Centre for
Oil Sands
Sustainability

Relation of Clay to Water Ratio with Yield Stress and Influence of Methylene Blue Index on Source Clays

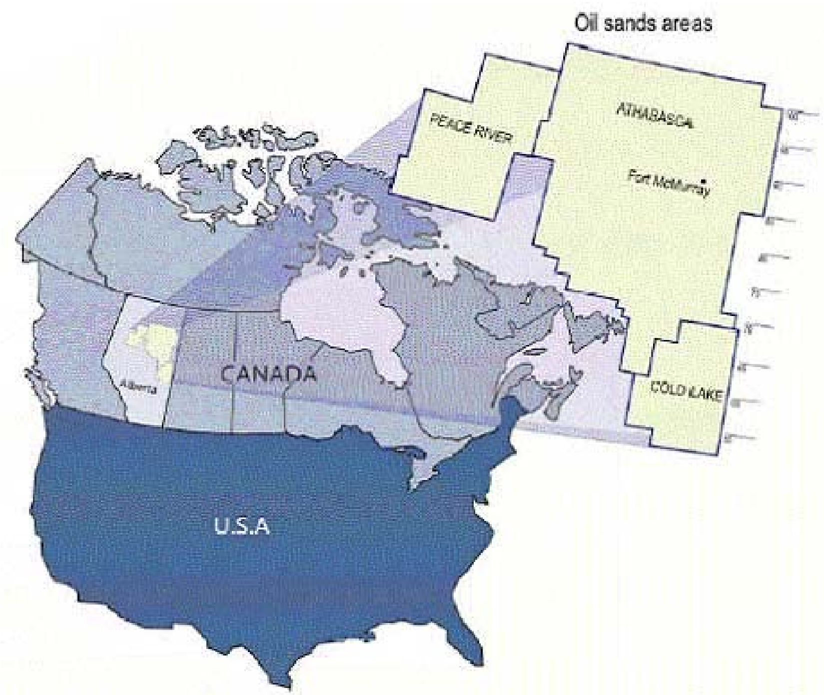
By: Harsh Selani, Heather Kaminsky, Andrea Sedgwick, Yunhui Li, and Vaibhavi Raval

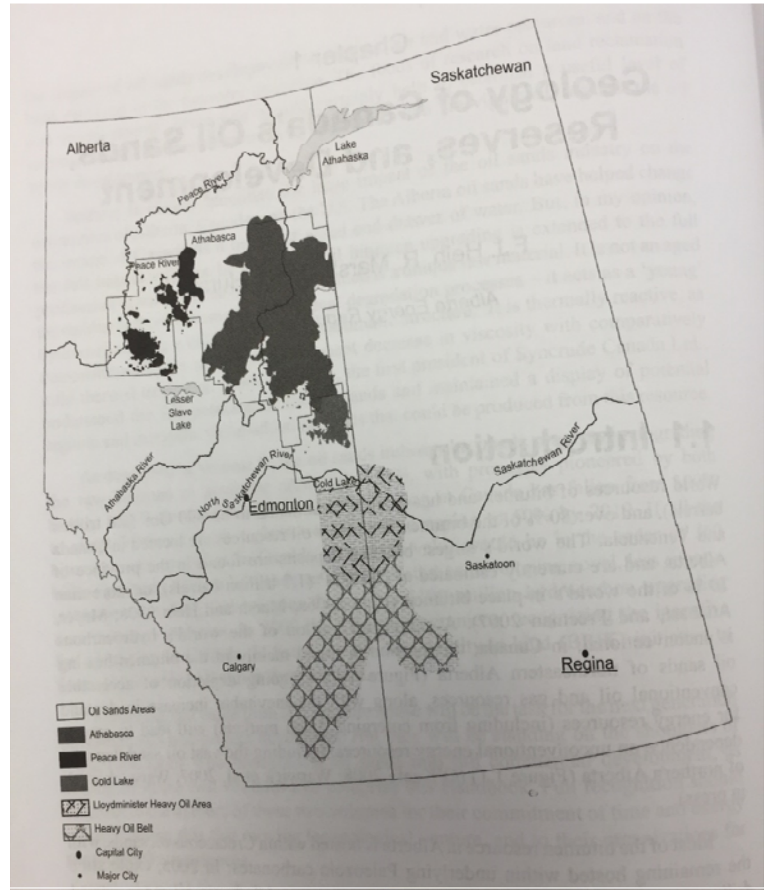
What are Oil Sands?

Image from http://www.syncrude.com/syn_library/images.html

- Bitumen
- Water
- Various minerals
- Water wet

Where are the Athabasca Oil Sands?





1) Alberta Oil Sands Technology and Research Authority, (1990) AOSTRA A 15 Year Portfolio of Achievement. Edmonton, Canada
2) Image from Masliyah, J, Czarneki and Z Xu (ed) (2013) Handbook on Theory and Practice of Bitumen Recovery from Athabasca Oil Sands Volume 2.

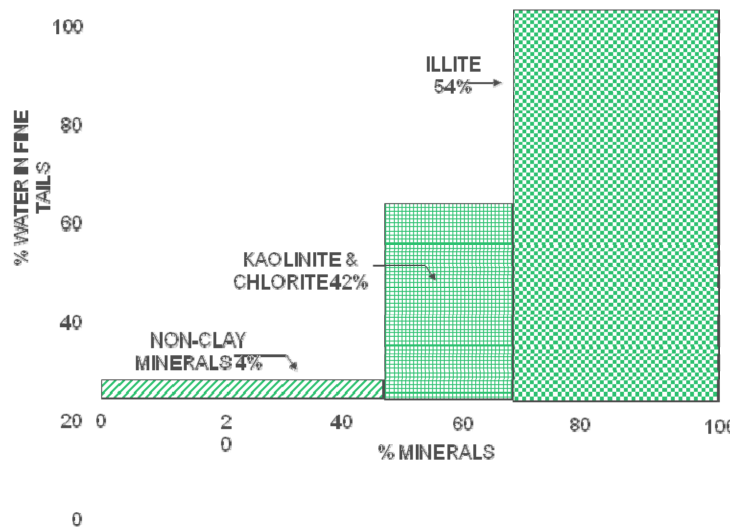
Alberta's Oil Sands Deposits

Oil Sands Tailings Problem

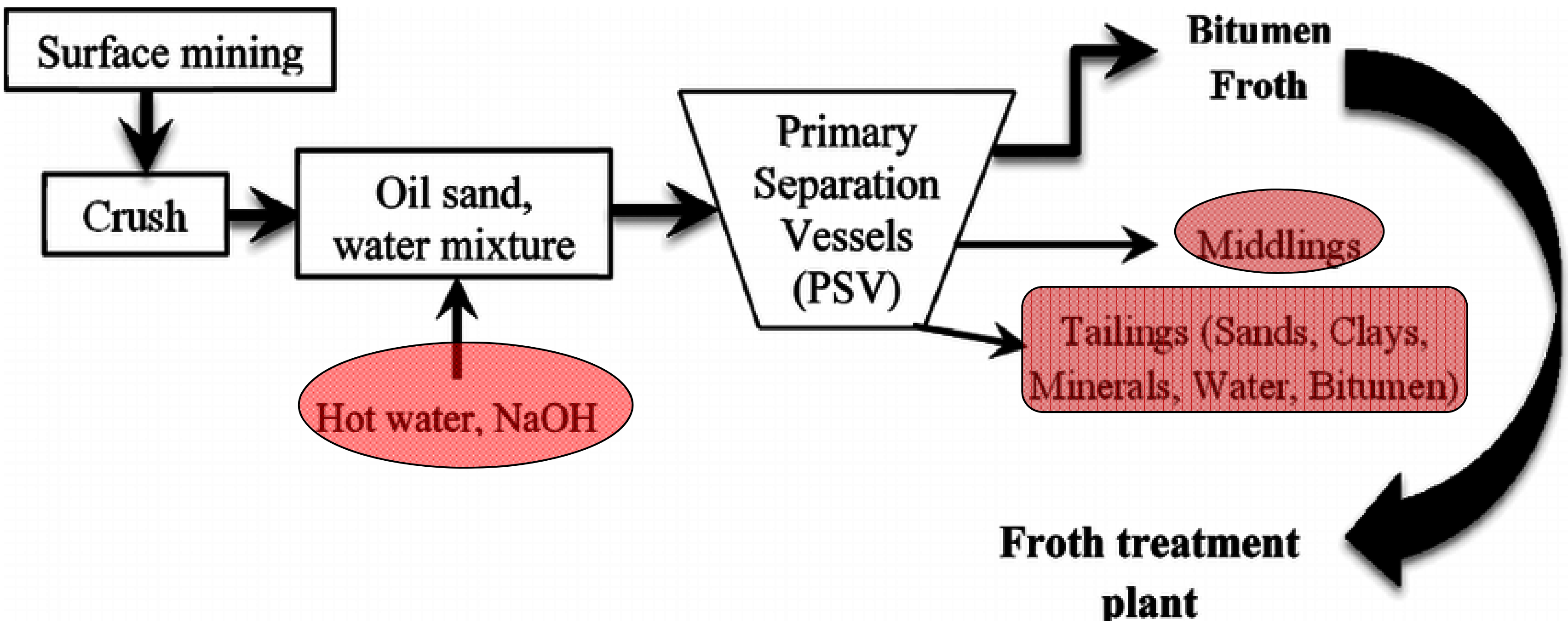
Satellite map of Oil Sands Tailings Ponds

Image from Google Maps www.earth.google.com

- ~1.2 Bm3 FFT currently accumulated
- Clays account for only ~50% of the minerals in the fluid tailings but hold 96% of the water

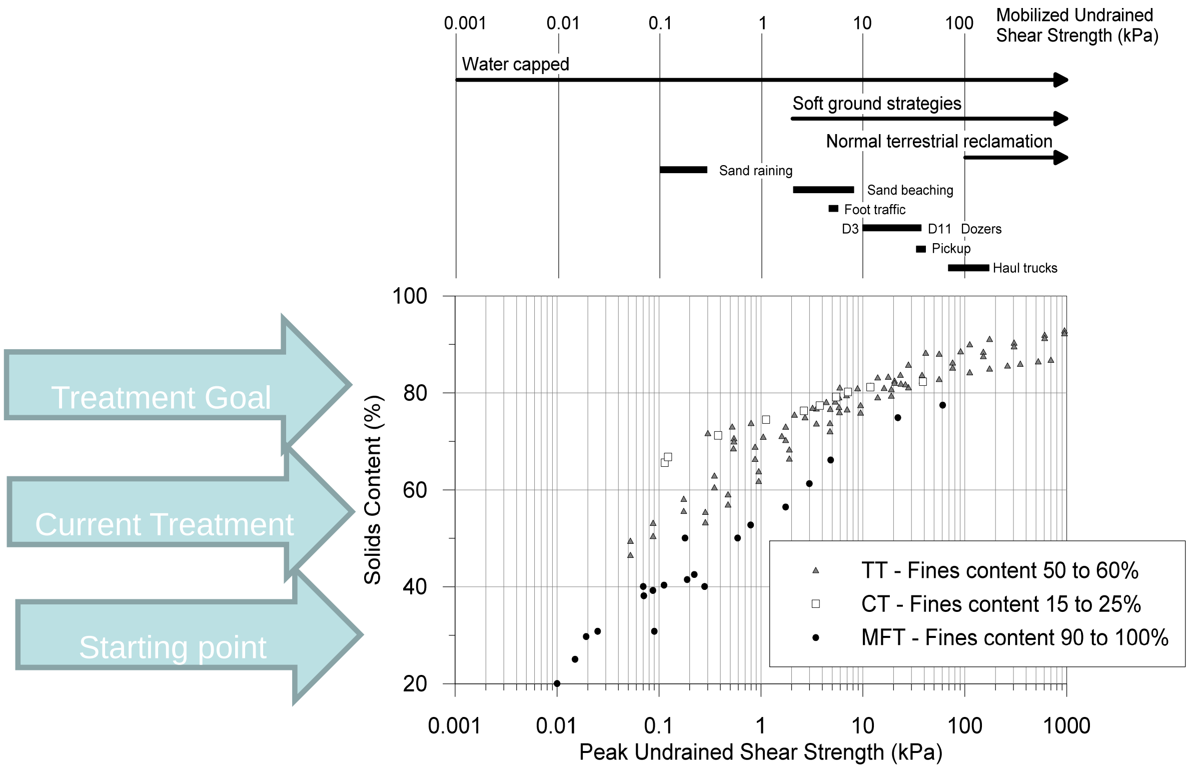


Hot Water Extraction Process



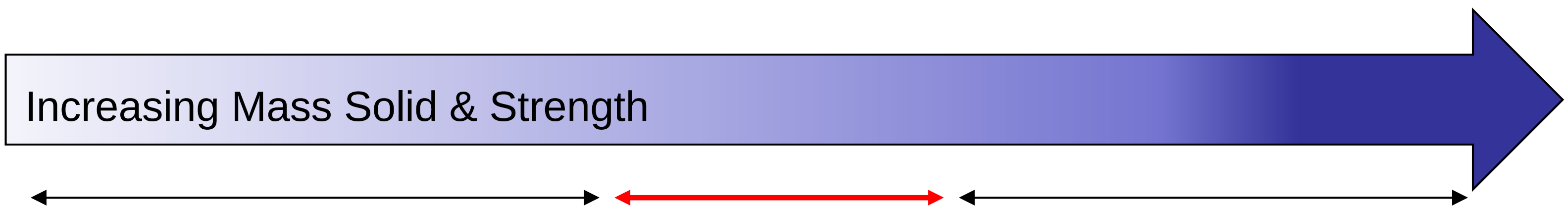
Froth treatment in Athabasca oil sands bitumen recovery process, Feng Rao and Qi Liu, Department of Chemical Engineering and Materials Engineering, university of Alberta, Mar 2015.

Oil sands tailings strength continuum



Suthaker 1995, Jakubick et al. 2003, Shaw et al. 2010, Jeeravipoolvarn 2010, Junqueira et al. 2011, Zhang 2012

The Tailings Zone



Pumpable Zone = Comfort zone for process engineering

Tailings Zone

Trafficable Zone = Comfort zone for geotechnical engineering

“Language” Gap in Engineering

Geotechnical Engineering

- Water Content (M_w/M_s)
- Void Ratio
- Yield Stress (of solid – strain dependent)
- Residual / Remoulded Strength
- Atterberg Limits
- Permeability
- Coefficients of Consolidation
- Effective Stress
- Pore Water Pressure

Process Engineering

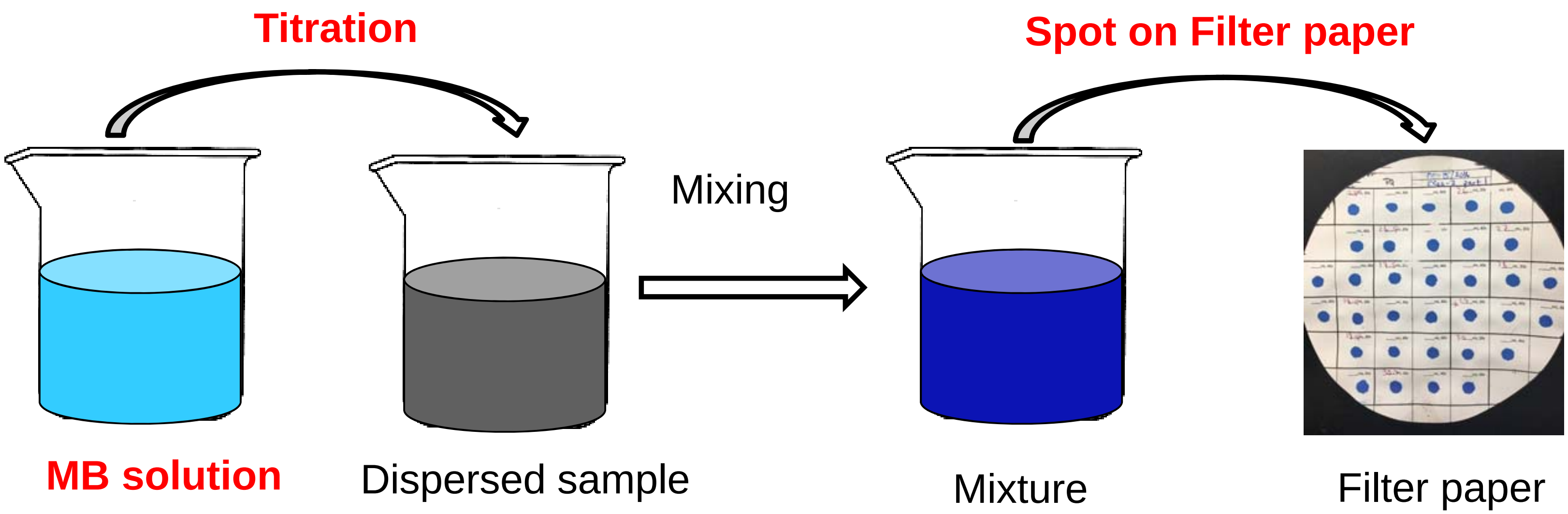
- Water Content (M_w/M_T)
- Solids Content
- Yield Stress (of a fluid – strain rate dependent)
- Residual / Remoulded Strength
- Clay content, Water chemistry
- Resistance to Filtration
- Settling Rate, Thickener Compaction

http://civilblog.org/2014/02/26/10-commonly-used-formulas-to-solve-geotechnical-problems-related-to-phase-relationship/

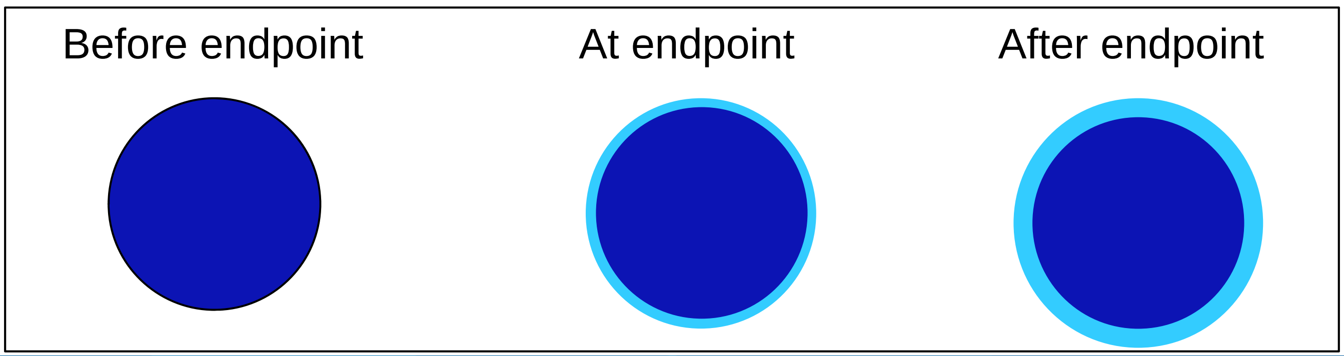
Bridging the Gap

- Transition is a continuum… can we use the same relationship/behaviors to describe the whole range?
- Rheometers can measure stress vs strain and stress vs strain rate
- Mineralogy in oil sands tailings ponds are not usually known- generally assumed to be similar to ore/homogenous. This is a bad assumption.
- There are mineralogical short cuts in both process and geotechnical engineering.
- Methylene Blue is a surface property measurement – provides great process insight, can it be used in geotechnical realm?

MBI Test Method



Spot at different stages of titration:



WE ARE ESSENTIAL TO ALBERTA

NAIT

Clays and Methylene Blue Testing

What does MBI tell us?

- Titration test measures water active surface area
  - Used as an INDEX test of “clay” activity
  - In oil sands converted often converted to a “% clay” –based on an old empirical equation.
  - The equation has since been used to create an index relative to a “typical” oil sands clay which holds 110m^2/g of water

$$MBI\,\frac{meq}{100g} = \frac{mls\ MB\ solution \times normality\ of\ solution \times 100}{mass\ solids\ in\ sample\ titrated}$$

$$\text{"\% Clay"} = \frac{\left(\frac{\text{MBI meq}}{\text{100g}} + 0.04\right)}{0.14}$$

WE ARE ESSENTIAL TO ALBERTA

NAIT

Clay to Water Ratio

$$CWR = \frac{\%\,Solids \times \%\,clay\ by\ MBI}{\%\,Water}$$

Water surrounds clay at uniform thickness

Clay particle of X m^2/g

CWR provides an indicator of the thickness of the water layer surrounding all the clay particles

Relationship Between MBI and Strength

- Assuming MBI provides information on the type and effective “quantity” (surface area) of clay mineral activity in a sample, strength should be directly related to this measure across the material type range

- Sample used- Bentonite, Kaolinite- KGa-2, MFT 1, MFT-2 and MFT -3.
- MFT taken from different operators and deposits over several years.

Sample ID	Bitumen	Mineral	Water	MBI	% Clay	CWR	Fines%	F/F+W
MFT 1	1.2%	24.7%	73.6%	14	100%	0.34	84%	0.53
MFT 2	2.6%	31.1%	64.5%	8	60%	0.29	48%	0.43
MFT 3	1.6%	32%	66.9%	12	80%	0.36	98%	0.60
Kaolinite KGa2				4	30%			
Bentonite (fisher)				128	920%			

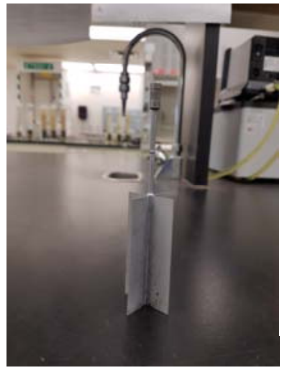
Synthetic Process Water

Chemicals	Weight, g
CaCl2.6H2O	17.1
MgCl2.6H2O	15.1
KCl	1.4
NaCl	17.0
NaHCO3	148.7
Na2SO4	21.4

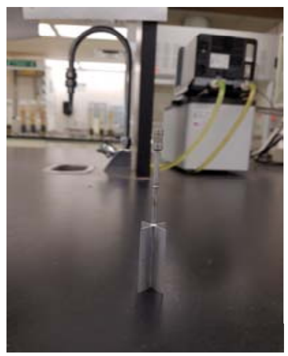
Species	Conc., ppm	Meq
Ca	13	0.16
K	18	0.16
Cl	40	0.46
Na	300	11.96
HCO3	488	8.15
SO4	80	0.93
Mg	8	0.16

Rheology

Dv3T Rheometer



Spindle # 71
Range : 0.07 Pa – 1.2 Pa

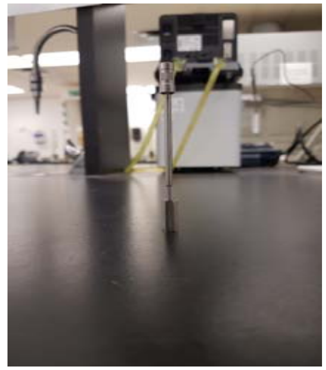


Spindle # 72
Range : 1.10 Pa – 3.77 Pa

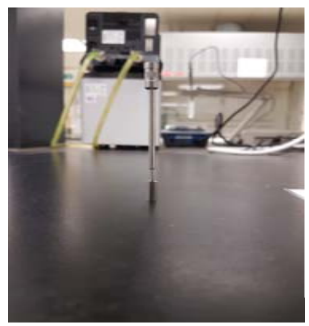
Spindle # 73

Range : 2.57 Pa – 5.00 Pa

Dv3T HB Rheometer

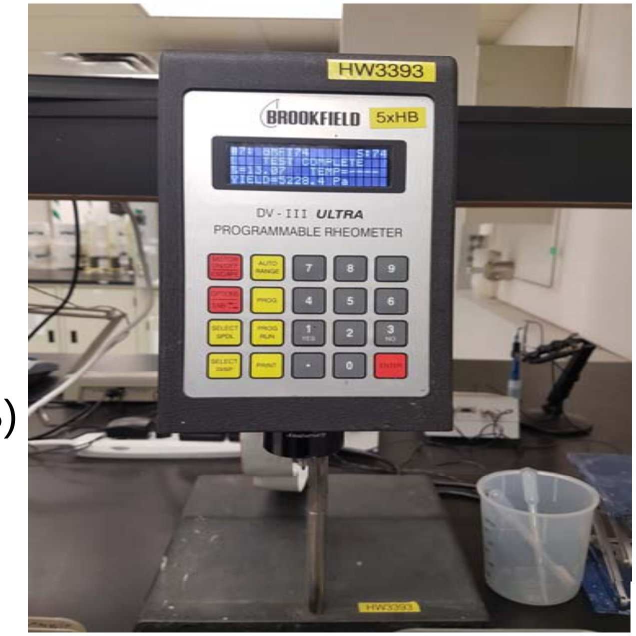


Spindle # 73
Range : 481.5 Pa – 697.39 Pa (For HB)
390.79 Pa – 1560 Pa (For 5xHB)



Spindle # 74

Range : 60.75 Pa – 400.0 Pa (For HB)
893.37 Pa - 9432 Pa (For 5xHB)



Dv3T 5xHB Rheometer

Sample Preparation:

Process water – replacing water chemistry

Source clays: Bentonite, Kaolinite → Mixed with synthetic process water (wt%)

MFT Sample → Centrifuge → Washed with DI water (2 times) → Added synthetic process water (replacing initial solids content)

- Allowed to dry, YS measured with time.
- Beakers weighed daily – mass loss attributed to change in solids – new solids content calculated

Solids content measurements, Yield Stress measurements

Source clays initially

Source clays after drying

MFT sample initially

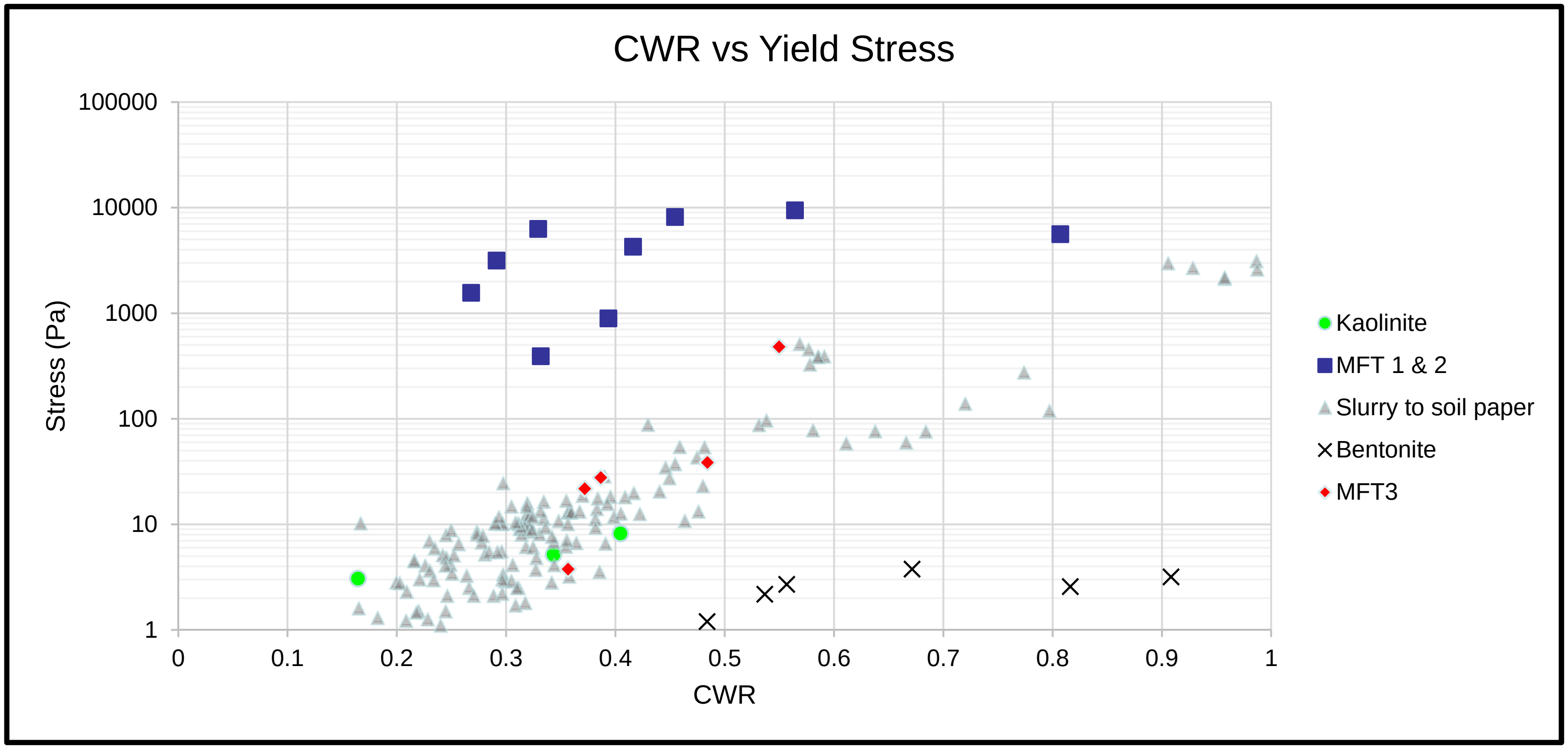
MFT sample after drying

WE ARE ESSENTIAL TO ALBERTA

NAIT

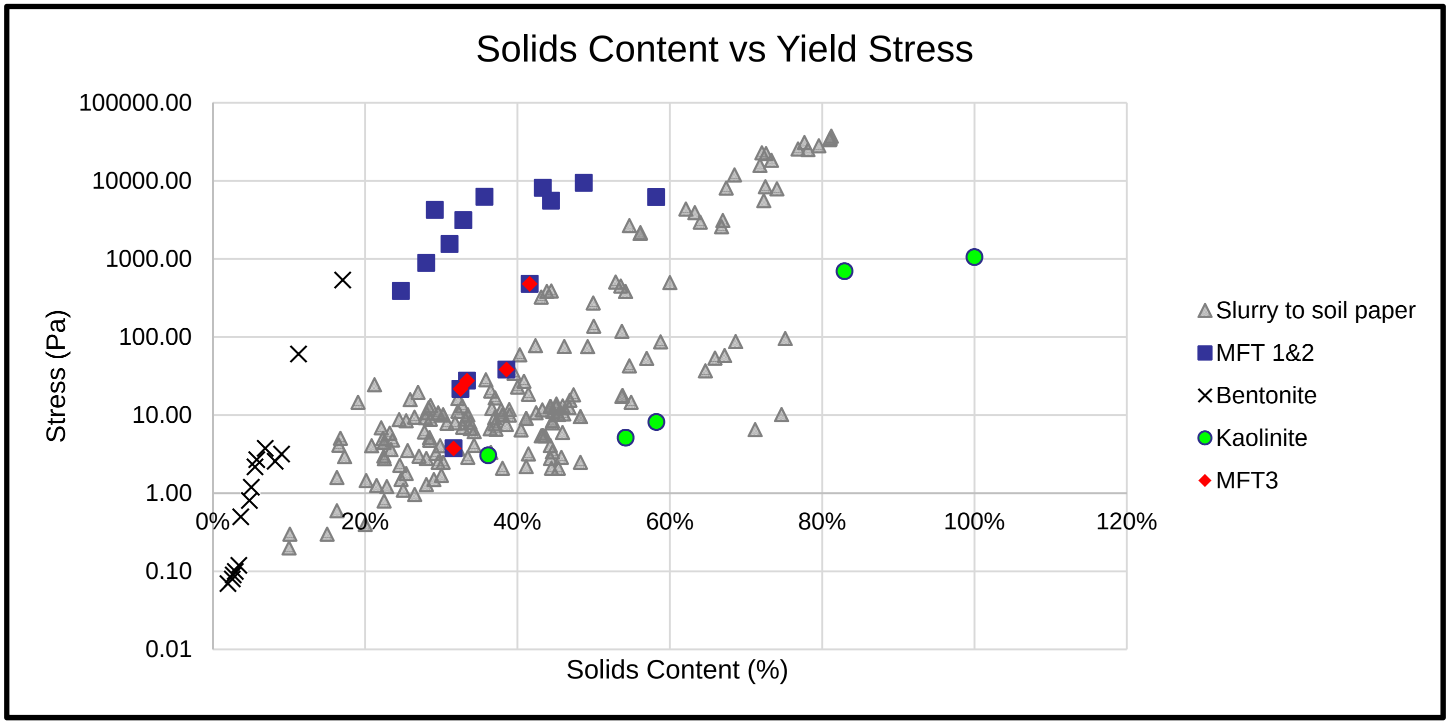
Results:

Clay to water ratio vs Yield Stress comparison



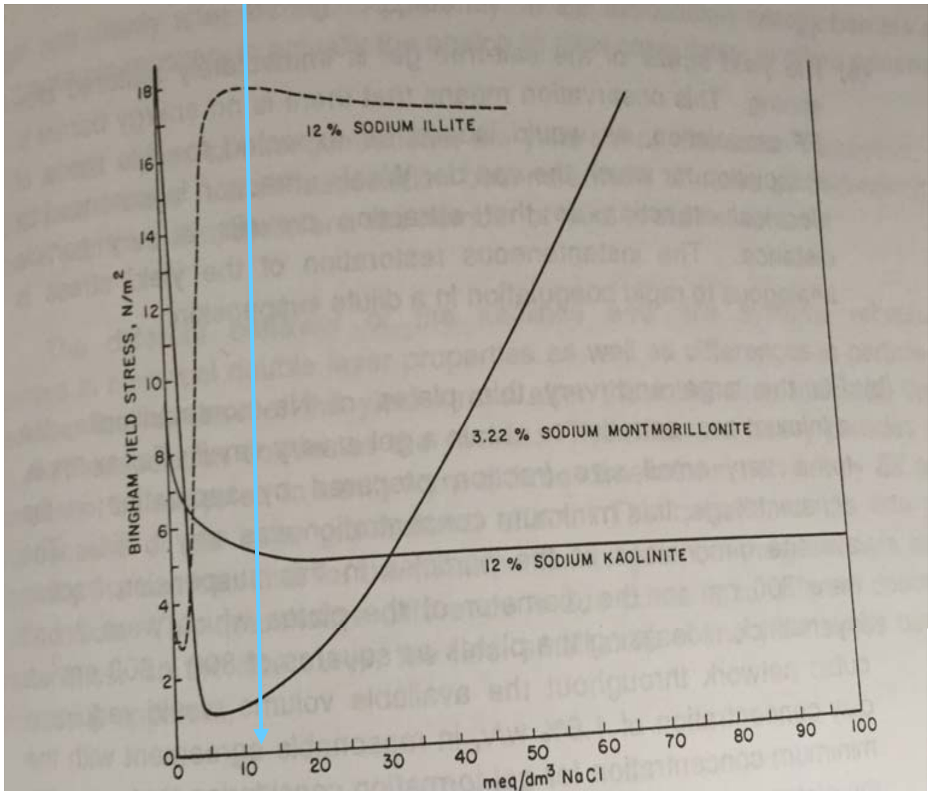
Wells, P.S., & **Kaminsky, H.A.W.** (2015) “Slurry to Soil Clay Behaviour Model – Using Methylene Blue To Cross the Process/Geotechnical Engineering Divide” Proceedings of the Tailings and Mine Waste Conference (TMSC), Vancouver, Canada

Solids Content vs Yield Stress comparison



Wells, P.S., & **Kaminsky, H.A.W.** (2015) “Slurry to Soil Clay Behaviour Model – Using Methylene Blue To Cross the Process/Geotechnical Engineering Divide” Proceedings of the Tailings and Mine Waste Conference (TMSC), Vancouver, Canada

Typical Oil Sands Clays – Yield Stress as a function of NaCl concentration



Concentration of synthetic PEW = 12 meq/dm³ NaCl

Typical oil sands = Kaolinite : Illite = 2:1

Figure from:
Van olphen, H. (1992) Particle Associations in Clay Suspensions and their Rheological Implications in CMS workshop lectures Vol. 4, Clay-water Interface and its Rheological Implications, N. Guven and R.M. Pollastro, eds., The Clay Minerals Society, Boulder, Colorado, 000-000.

Conclusions

- Clay to water ratio is useful in a limited context when mineralogy is reasonably consistent.
- Not all MFTs follow slurry to soil model and cannot be predicted from MBI effects.
- Mineralogy matters. This will play a role in comparing behavior between leases or with source clay behavior
- Water chemistry range for typical oil sands process water saline enough to end up in a stable yield stress regime for kaolinite and illite. This area corresponds to a minimum in montmorillonite yield stress.
- Significant increase or decrease in salinity anticipated to have a major impact on yield stress for slurries containing smectites.

THANK-YOU

QUESTIONS?