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GEOSCIENCE
new horizons
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SPE Caprock Integrity Panel SAGD and Unconventional Reservoirs

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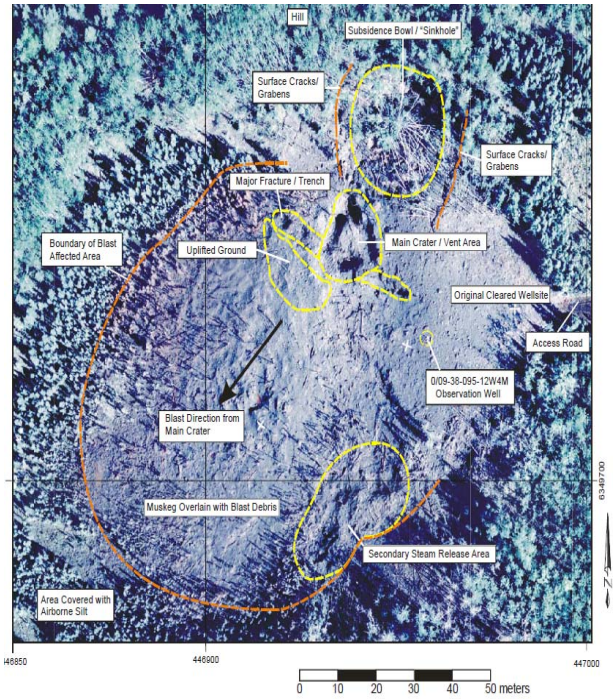
Outline of presentation:

- Reminder of issues
- Review of SAGD forces
- Part I
  - Most recent regulatory changes
- Part II
  - Better geological description still the “foundation” of engineering analysis
- Part III
  - Risk evaluation - the wellbore is important!
- Conclusions – not business as usual (yet)

Context

Primrose

Joslyn



Jackfish

No fatalities

Spills cleaned up

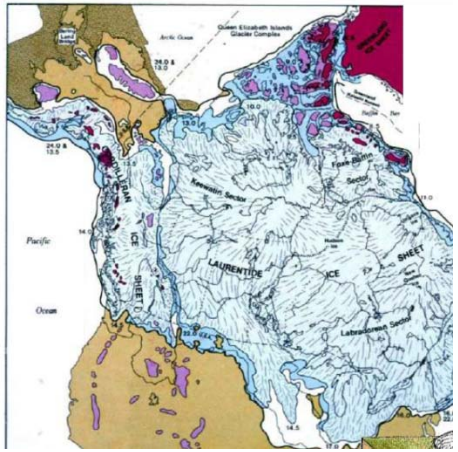
Hurts perception

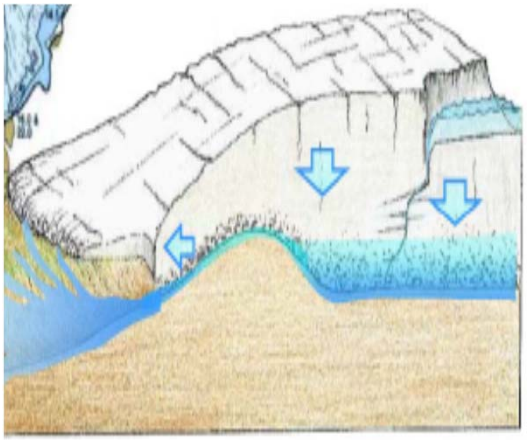
Part I: Recent regulatory changes

AER: five documents for comment:

CODE	TITLE
RC-01	Summary of Conclusions from Reservoir Containment Project
RC-02	**Caprock Criteria and Information Requirements ****
RC-03	**Development of the Maximum Operating Pressure Formula ****
RC-04	Limitations of Geomechanical Models
RC-05	Monitoring Reservoir Containment in Thermal EOR

Geological issues (1)





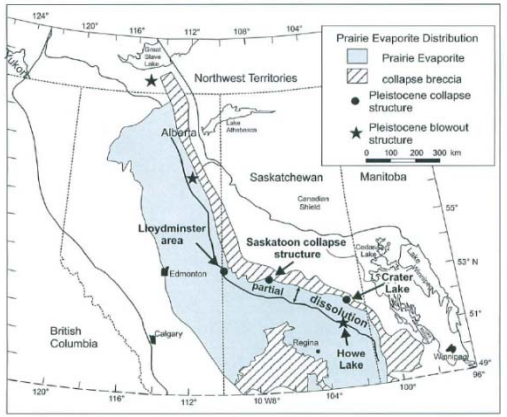
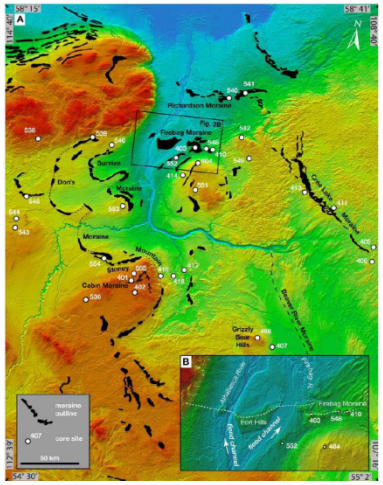
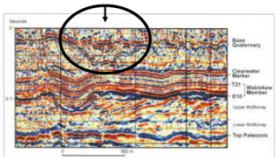


Figure 9. Map of the subsurface extent of the Prairie Evaporite formation. Areas of collapse breccias represent regions where the Prairie Evaporite has been dissolved and overlying units have collapsed to infill void space (after Meijer Drees, 1994). Pleistocene age collapse and blowout structures (discussed in text) are indicated.

10 – 9.5 000 BP (modified from T. Fisher)

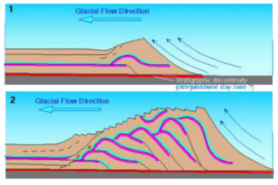


Glacial Meltwater Channels

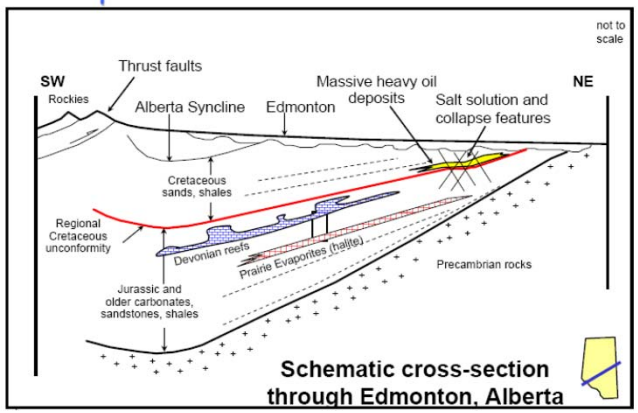


(modified from Langenberg & Hein)

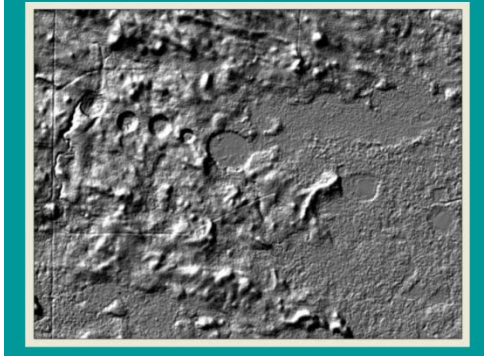
Glacial Thrust Triangle Zones: Fort Hills, Fort MacKay, Cold Lake



Compressional Basin Section



LiDAR (LIght Detection And Ranging)



Geological issues (2)

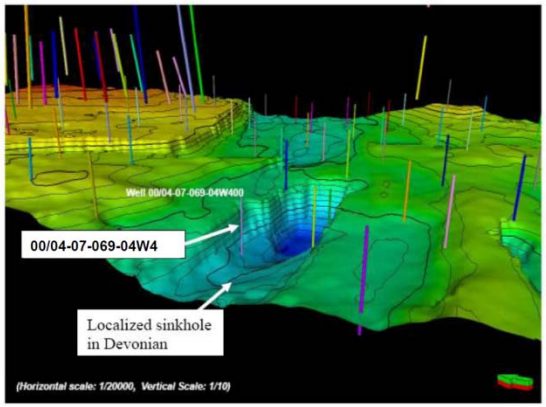
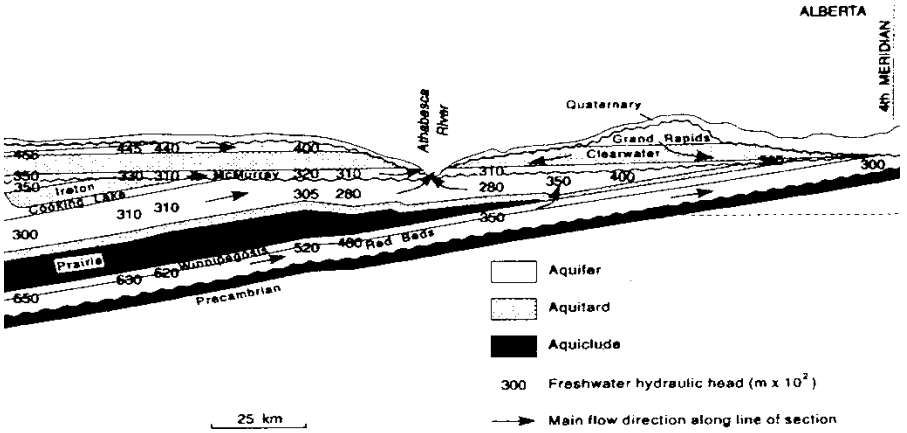
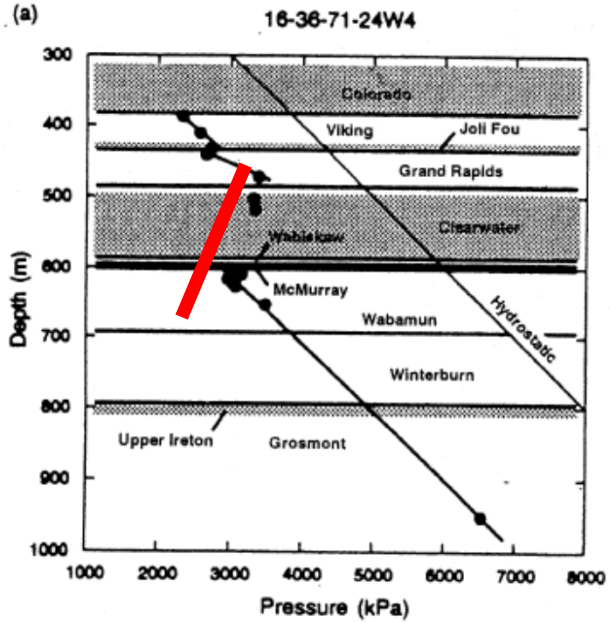
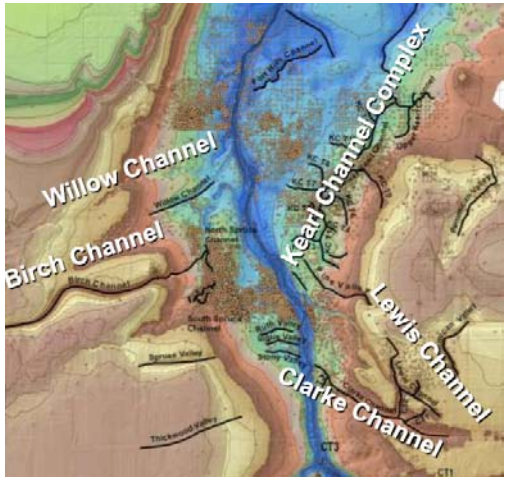


Figure 11. 3-D seismic mapping of localized sinkhole form the Husky Caribou Application







Part I Summary

- Extensive technical discussion
- AER indicates fundamental failure mechanism not completely resolved.
- Geomechanical modelling from industry requires improvements
- Requested feedback from industry. Constructive suggestions have been made
- Switch from ladder based enforcement

Part II:
Better geological description

Draft reservoir containment documents indicate this is now a requirement in the interim and likely future.

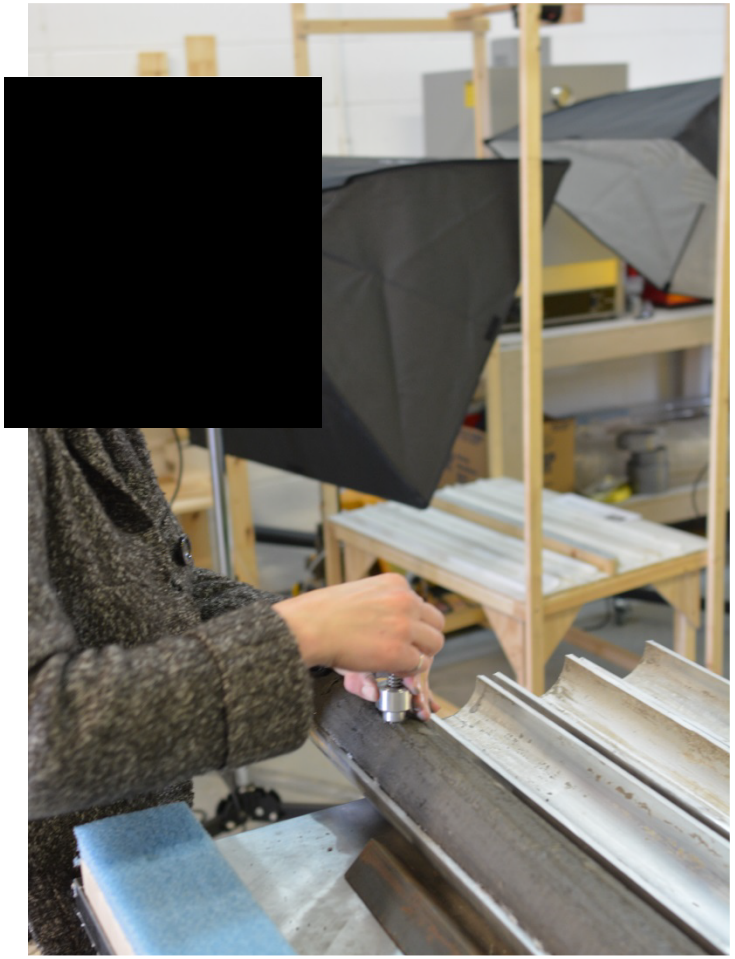
Proper handling of core

Core must be handled properly:

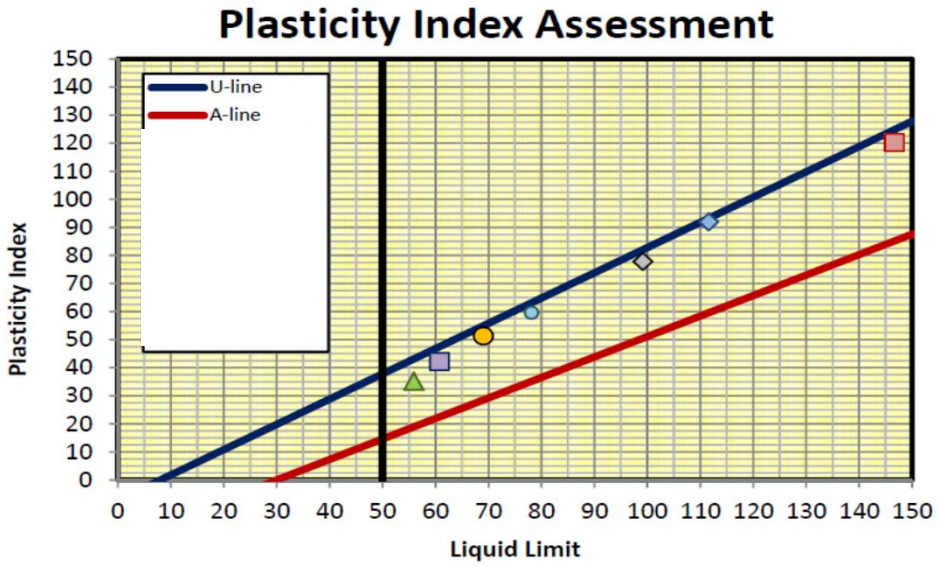
- Stored in a heated place
- Must be carefully handled – not dropped and damaged
- Moisture content must be measured and preserved
- Tubes must be sealed
- Cannot be slabbed for strength testing!

Wrapping and photo record

Testing and storage



Atterberg limits (RC-02 / RC-04)



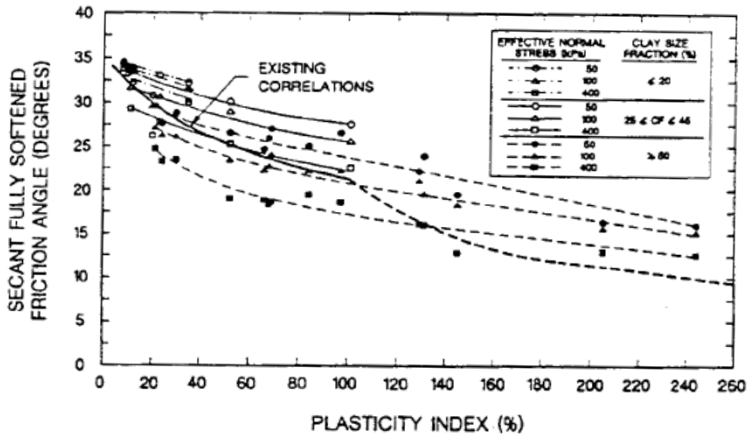


FIG. 6. Relationship between Fully Softened Friction Angle and Plasticity Index

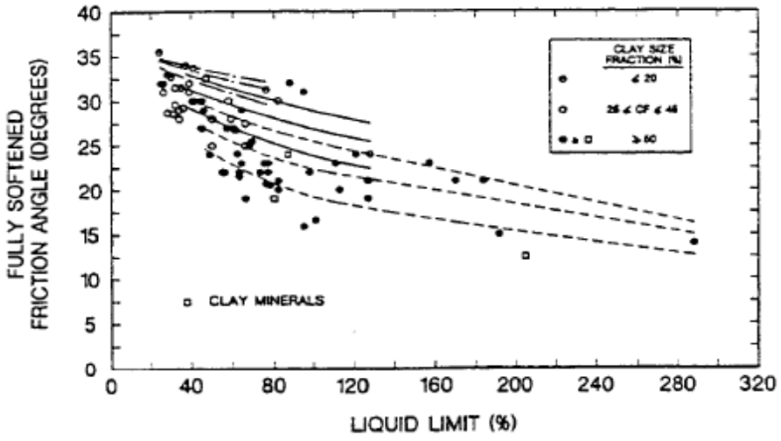
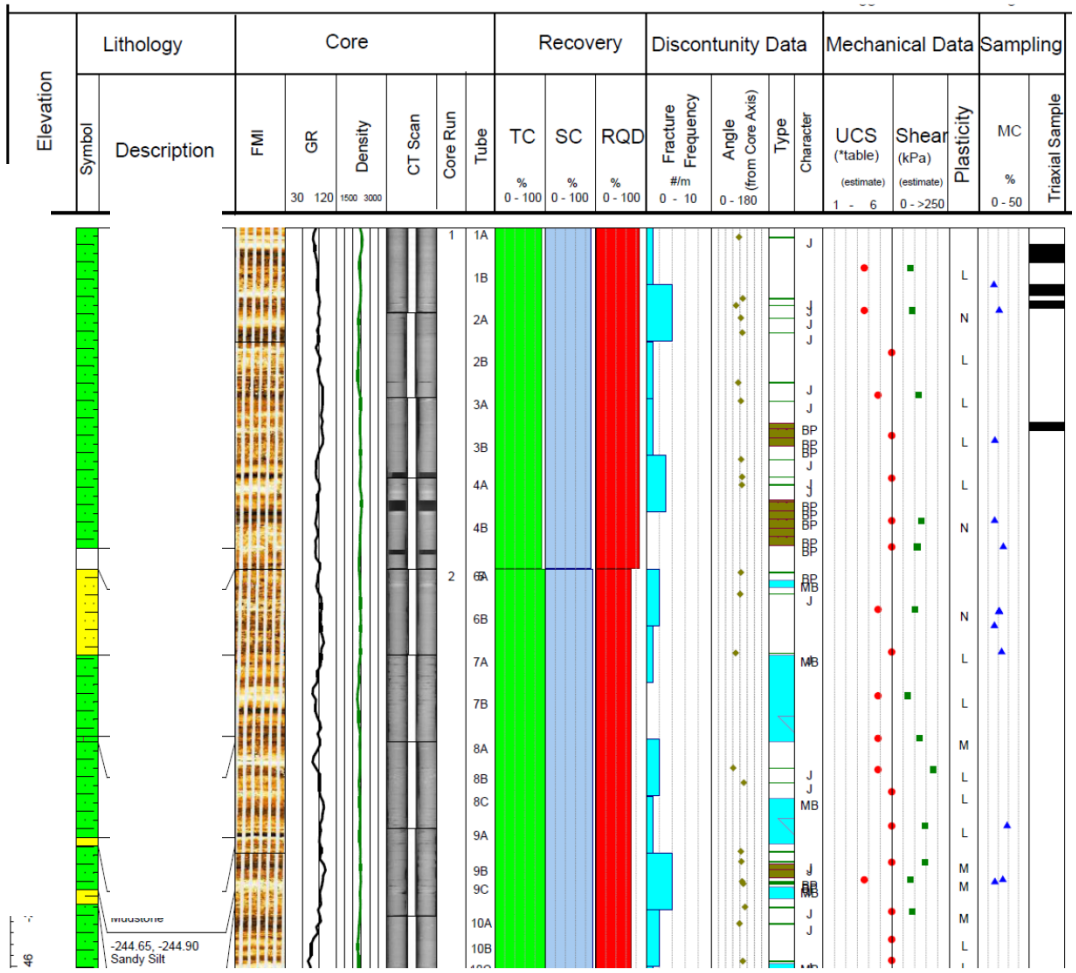
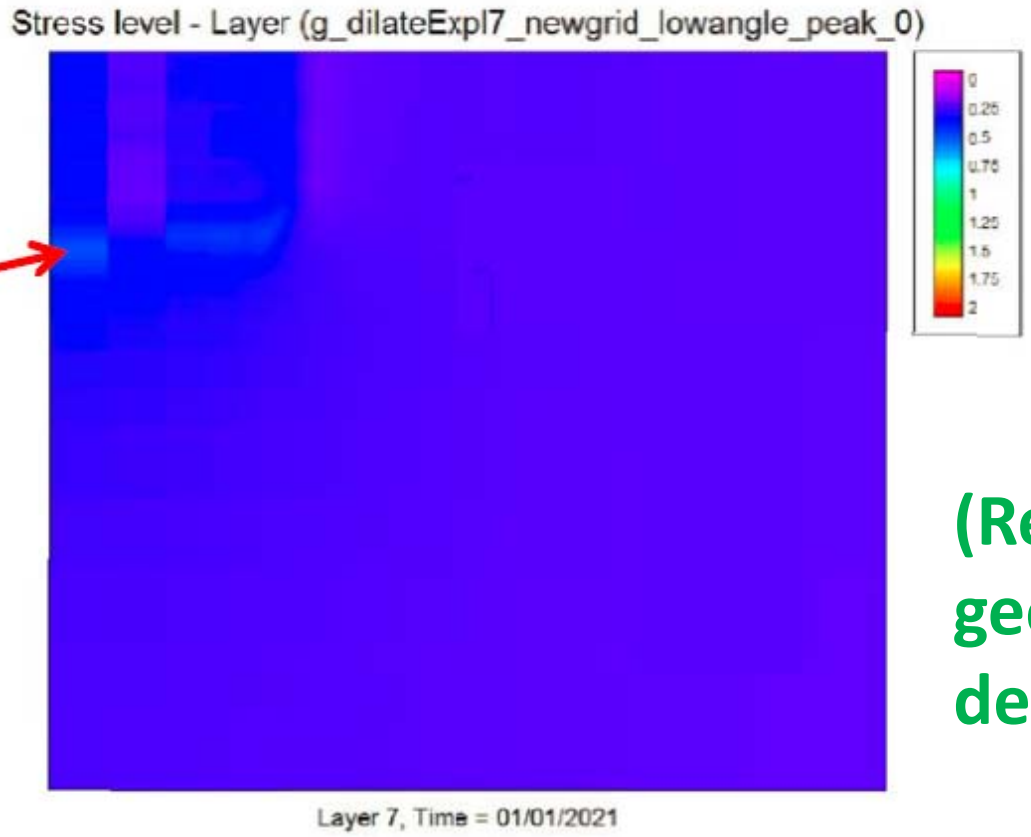


FIG. 5. Comparison of Published Fully Softened Friction Angles and Proposed Relationship

Engineering log of core (RC-02)



Overdevelop chamber; or, account for heave variation?



Permeability variation, Note typical cake slice character due to gridding.

(Read geological description)

Curvature test? New geostatistical criteria?

Part II Summary

- Core is the foundation of other analysis
- Simple tools are being underutilized
- Diametric opposite of oil sands core
- Subsequent analysis includes
  - » Triaxial testing
  - » Geomechanical / thermal reservoir modelling
  - » Stress interpretation
  - » Identification of discontinuities (fractures)
- Logically can be combined into a service module

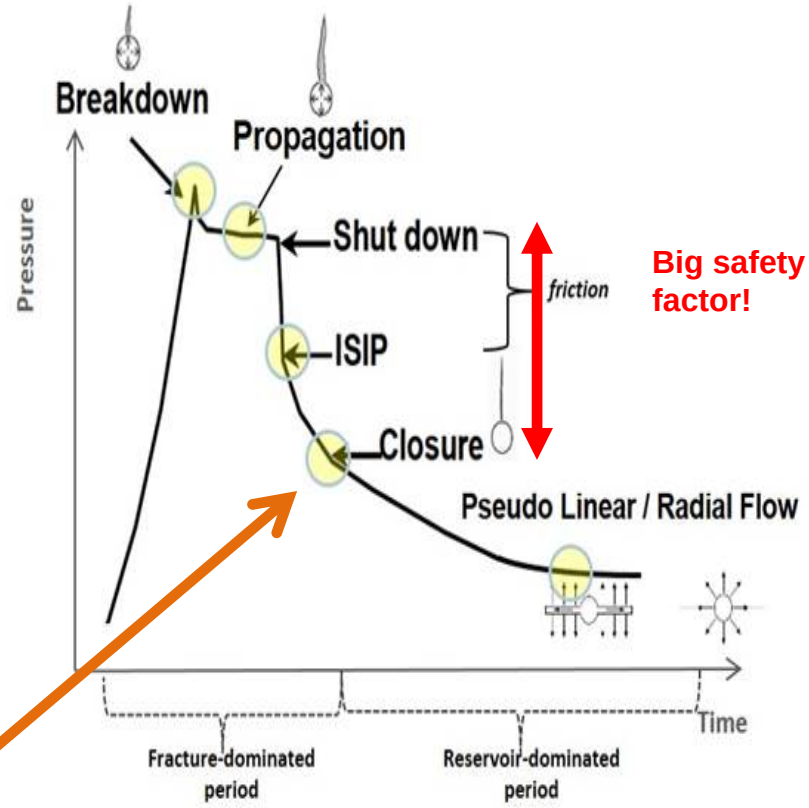
Part III:
Wellbores are part of the issue

MOP calculation

MOP rule cornerstone of RC series

- Geomechanical modelling does not predict Joslyn failure, no published models
- Uncertainty in FEM / thermal reservoir models
- Therefore MOP rule, classic frac limitation:

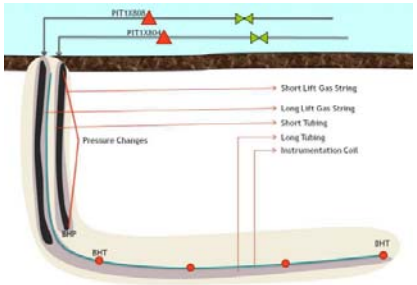
  $P_{closure} * (1 - SF)$
- High inherent safety already?



Lots of debate on how to do this!

Slugging it out - Devon

- Joel Slobogian of Devon (quote)
  - *Following two separate catastrophic well integrity related events at Jackfish in 2011 and 2013, Devon has been making strides to implement a risk based decision making within production operations*
- "Risk" outlined was a subcool event in wellbore (quote)



1. Failure to adequately understand and/or acknowledge severity and potential systemic implications of previously found sand erosion damage
2. Operation of B3 well pair at low subcool levels that over time led to steam channeling and ultimately liner failure due to sand erosion
3. Lack of consideration of and planning for a well failure

Is this a surface facilities issue?
Started with jetting in liner.

OK, what caused jetting?

- Thermal expansion
- Effect of slots
- Hole drilled – liner run – soil collapses on liner?

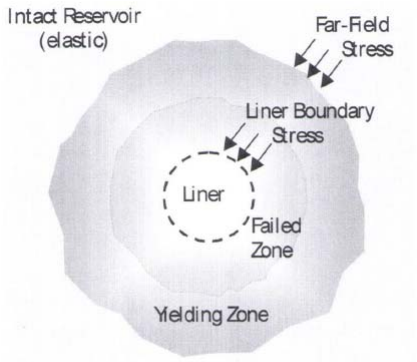


Figure 1. Schematic showing concentric zones of material behaviour surrounding a horizontal liner installed in unconsolidated sand.

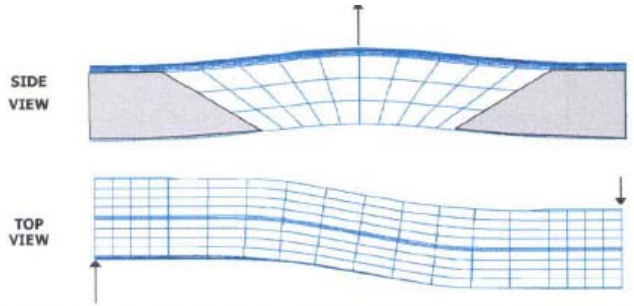


Figure 3. Prevalent buckling modes for slotted liner struts as predicted through numerical modelling: radial buckling (top) and circumferential (or "torsional") buckling (bottom).

Surface line problems

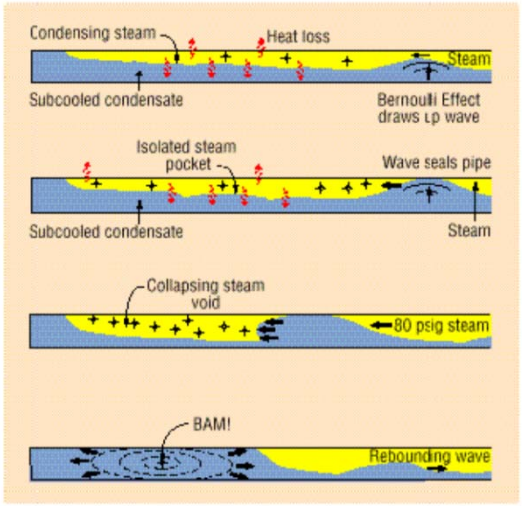
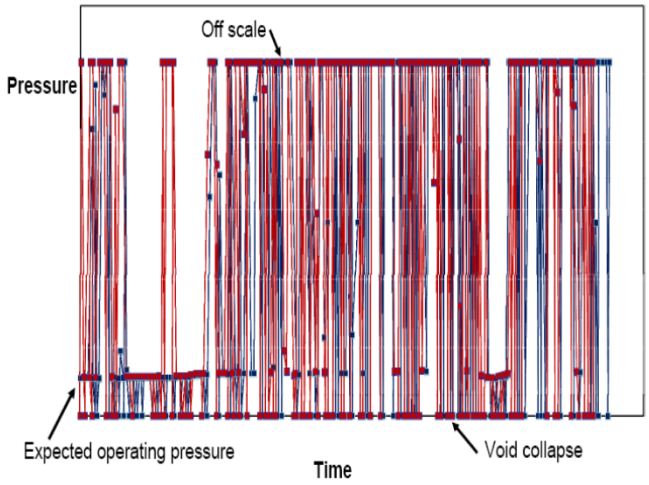


Figure 1. Condensation induced water hammer

AER Report

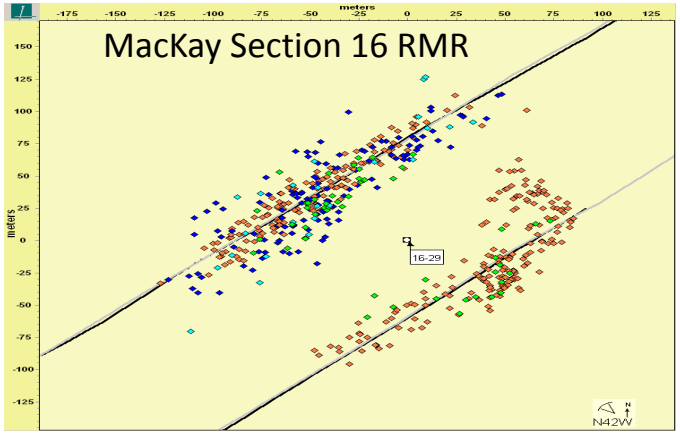
Simple models

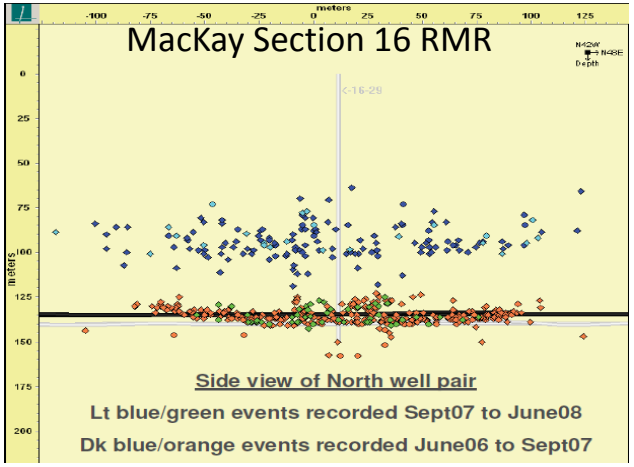


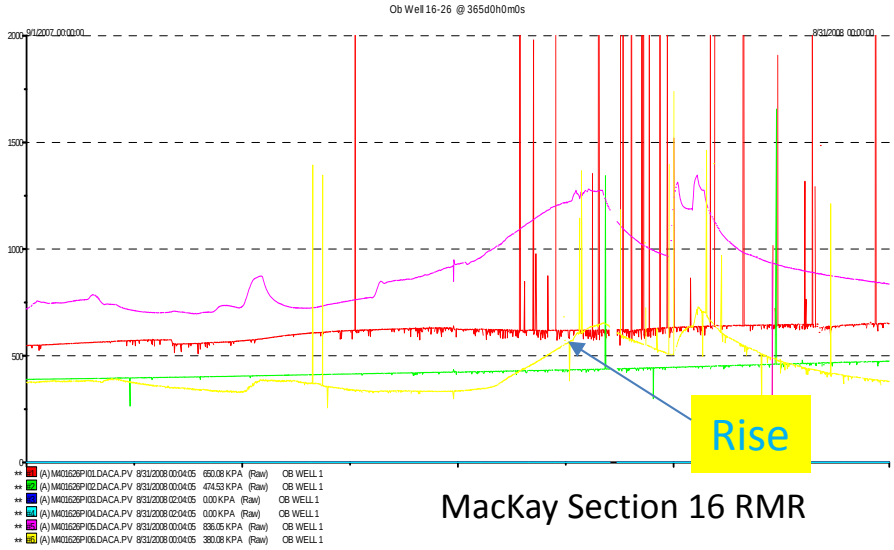
Observed wellbore data pattern (buggy?)

web

Wellbores very unstable Edmunds and Good (Geysering)







MacKay Section 16 RMR

Shearing of formation strong enough to cause micro-seismic event like a hydraulic fracture?

Observation well data i.e. this is through formation

Reference: InSitu Progress Reports, Petro-Canada MacKay River 8668 Performance Presentation 2008.pdf

What is underlying physics?

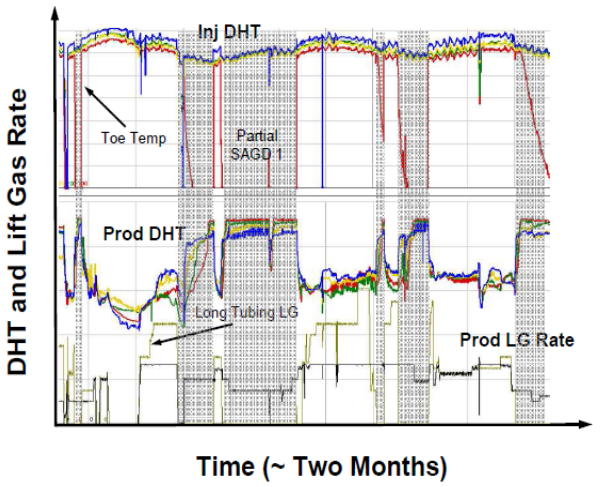
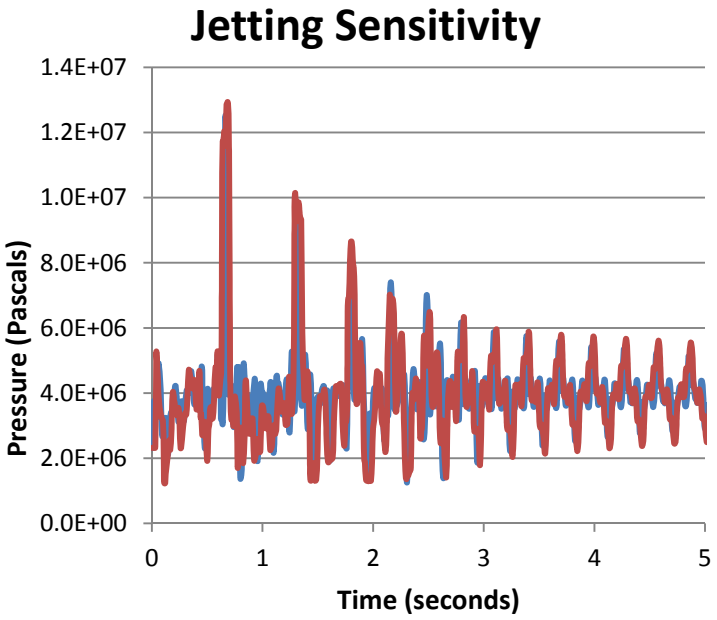
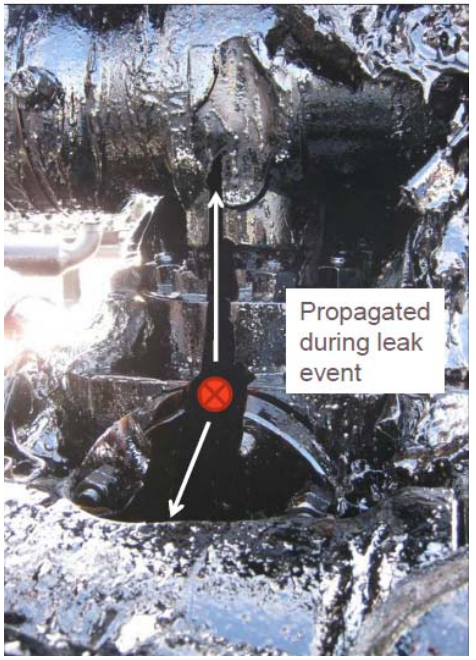


Figure 14 Downhole temperature and lift gas rate changes of a SAGD Wellpair in Jackfish SAGD project





Washing of fluids through slots back and forth?
Deformation of casing and slot width altered?

Part III Summary

- "Risk" identification latest approach
- MOP's formula long history in use
- Factor of safety not tied to closure pressure
  - In this case is 0.9 to 0.8 significant?
- Closure stress contentious interpretation
- What about physics?

Presentation summary

- Three areas highlighted
  - Regulatory process in motion – watch this – clear shortcomings in understanding outlined by AER
  - More complete geological description
  - Risk base analysis latest approach – physical explanation incomplete
- More complex than anticipated
  - fundamental research, collaboration and recognition of “inter-dependencies”

Questions
&
Discussion

YouTube videos

- Non SAGD – general CIWH – professional
  - This is for a valve closure
  - http://youtu.be/X9UbzcanuDk
  - Classic condensation induced water hammer (CIWH)
  - http://youtu.be/-z6W1uiKFSQ
  - The clear steam system is really quite impressive
- SAGD specific (amateur)
  - http://youtu.be/zhRlllivJH4
  - http://youtu.be/1QFj4F03JT0
  - http://youtu.be/nLH4bFVtf64
  - http://youtu.be/e0_jO87EQBA
- Can this be expected to effect calculation of MOP?