

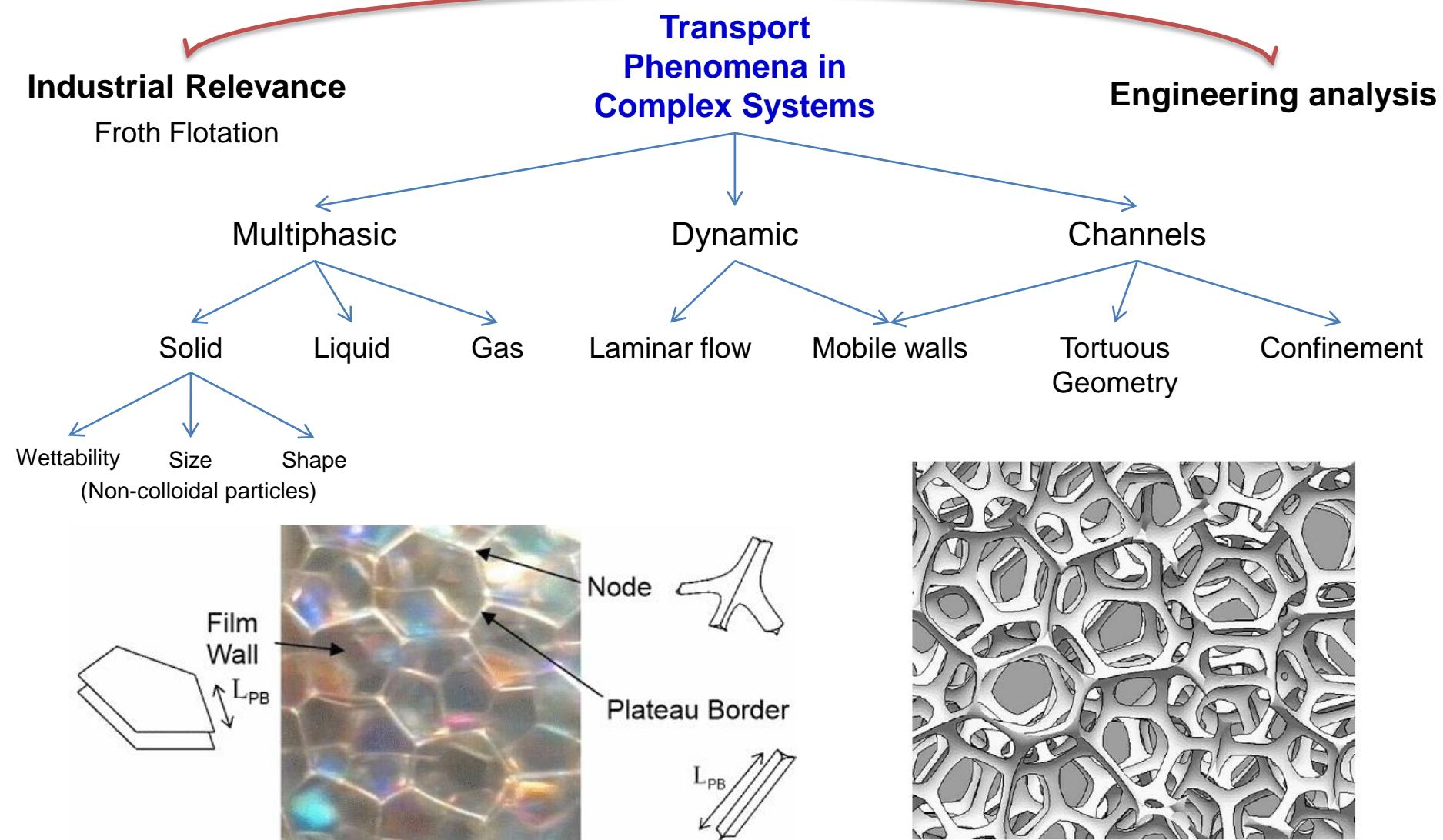
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# **The Effect of Particle Size and Shape on Transport Through Confined Channels in Three-phase Froths**

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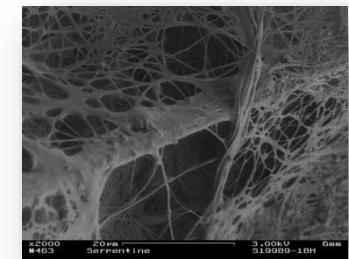
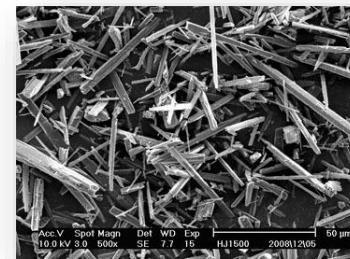
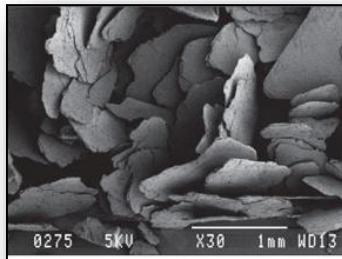
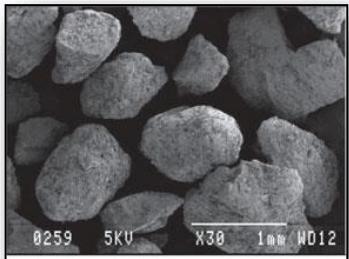
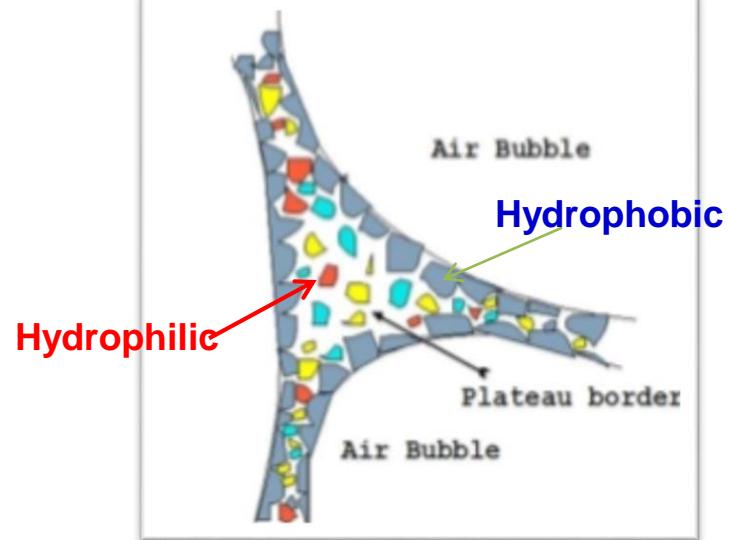
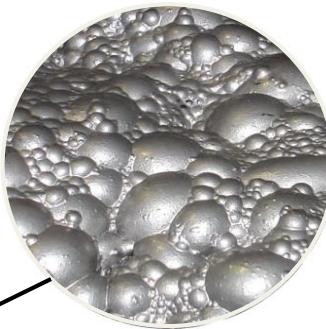
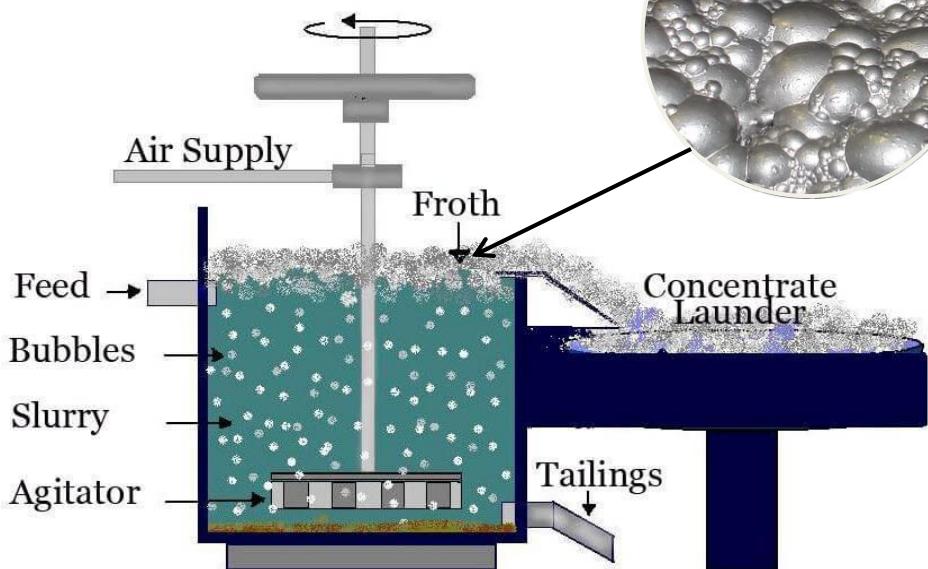
# Introduction



# Mineral Froth Flotation

Large plants: ~250,000 tons/day

## FLOTATION PROCESS



How does hydrophilic particle aspect ratio affect transport?

# Modeling the flow of solids in froth

- Gas motion
  - Laplace equation & Darcy's law for porous media
- Liquid motion:
  - Foam drainage equation → Poiseulle flow
  - Gravity
  - Capillary forces
  - Viscous drag
- Unattached Solids motion
  - Liquid velocity- advection
  - Particle settling velocity
  - Particle dispersion (geometrical)



$$\frac{dA}{dy} = \frac{-\lambda k_1 A^2 + \lambda J_g A - \frac{Q_l}{A_{col}}}{\lambda k_2 \sqrt{A}}$$

$$\text{where } k_1 = \frac{\rho g}{3C_{PB}\mu} \text{ and } k_2 = \frac{(\sqrt{\sqrt{3}-\frac{\pi}{2}})\gamma}{6C_{PB}\mu}$$

Newtonian viscosity

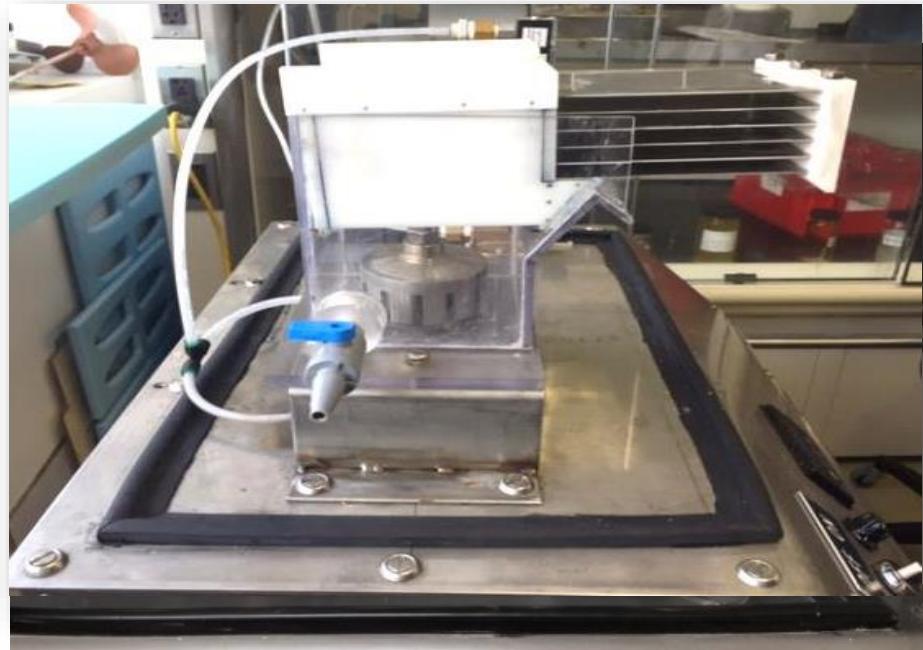
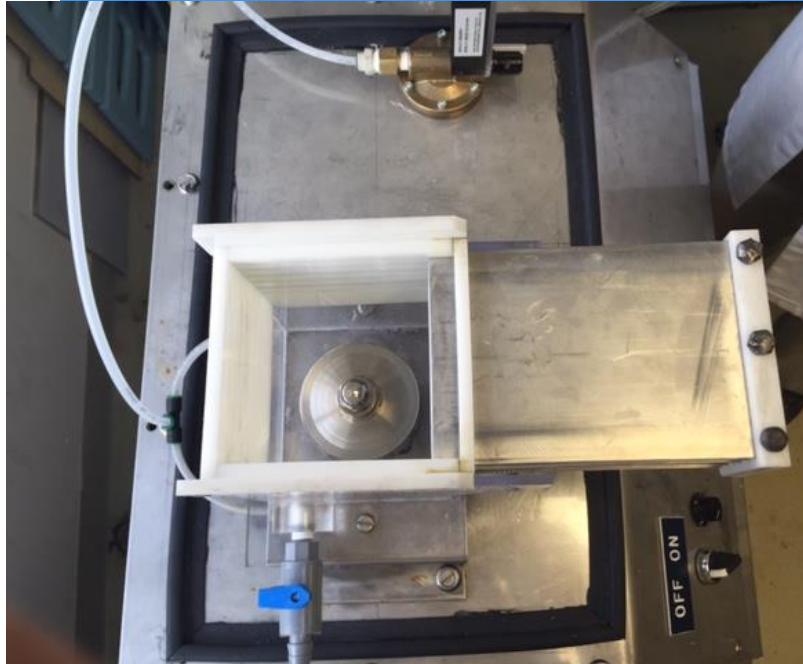
$$v_l = \frac{Q_l}{A_{col}} \frac{1}{\epsilon}$$

$$v_{set} \approx \frac{1}{3} \frac{g(\rho_s - \rho)d_p^2}{18\mu}$$

$$D_{Axial} = \frac{v_{l-rel}^{1.5}}{\sqrt{k_1 \left( \sqrt{3} - \frac{\pi}{2} \right) Pe}}$$

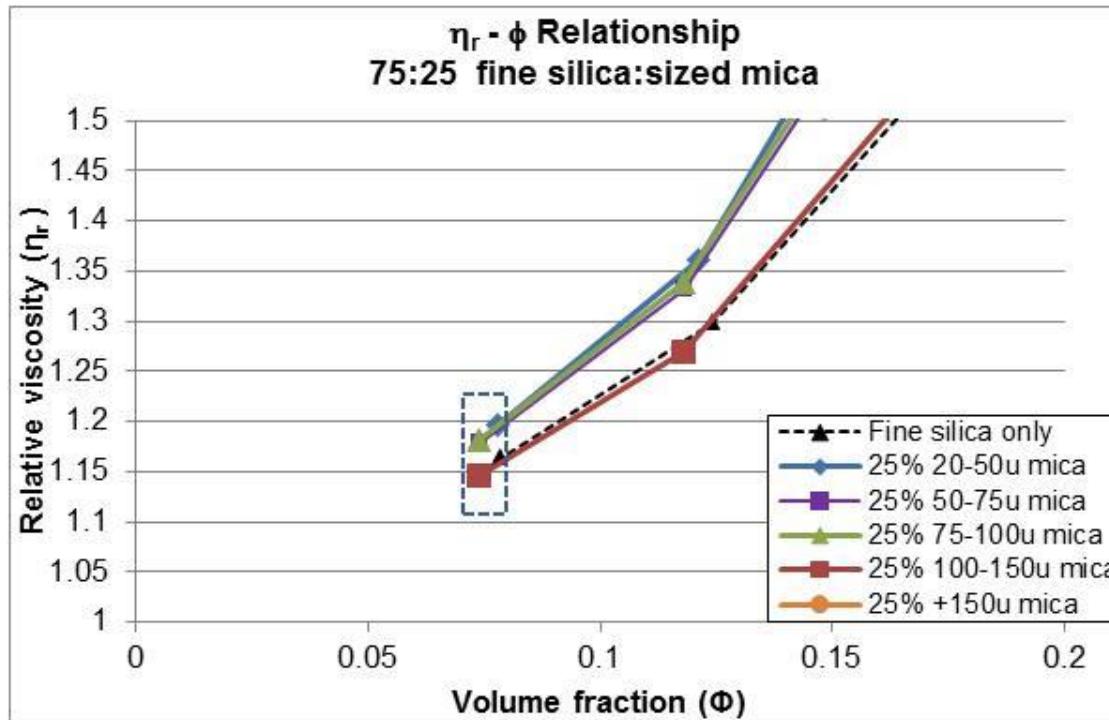
$$C_{PB} = 10 \sim 50$$

# Froth sampling



Designed & fabricated froth sampler to obtain composition as a function of depth

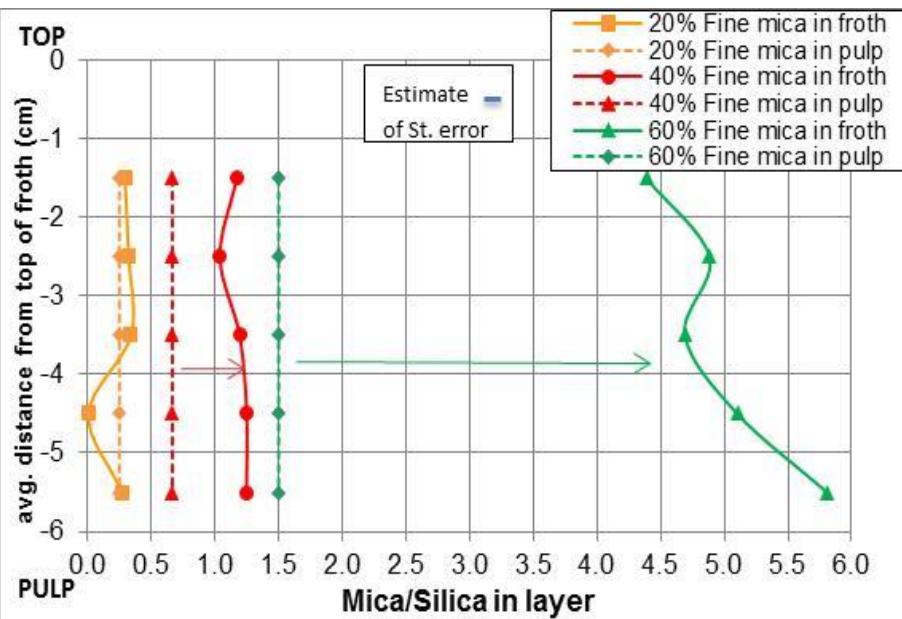
# Bulk rheology measurements- Mica mixtures



$$\eta_r = e^{\left( \frac{B\phi}{1 - \frac{\phi}{\phi_{max}}} \right)}$$

- Volume fractions in flotation are much lower
- Small differences between platy mica and rounded silica
- Bulk rheology measurements alone insufficient to describe transport behavior for *platy mica particles*

# Hydrophilic Particle transport through froth

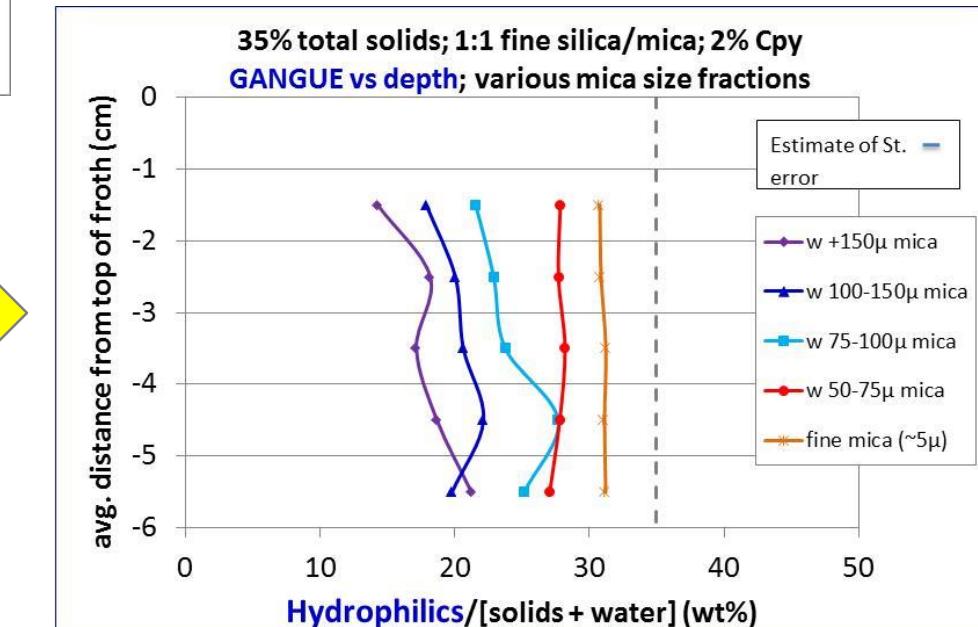


Fine mica + fine silica (various ratios):

- Preferential transport of platy mica particles vs. globular silica particles

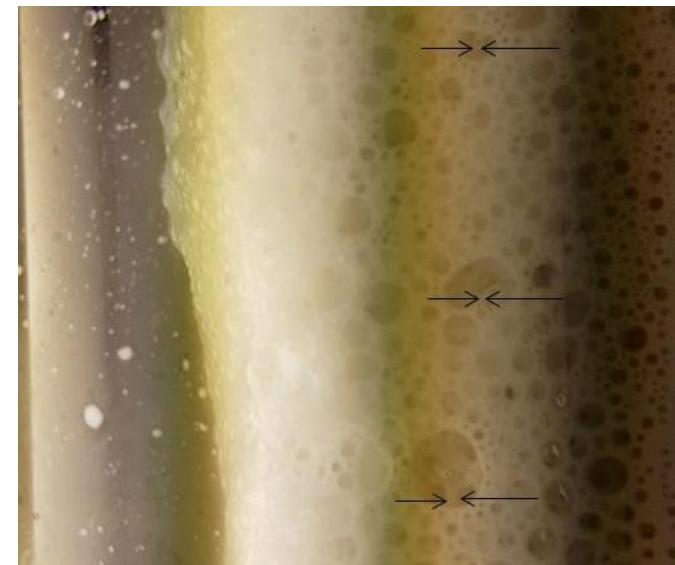
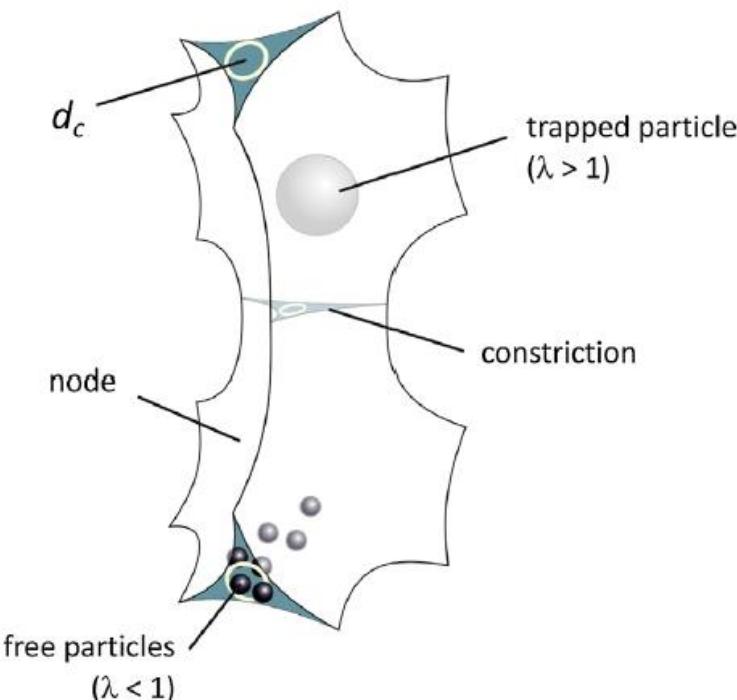
Various mica + fine silica (1:1 ratio):

- Platy mica transports slower with increasing size

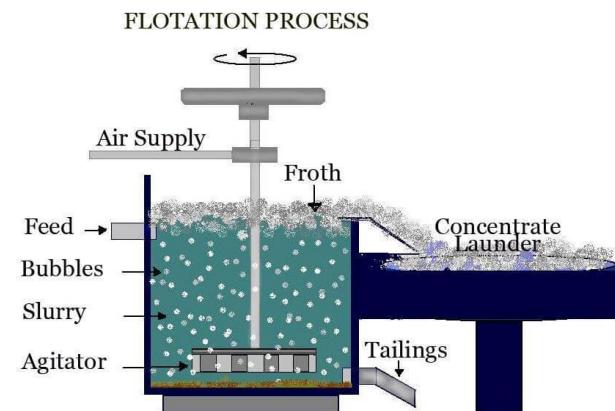
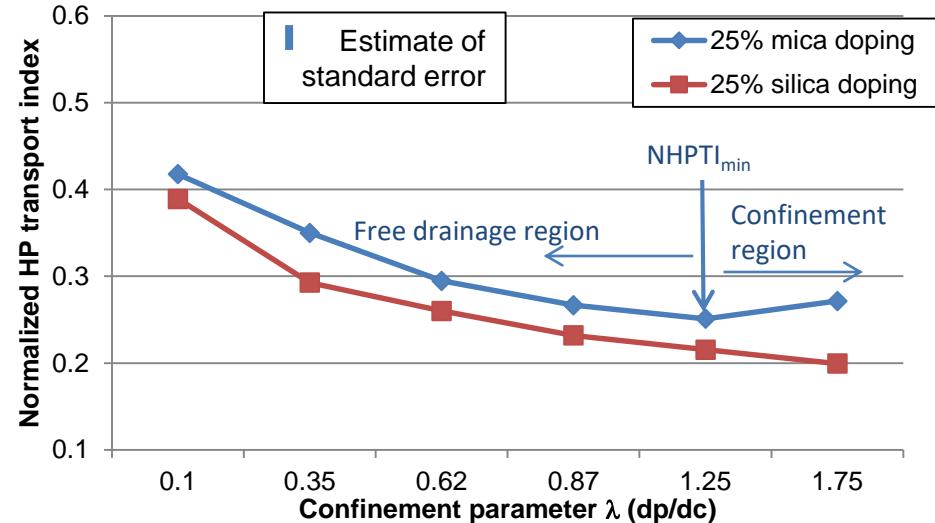


# Confinement of particles

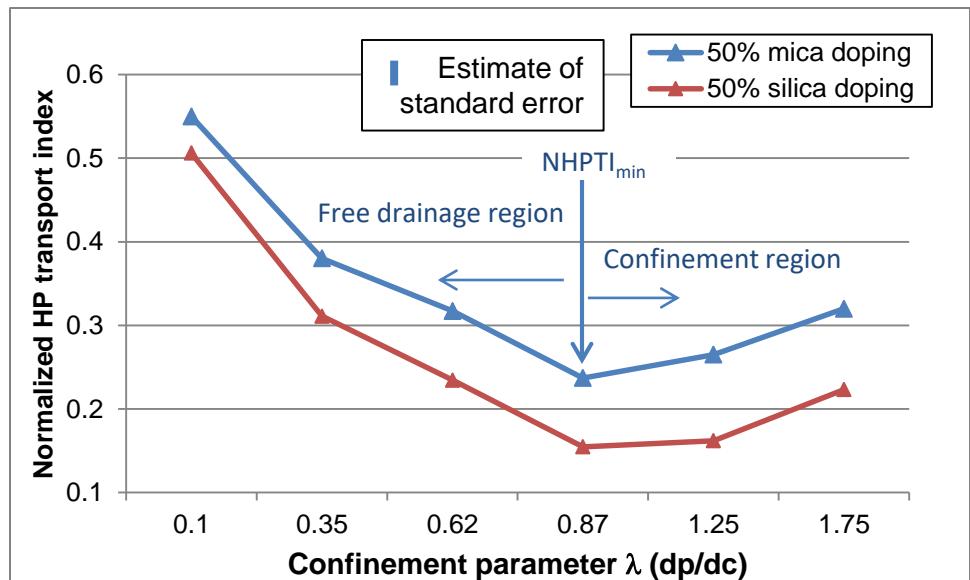
- Confinement parameter  $\lambda=d_p/d_c$ 
  - Visual observations suggest  $d_c=100-250\mu$
  - Particles greater than  $\sim 100\mu$  should be subject to confinement effects
  - High Axial Ratio particles are confined > low Axial Ratio particles



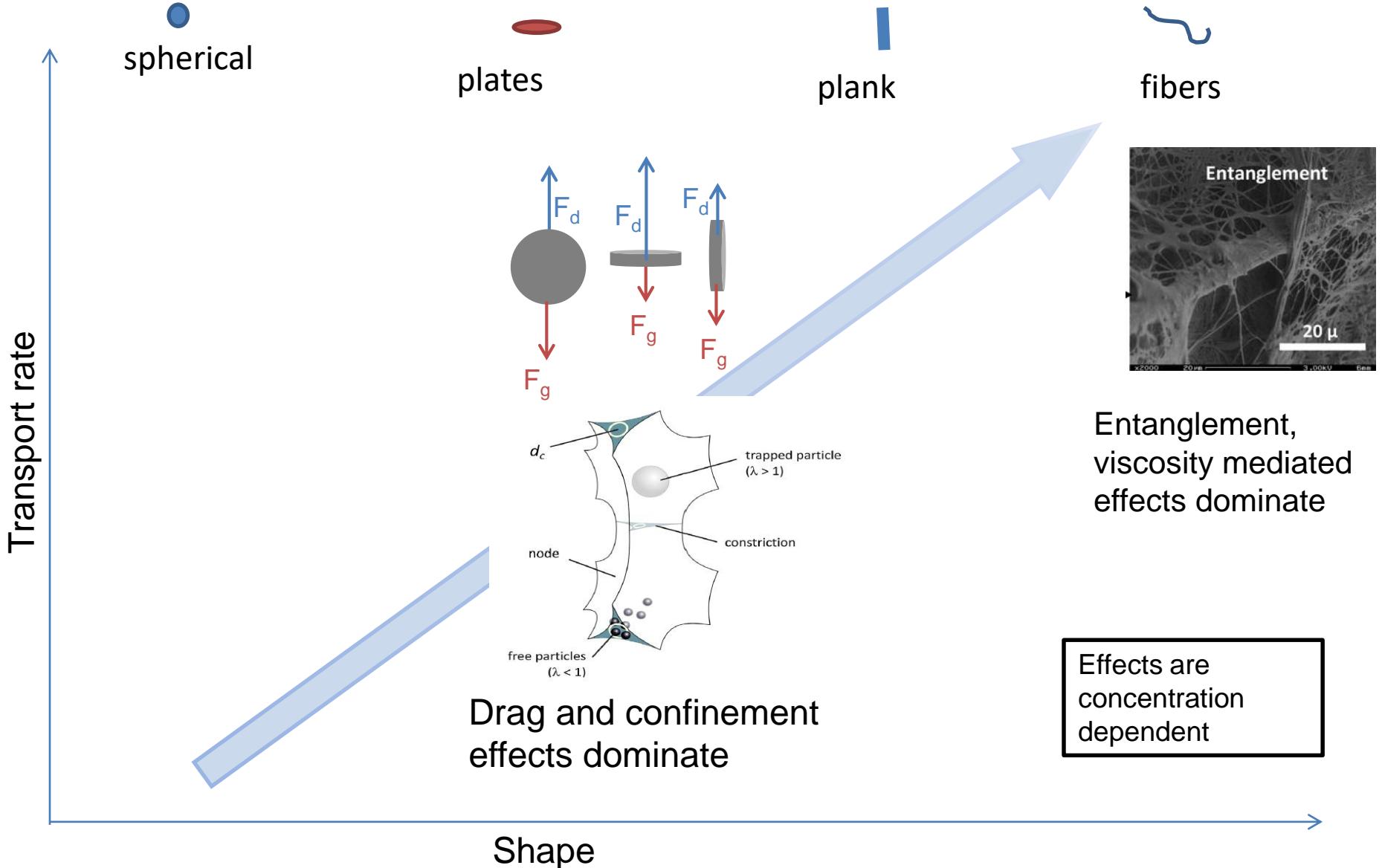
# Elucidating results in doped ore flotation



- Recovery of mica always greater than recovery of silica of comparable size
- Confinement important when particle size approaches size of channels
  - Effect is concentration dependent



# Impact of shape on transport



# Summary

- Current models still consider interstitial fluid as Newtonian, and do not account for geometry or confinement effects
- Novel apparatus for compositional analysis of froth
  - Quantify effects of particle size and shape on mass transport through confined channels
- Bulk rheological measurements using new tools
  - Viscosity contributes but cannot explain all the transport rate differences between platy and spherical particles
- Novel experiments
  - Drag-drainage balanced vs drag-dominated froth sampling
- In drag dominated regime, mica transports > silica for all sizes
- Confinement occurs for platy mica > rounded silica when  $\lambda>1$



# Acknowledgement

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