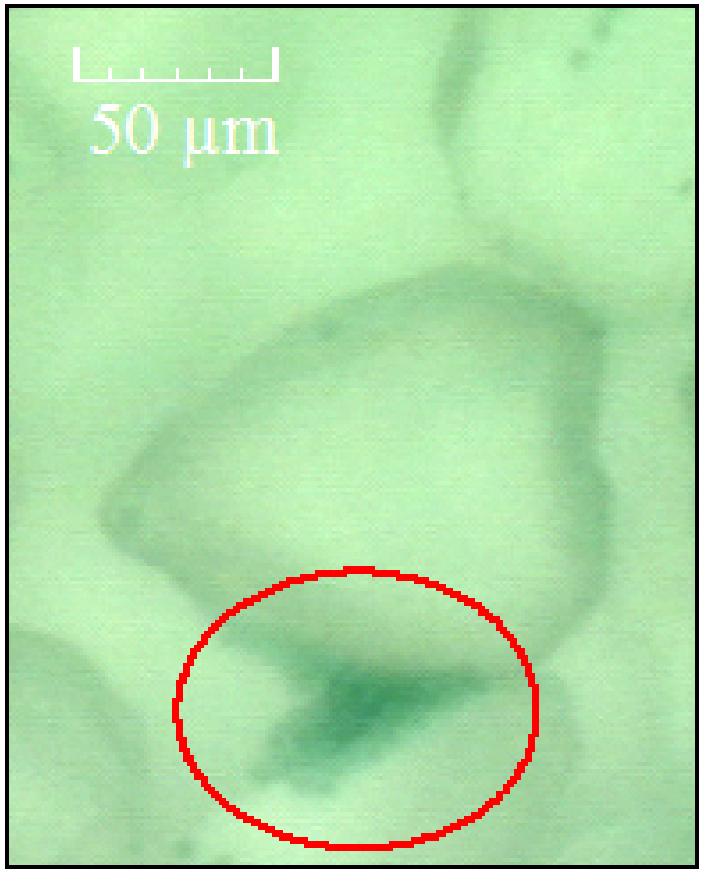


- **Porewater:** filtered, deionized water

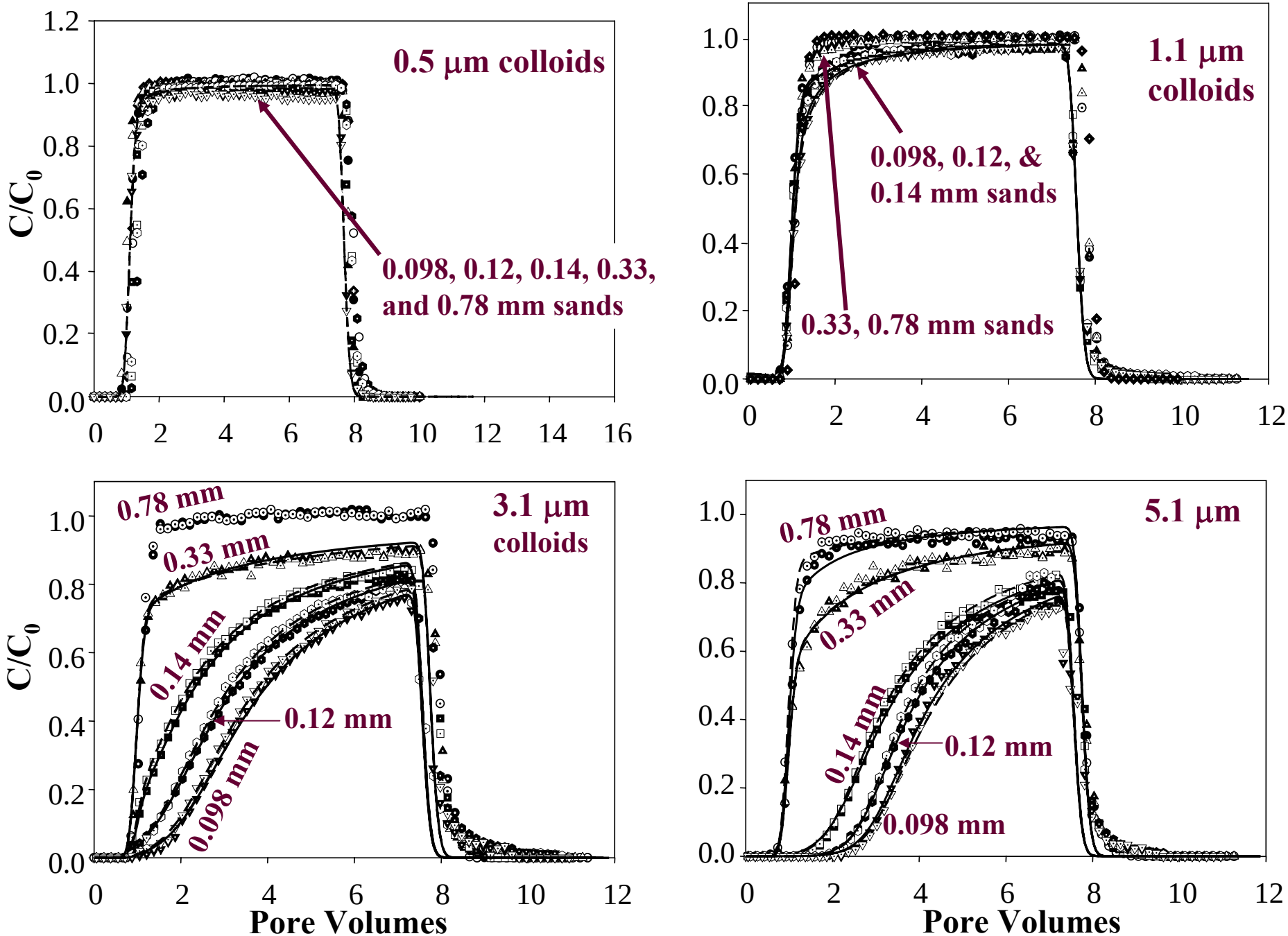
- **Porous Media:** cleaned quartz sand
  sizes: 0.098 mm, 0.12 mm, 0.14 mm, 0.33 mm, and 0.78 mm

- **Colloids:** latex particles with carboxyl functional groups
  sizes: 0.5 μm, 1.1 μm, 3.1 μm, and 5.1 μm

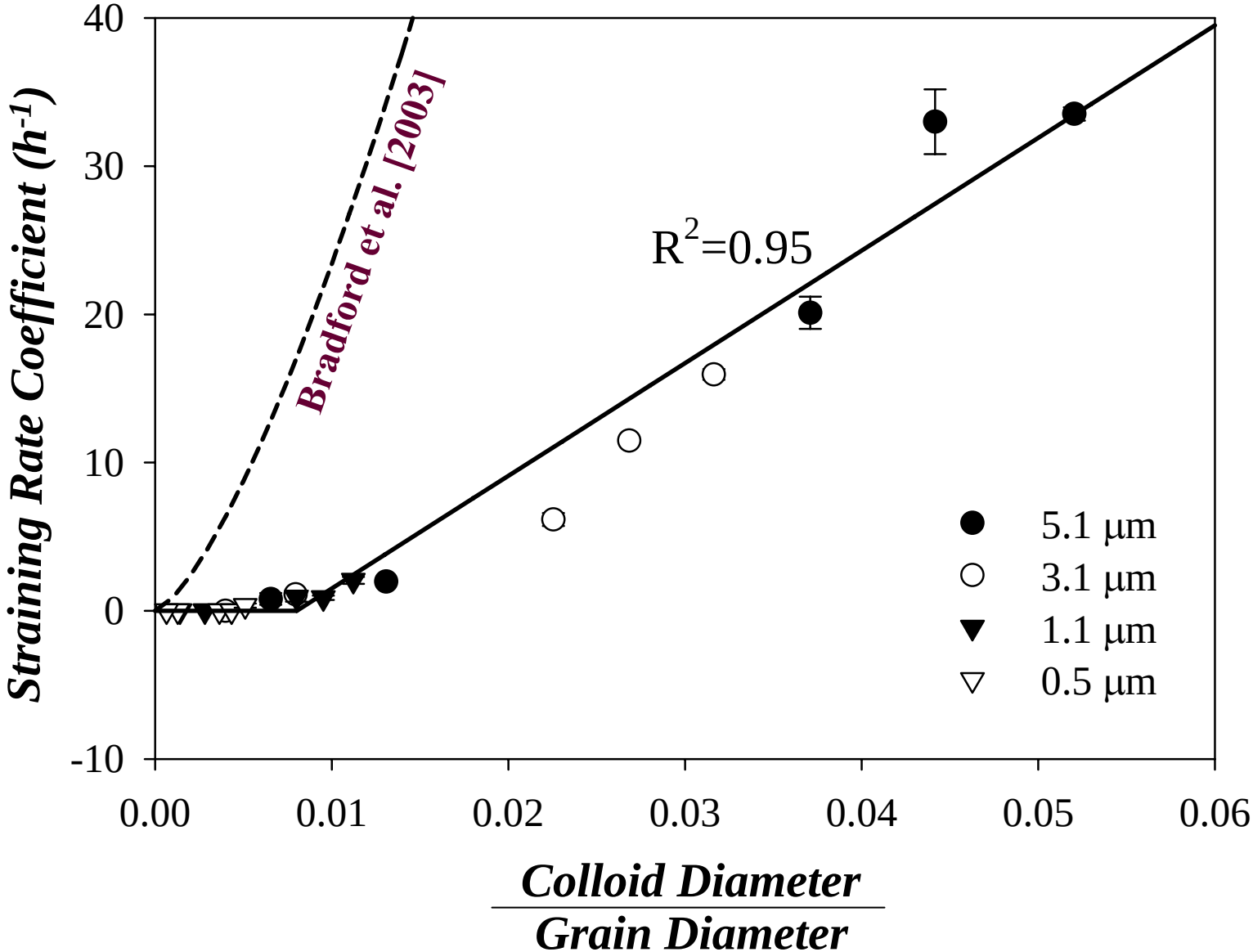
Straining

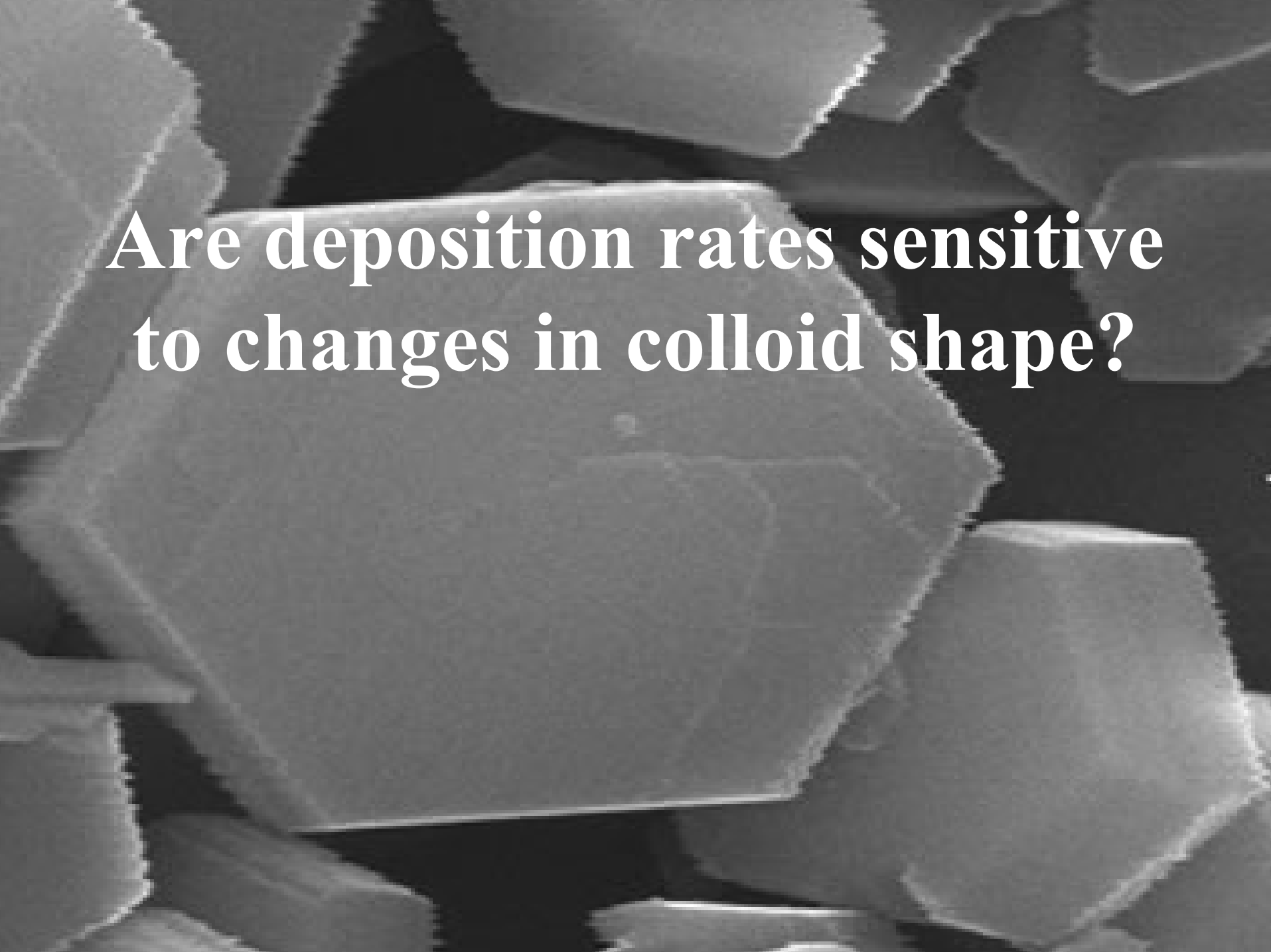


Colloid Breakthrough Curves



Straining Rate versus Colloid-Size-to-Grain-Size Ratio





Are deposition rates sensitive to changes in colloid shape?

Column Experiments

Porous-Media Treatments
(quartz sand)

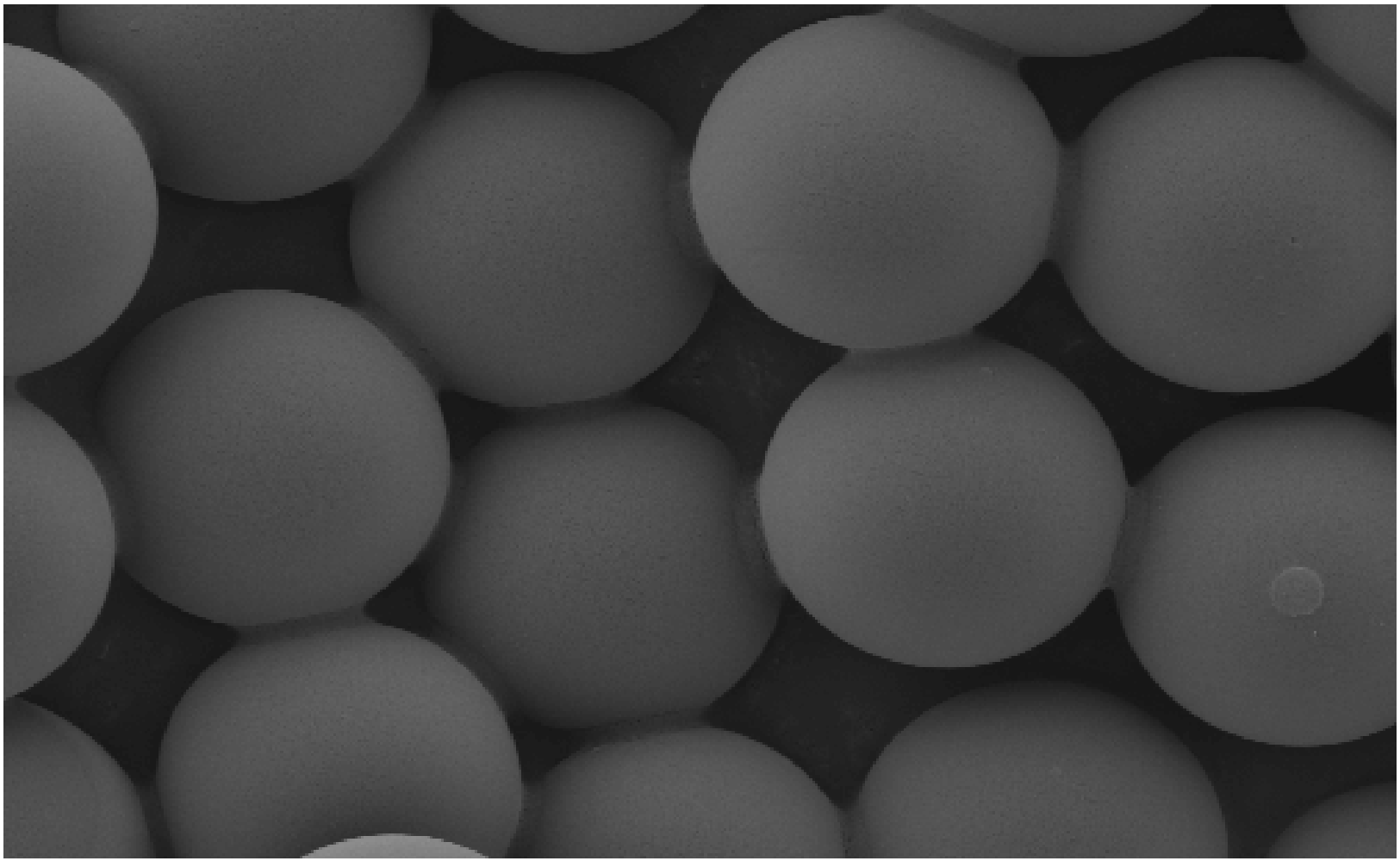
0.12 mm **0.33 mm**
0.14 mm **0.78 mm**

Colloid Treatments
(sulfate-modified polystyrene latex particles)

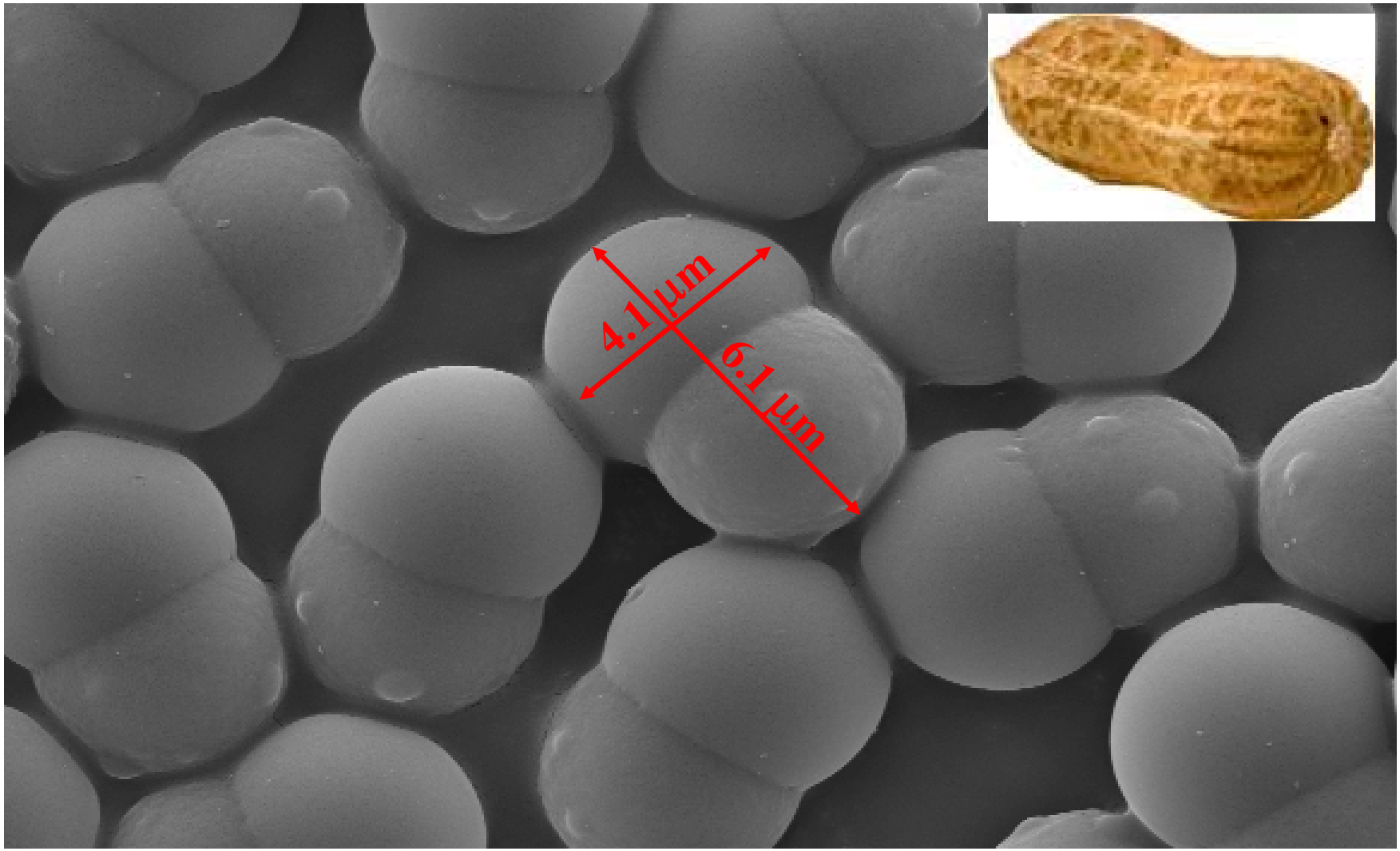
1.9 μm spheres
2.8 μm spheres
1.9 μm x 2.8 μm peanut-shaped

4.0 μm spheres
5.1 μm spheres
6.1 μm spheres
4.1 μm x 6.1 μm peanut-shaped

Spherical Colloids
(diameter = 5 micrometers)

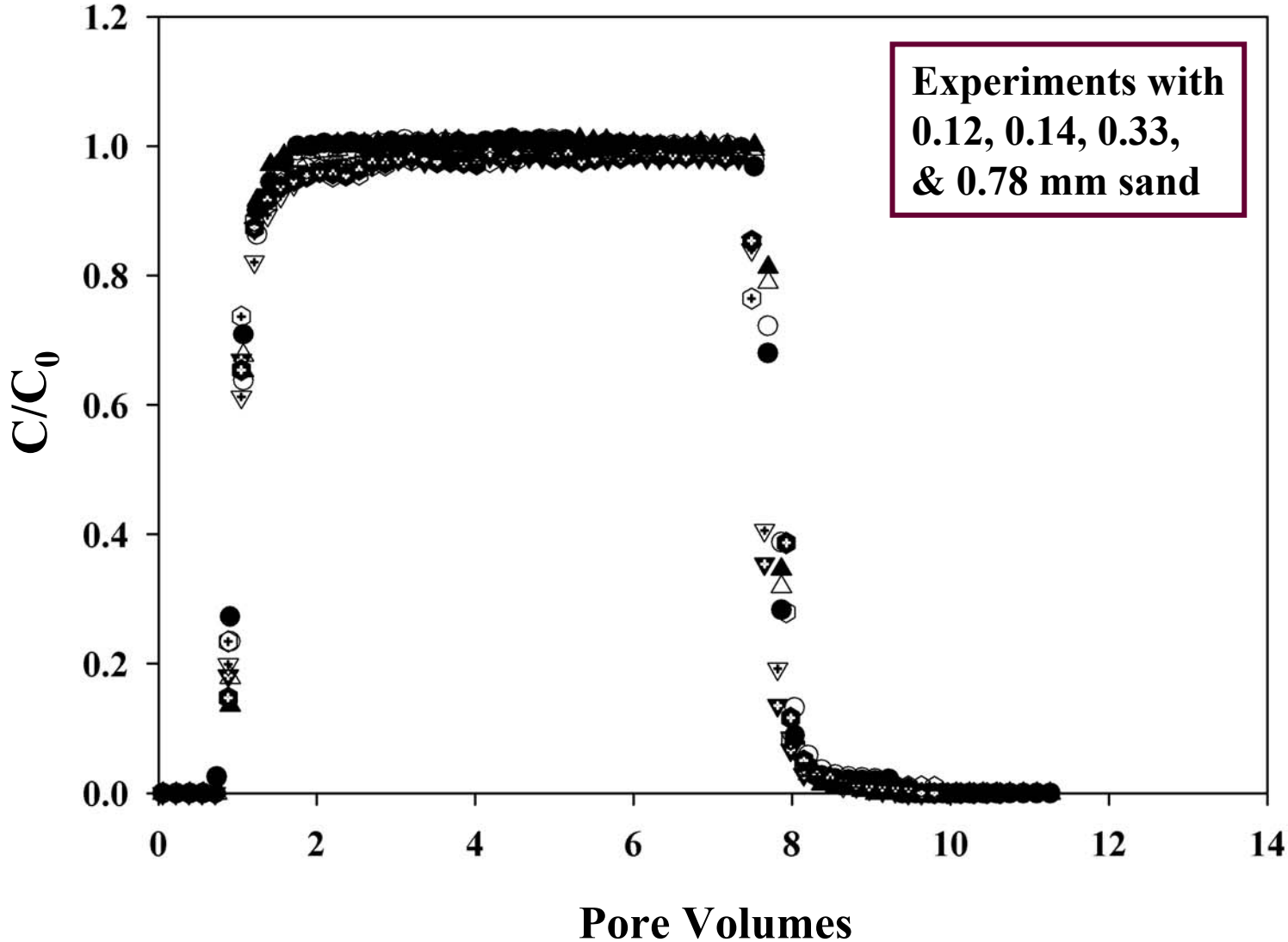


Peanut-Shaped Colloids
(size = 4.1 x 6.1 micrometers)



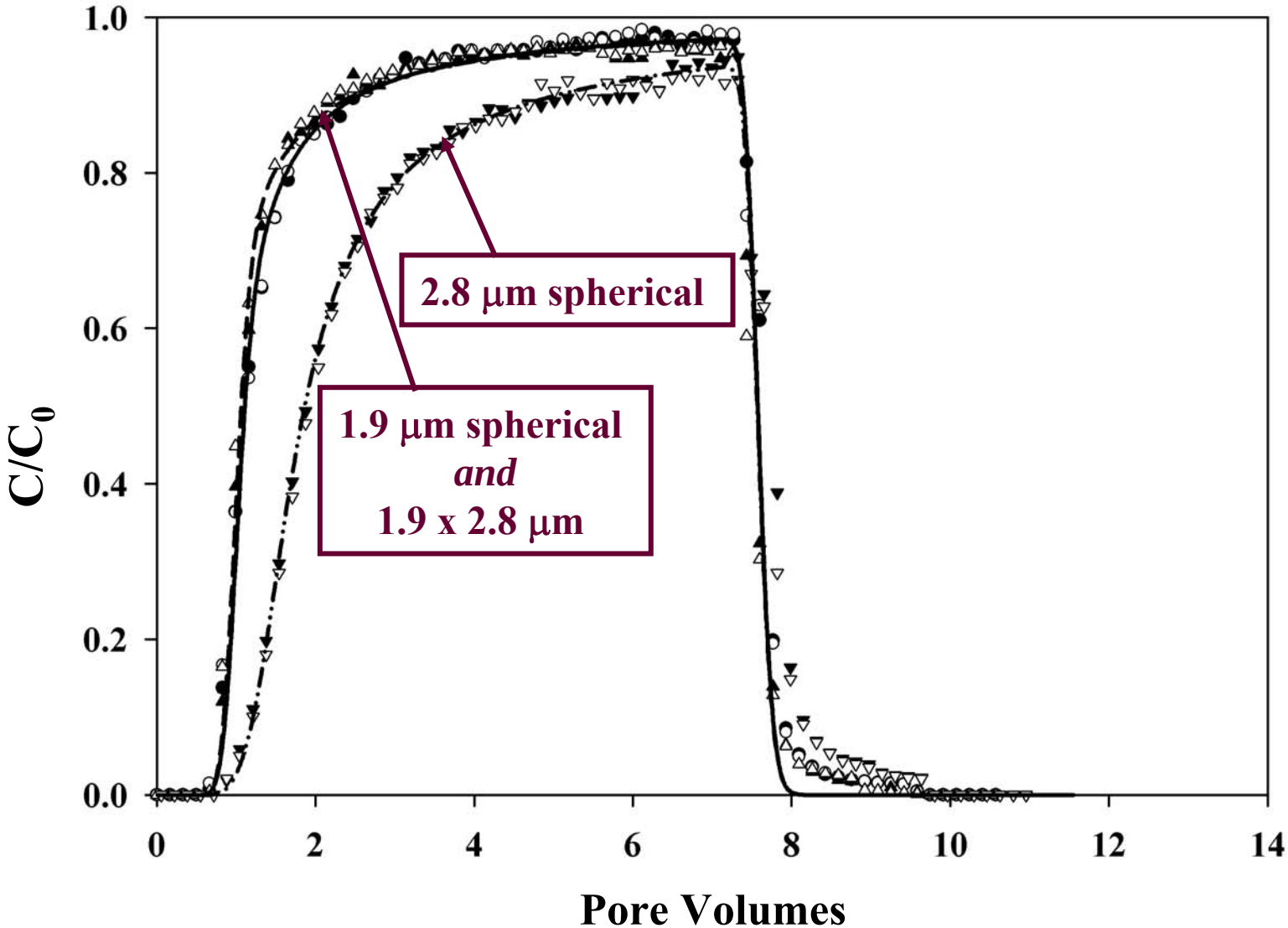
Grain-Size Effects on Colloid Transport

0.5 μm *spherical* colloids



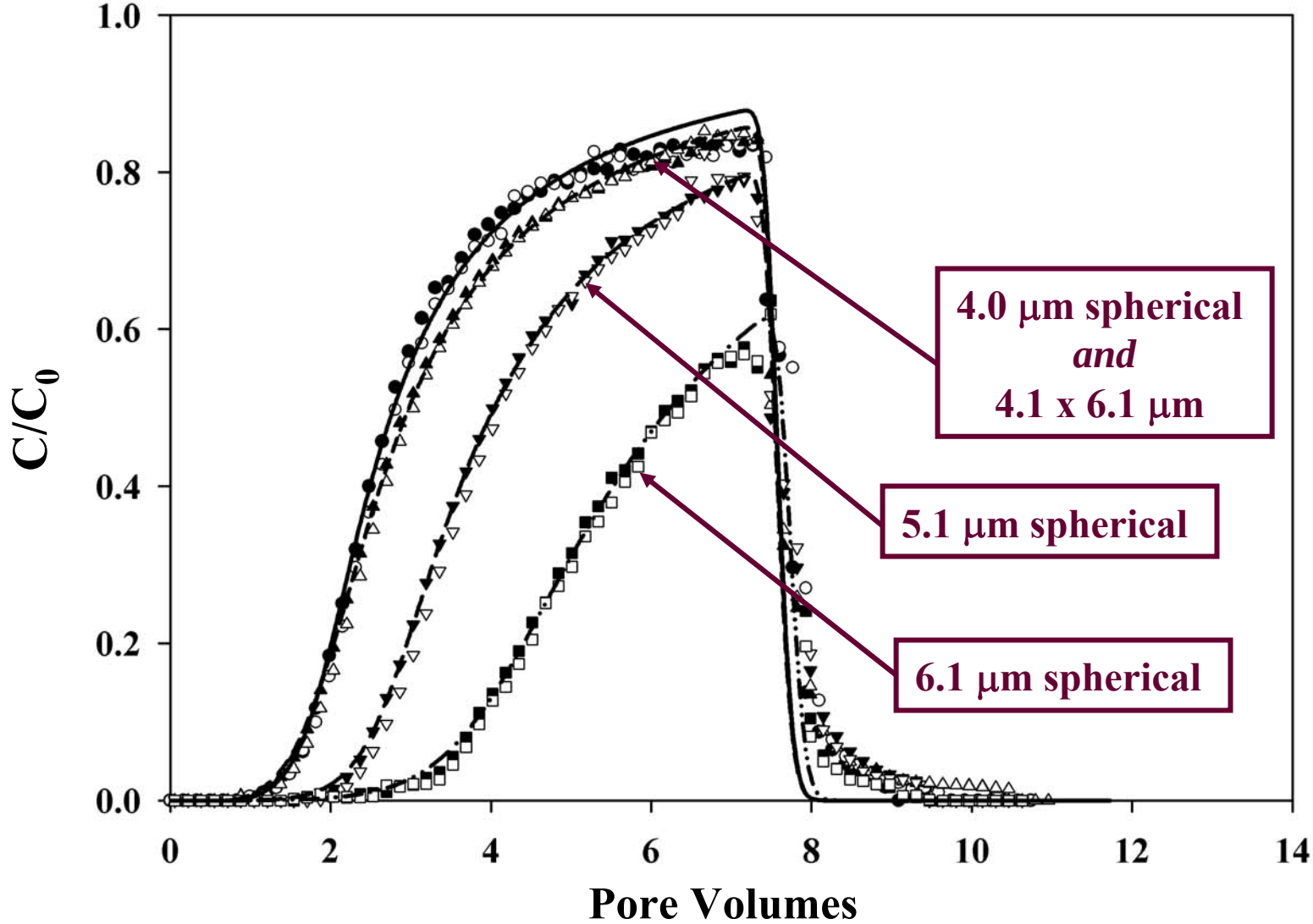
Colloid-Shape Effects on Transport

0.12 mm sand



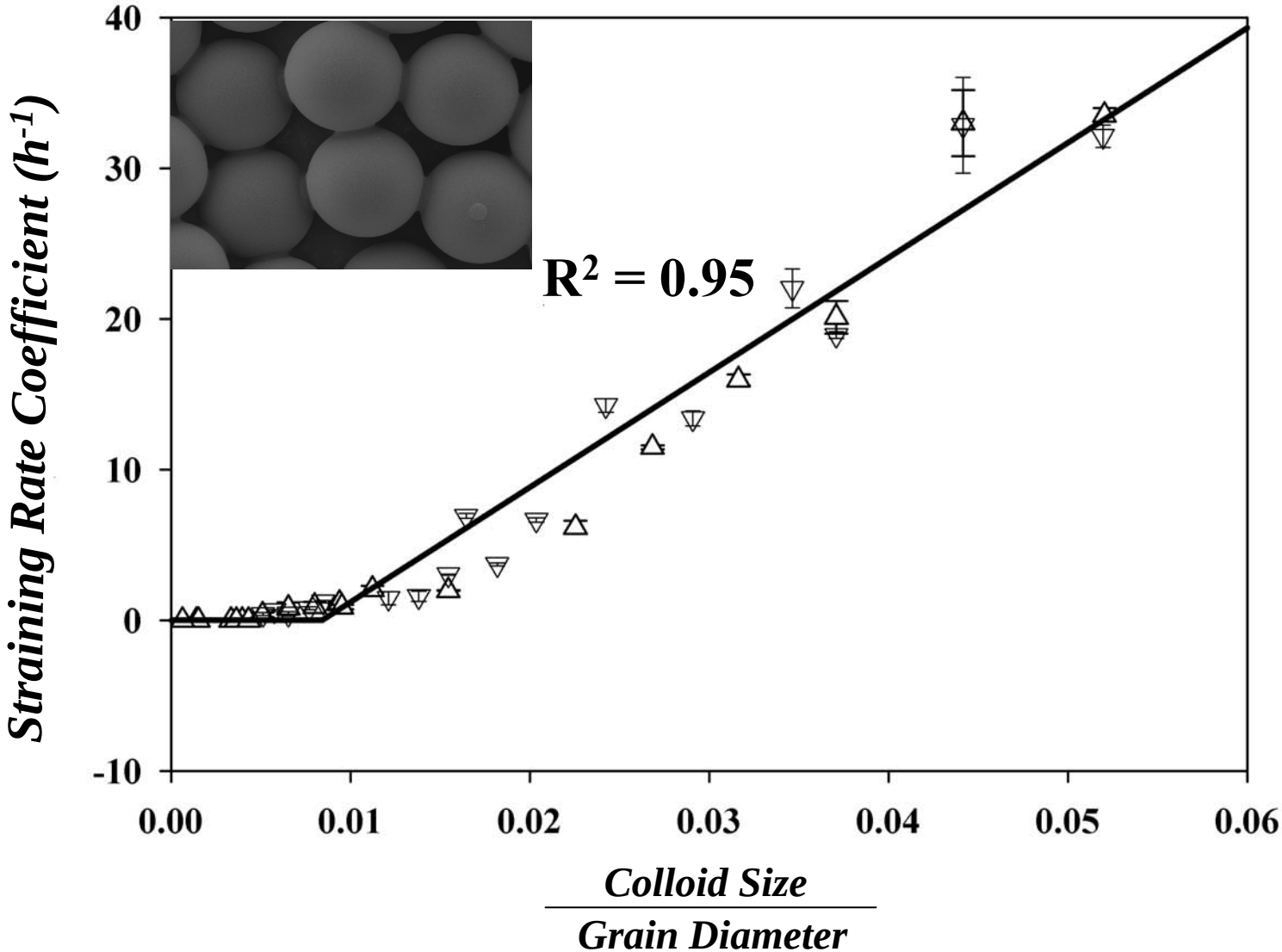
Colloid-Shape Effects on Transport

0.12 mm sand



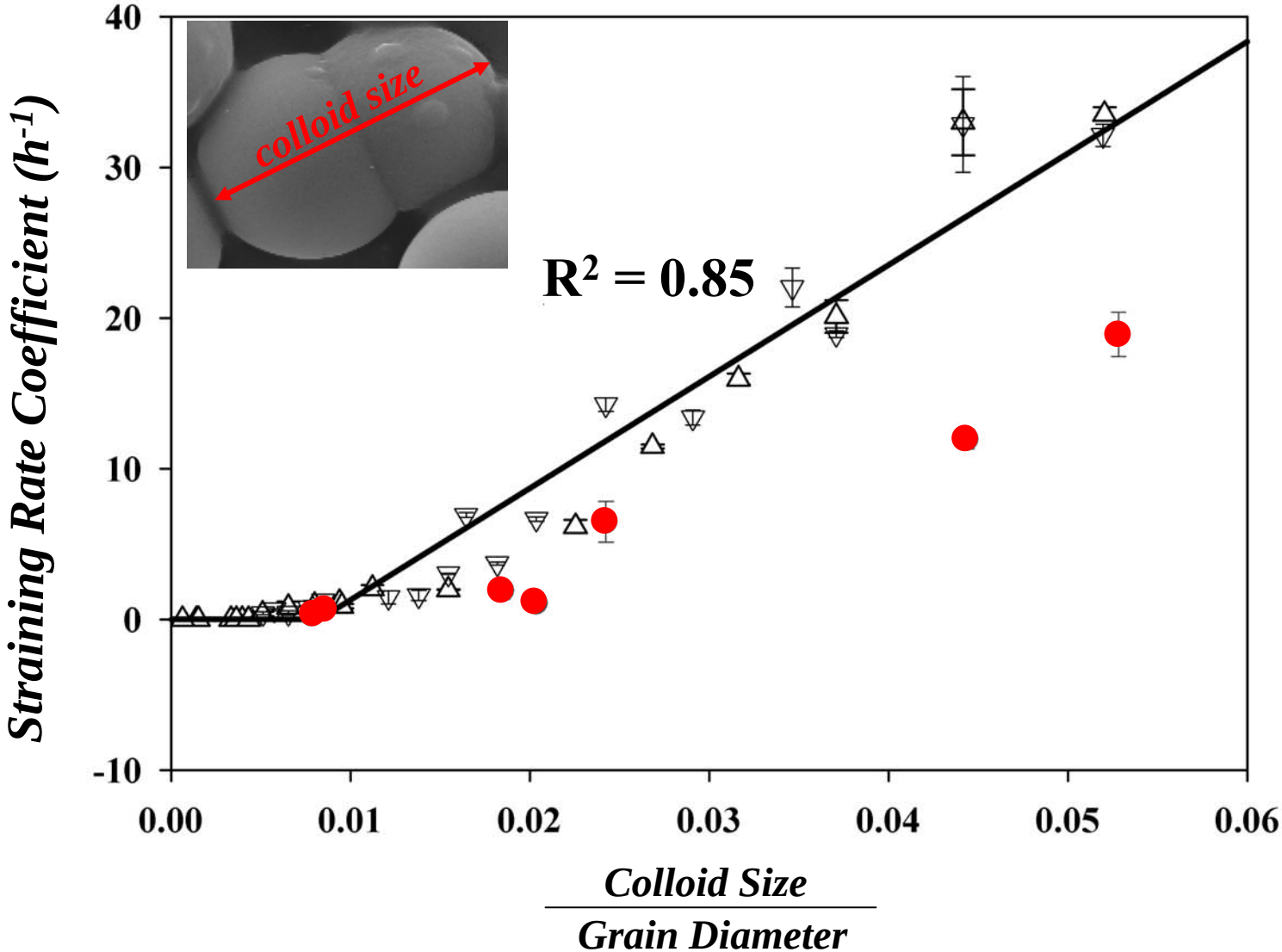
Straining Rate versus Colloid-Size-to-Grain-Size Ratio

(Spherical Colloids)



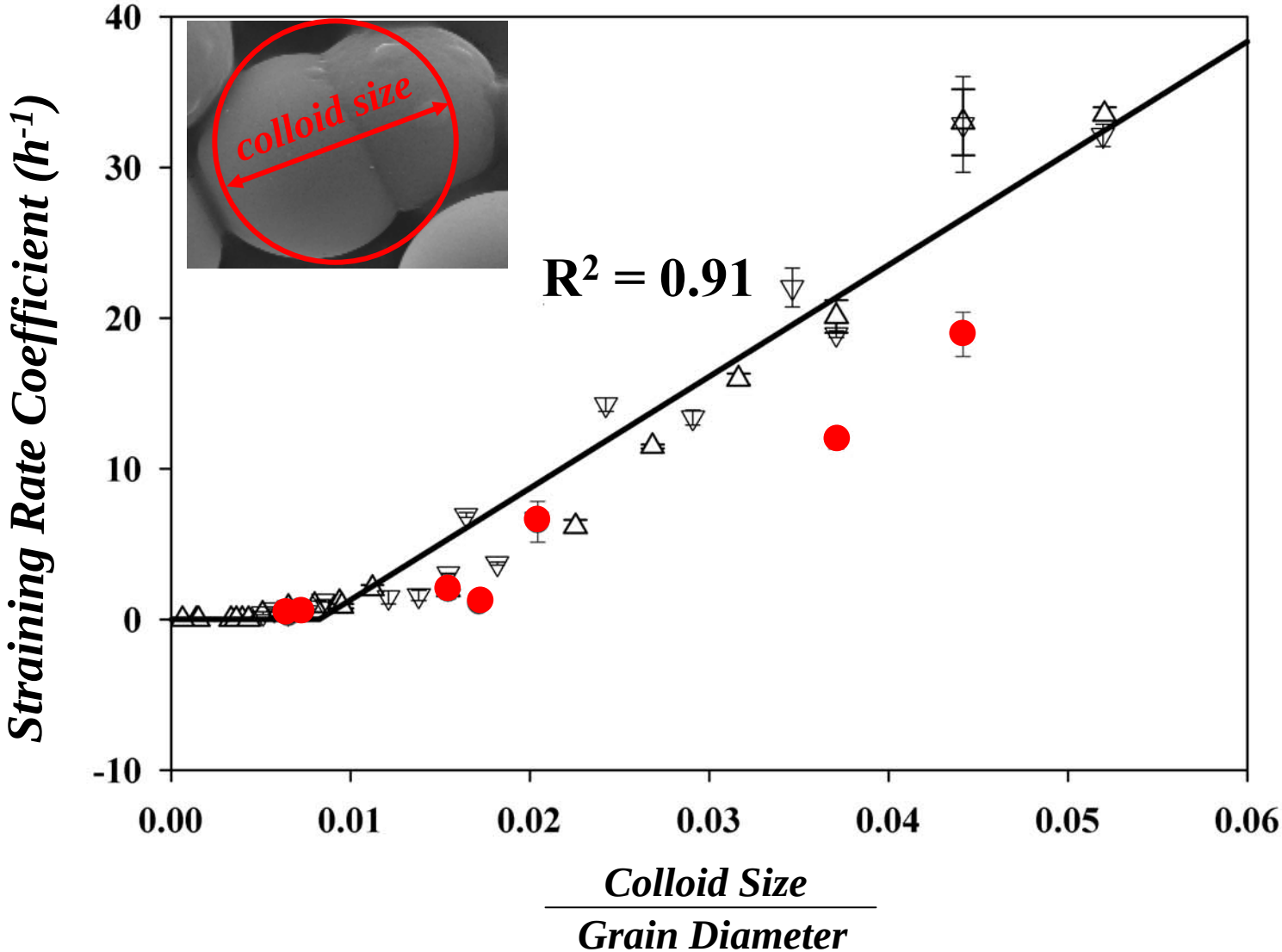
Straining Rate versus Colloid-Size-to-Grain-Size Ratio

(Colloid Size = Major Axis Length)



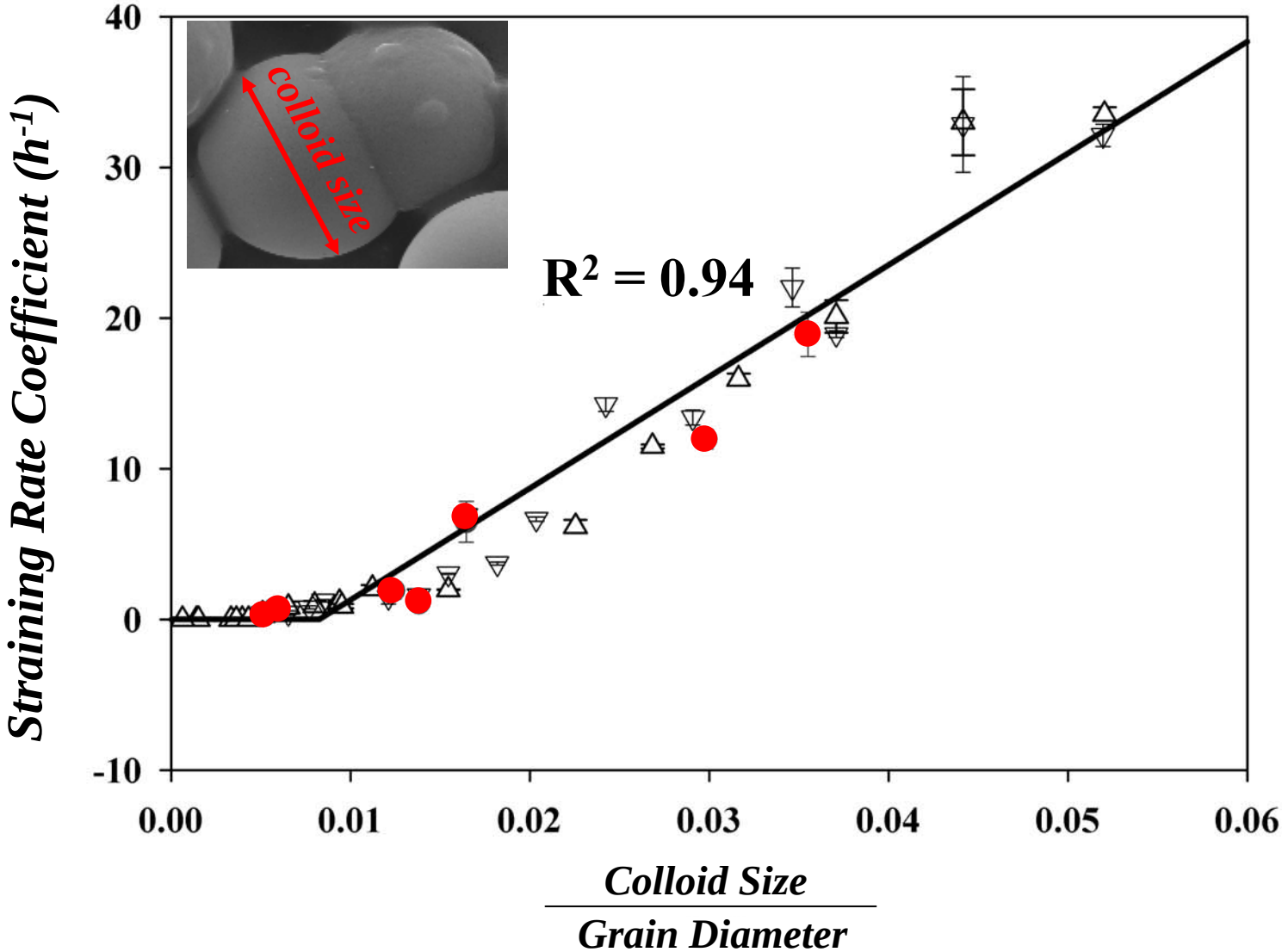
Straining Rate versus Colloid-Size-to-Grain-Size Ratio

(Colloid Size = Equivalent Diameter)

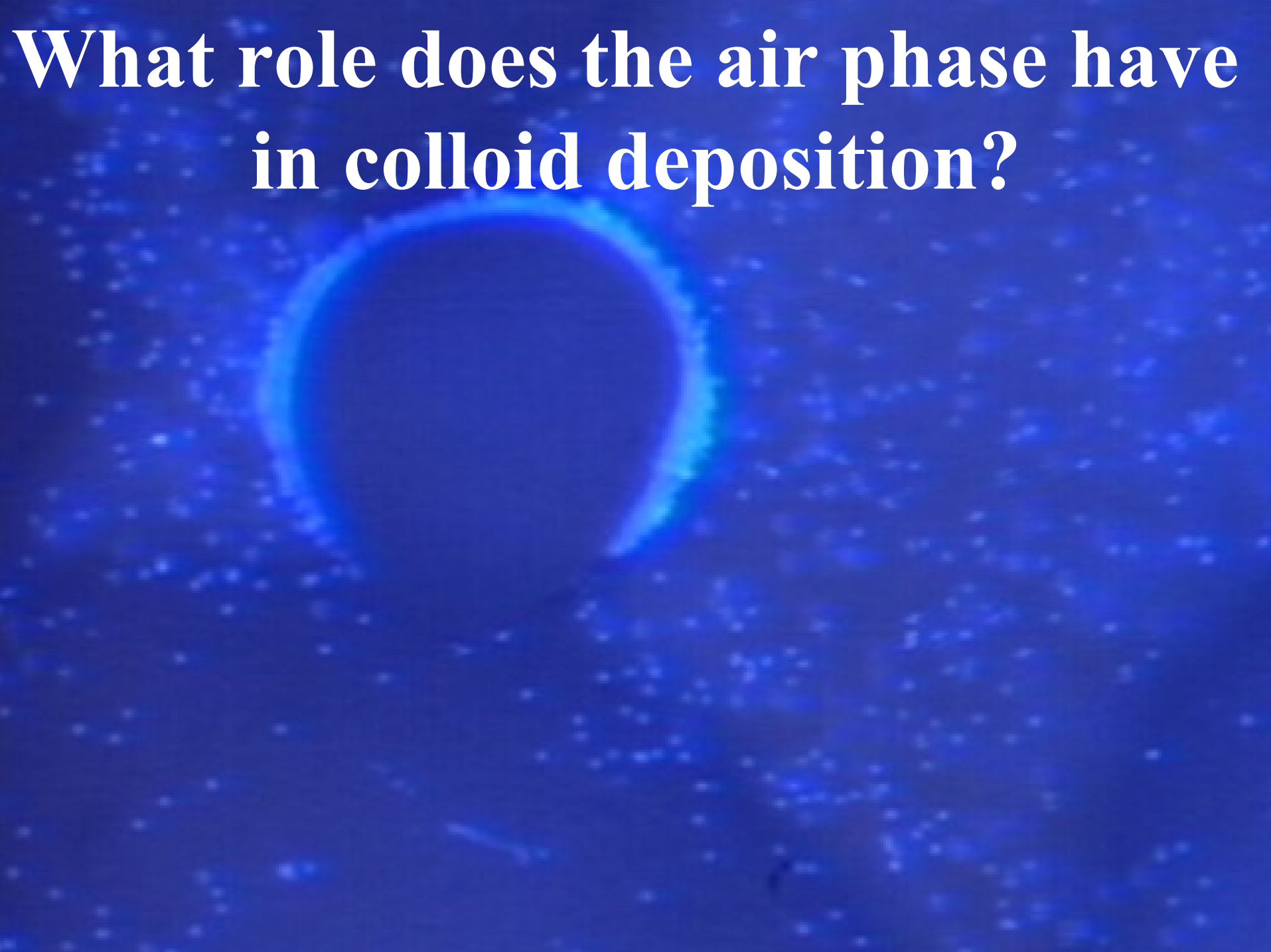


Straining Rate versus Colloid-Size-to-Grain-Size Ratio

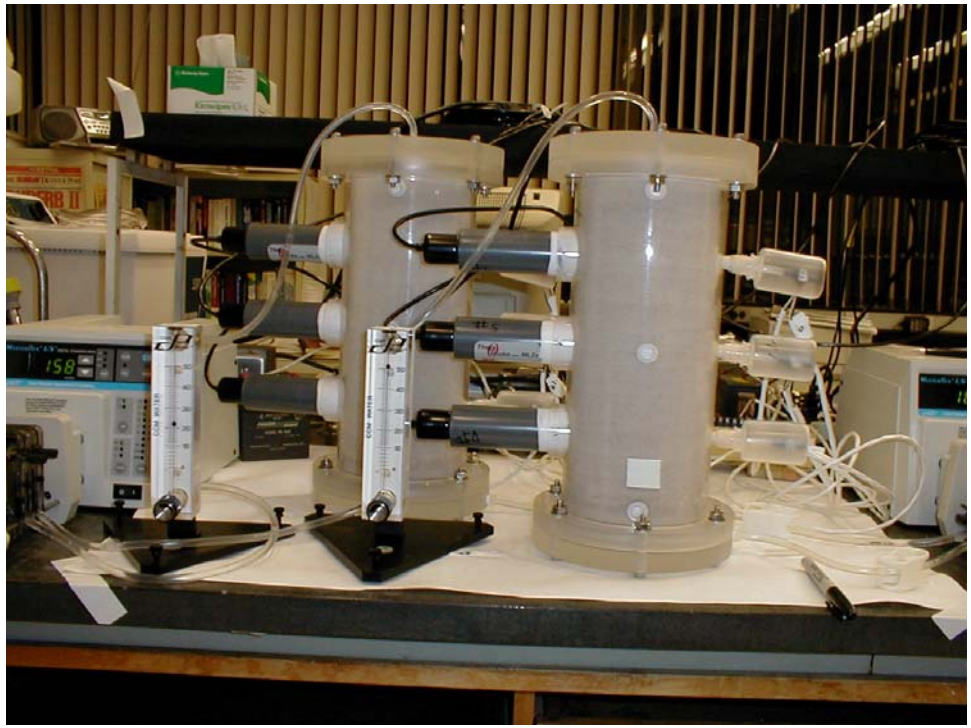
(Colloid Size = Minor Axis Length)



What role does the air phase have in colloid deposition?



Column Experiments



Colloids: silica, kaolinite, illite

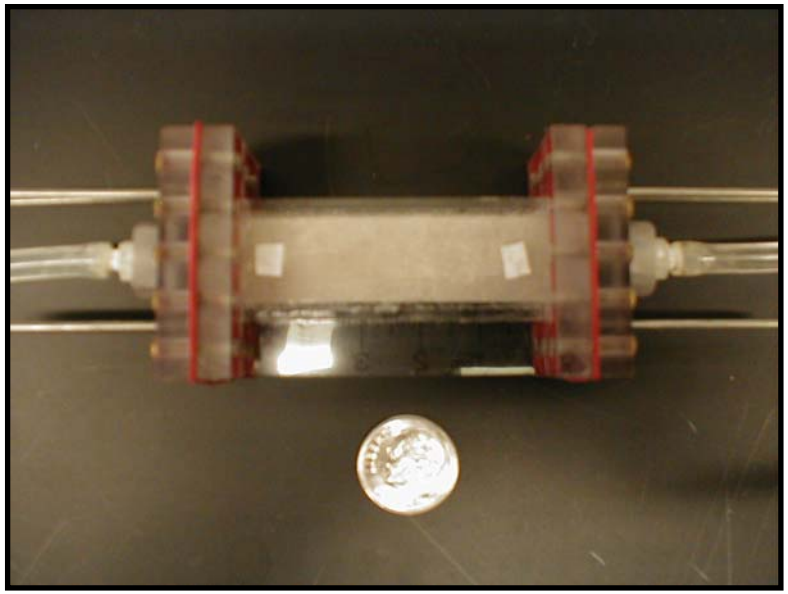
Porewater pH: 7.4

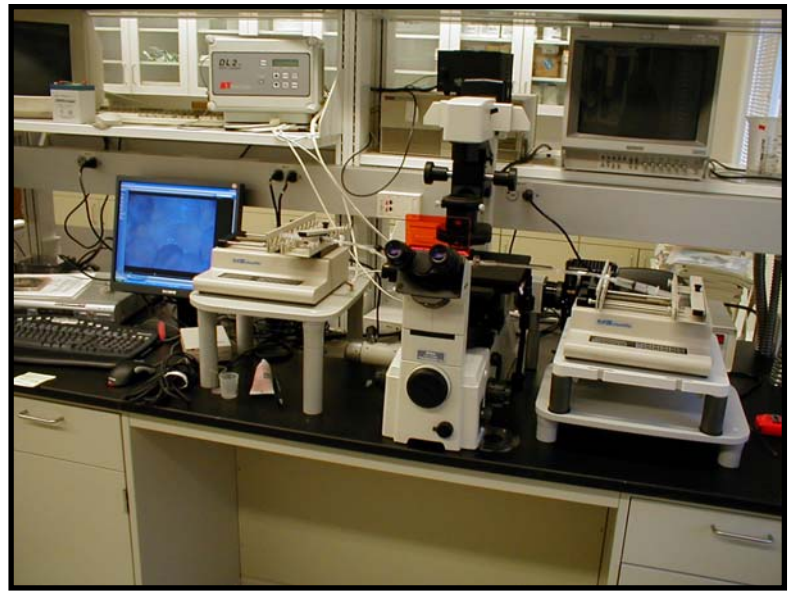
Porous medium: quartz sand

Ionic strength: 2×10^{-4} M to 0.2 M

Moisture content (Θ): 0.09 to 0.34

Visualization Experiments

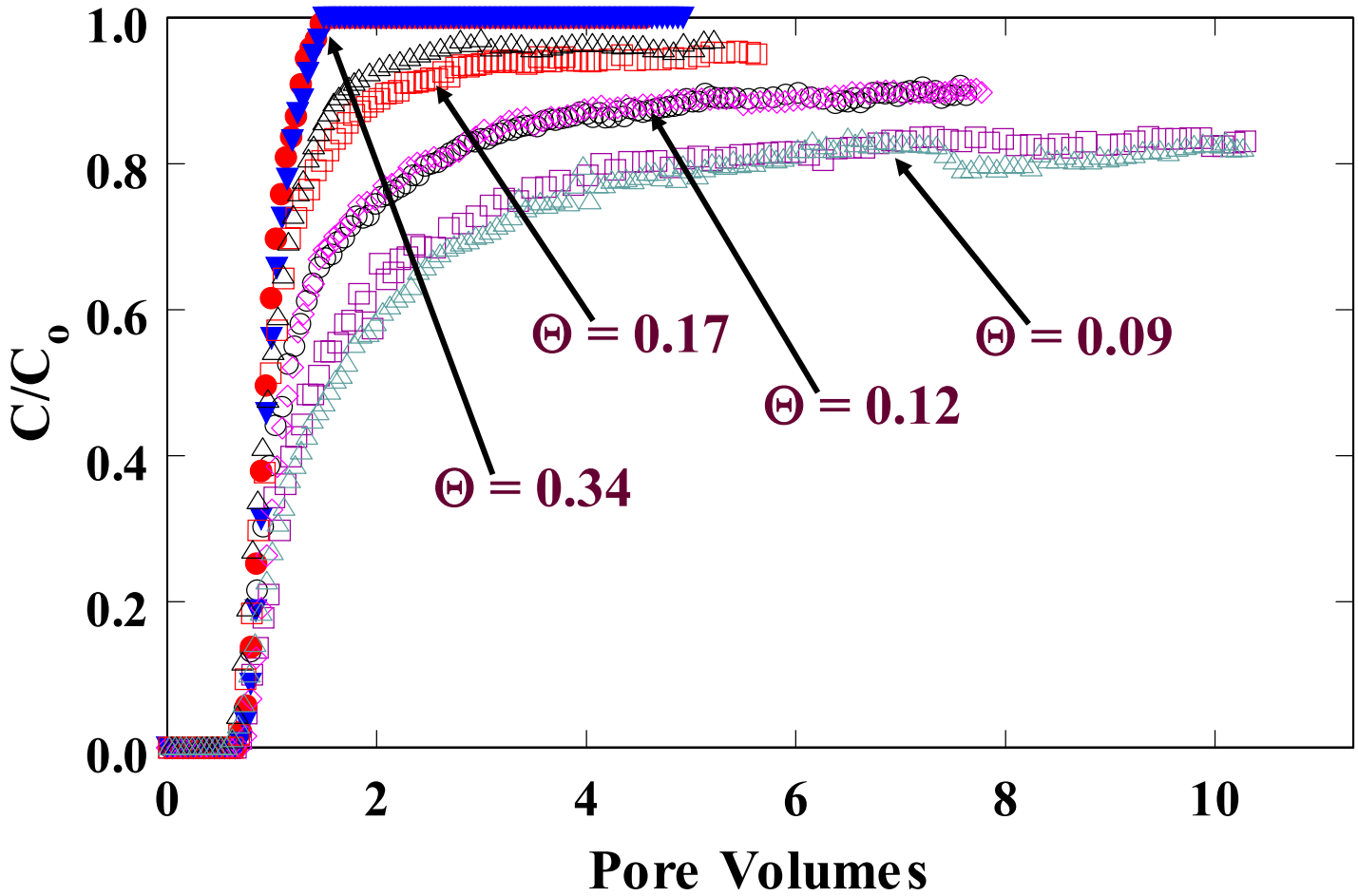




Materials and Conditions

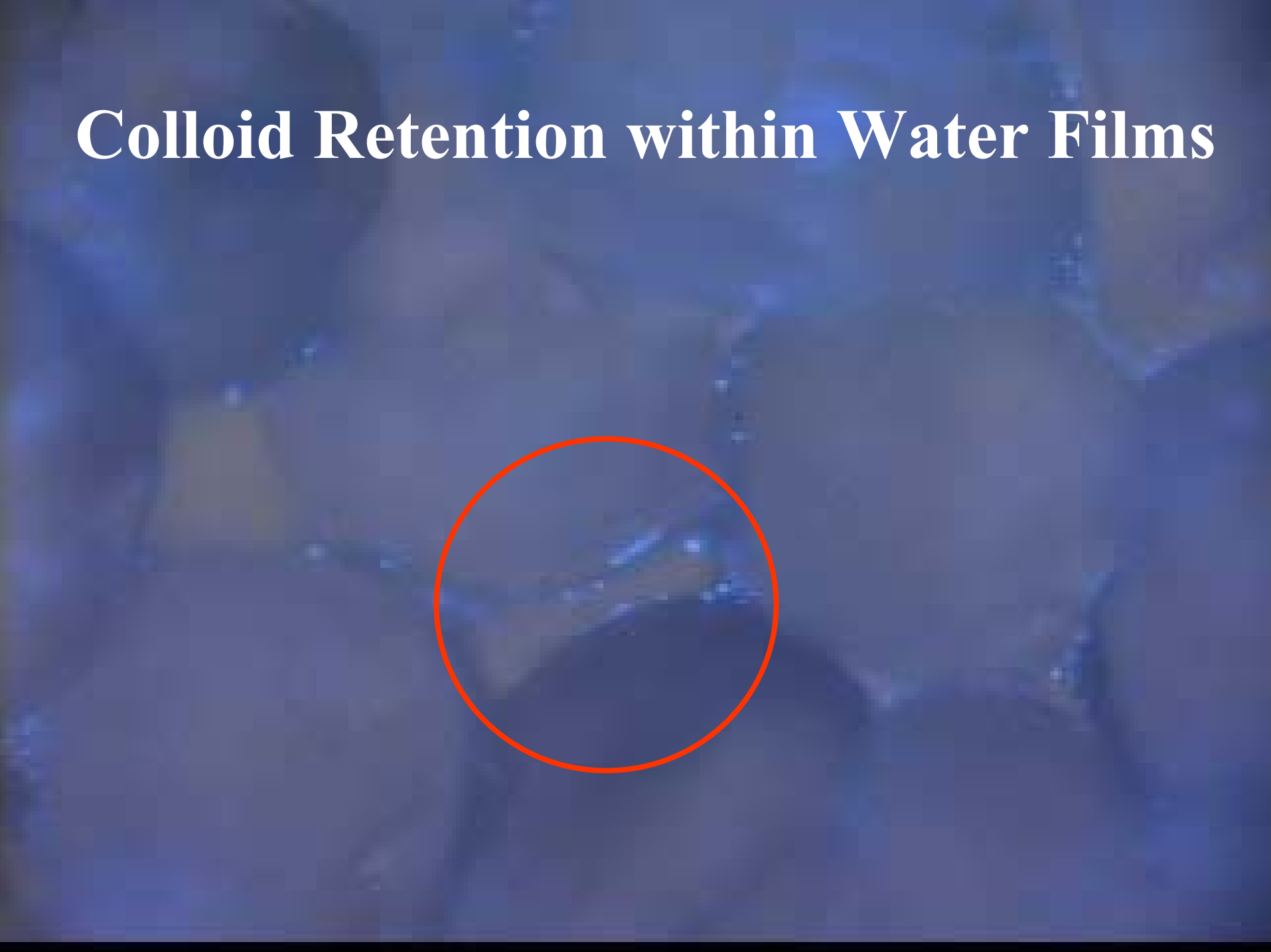
- **Colloids:** 2 μm microspheres
- **Porous media:** quartz sand
- **Moisture content:** 0.23 to 0.40
- **Flow:** steady

Moisture Content Effects on Silica-Colloid Transport

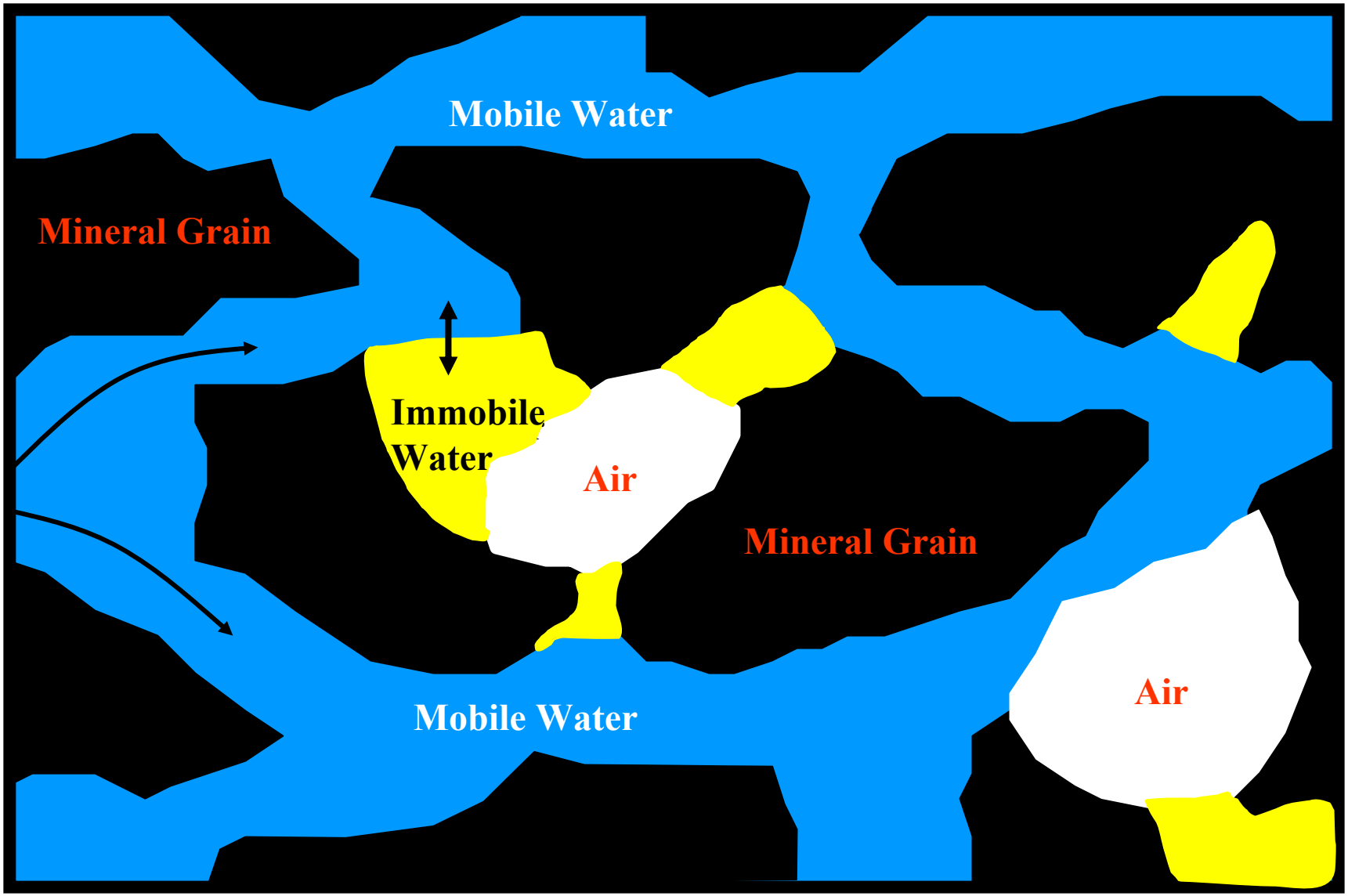


Colloid Retention on Trapped Air Bubble

Colloid Retention within Water Films



Mobile and Immobile Water in Unsaturated Media



From van Genucthen and Wierenga, 1976

Colloid Accumulation in Stagnation Zones

Colloid Accumulation in Stagnation Zones

Acknowledgements

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