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Prediction and Management of Solids Production in Typical Surat Basin Coal Seam Gas Reservoirs, Eastern Australia

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Presentation Outline

- **Introduction**
  - Physics of Solids Production
  - Well Completion & Production in Coal Seam Gas Wells
- **Surat Basin CSG Fields Specifics**
  - Walloon Coal Measures
  - Nature of Problem and the Study Motivation
- **Rock Mechanics Testing and Geomechanical Evaluation**
  - Mineralogy: SEM & XRD
  - Mechanical Properties, Water Sensitivity and Rock Weakening
  - Core-log Calibration and Stress Profiling
  - Solids Production Prediction
- **Implications for Solids Management**
  - Field Observation and Remedies

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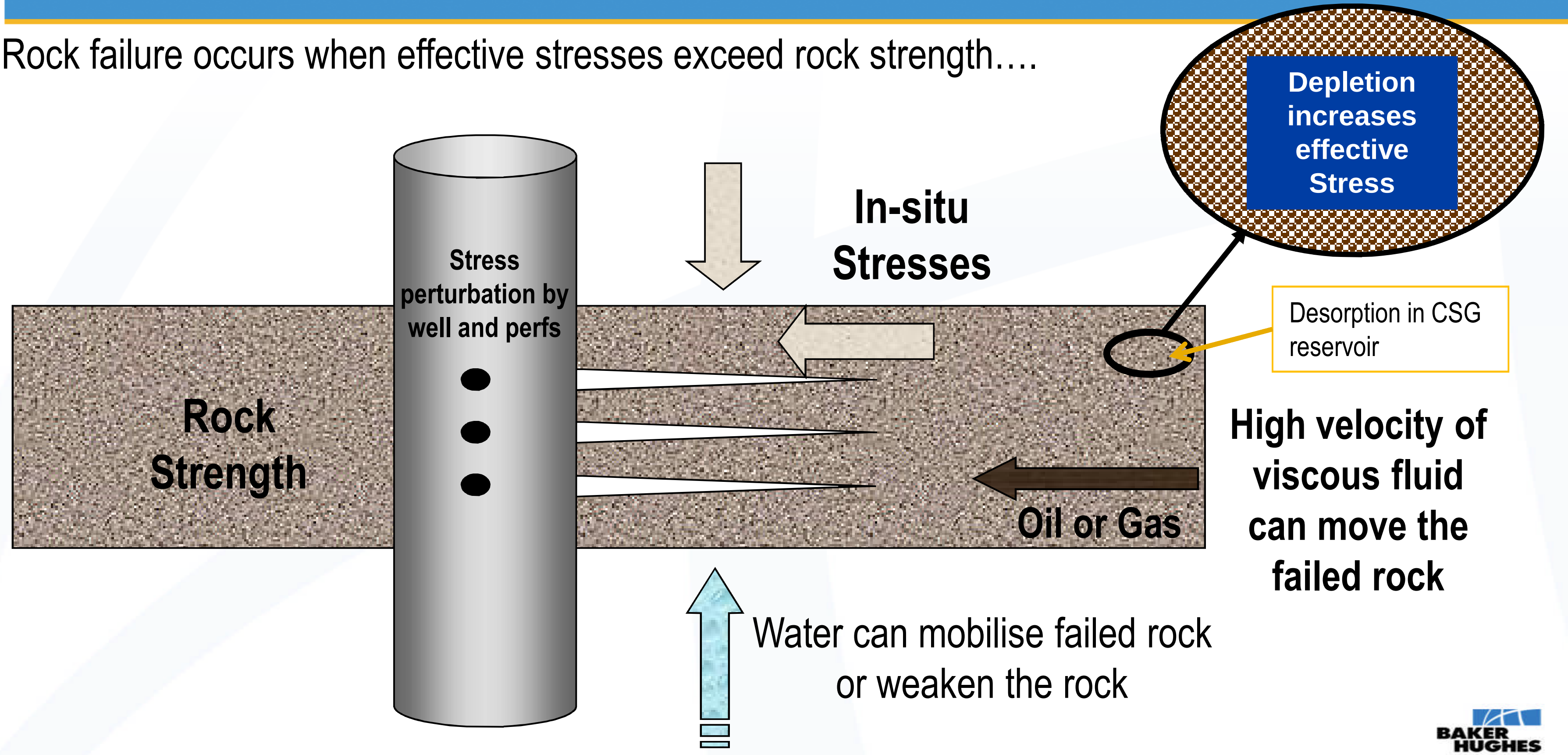
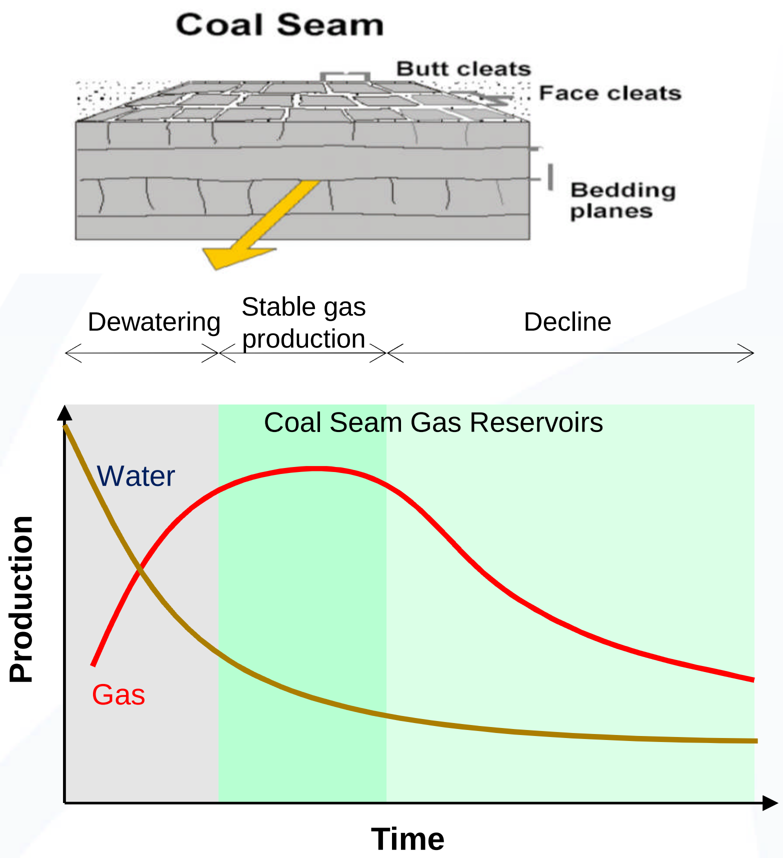
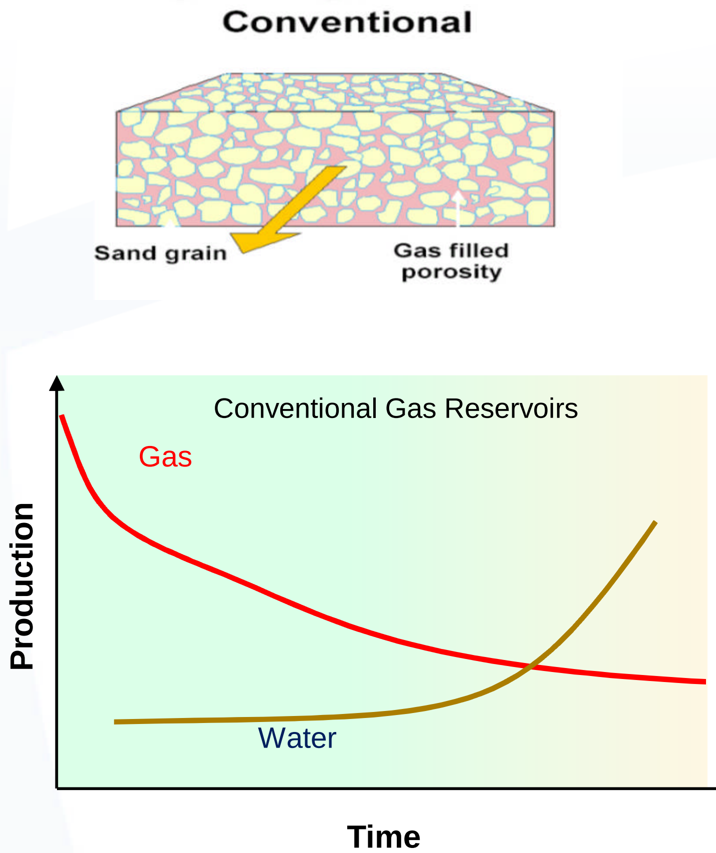
What Influences Solids Production?

Rock failure occurs when effective stresses exceed rock strength….

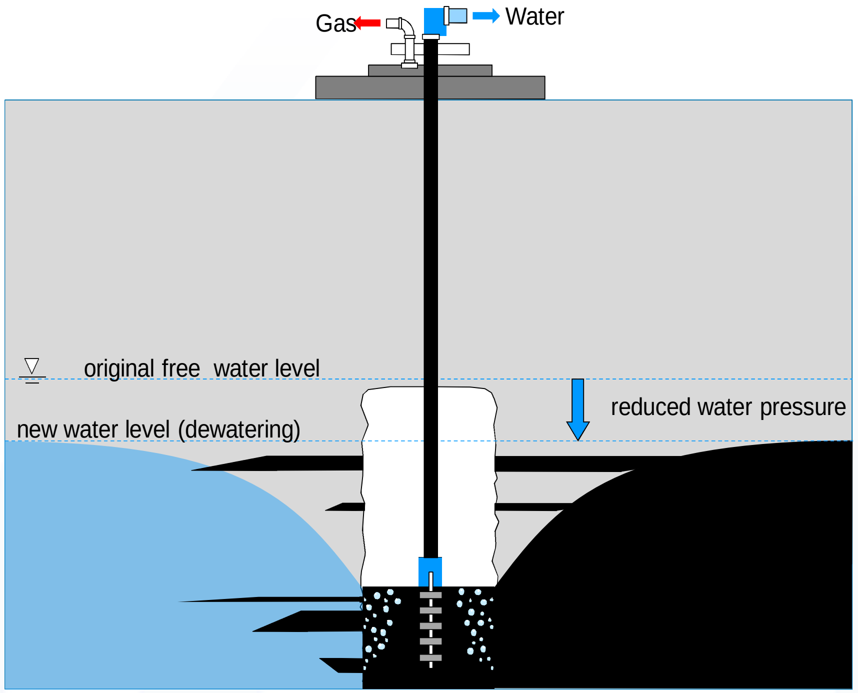


CSG vs. Conventional





CSG Completion: Multi-Thin Seams, Small Net Pay



1- ***Under-ream open/cased & perf. holes***

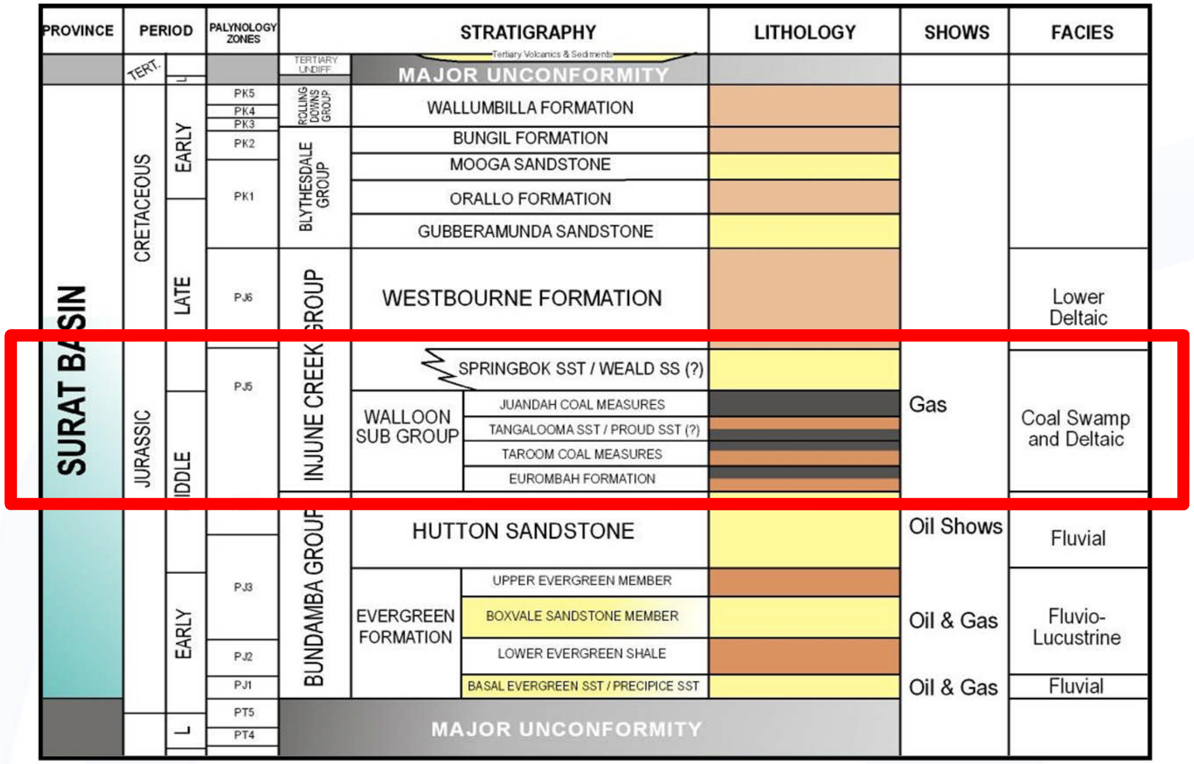
- Risk of solids production from non-coaly rocks with rapid dewatering:
  - High DD/depletion rates
  - Exposure to water; swelling, etc.

2- vertical well with cavity completion, not applicable due to interbeds

3- **Cased hole hydraulic fracture stimulation**

4- vertical open hole-under ream + in seam open hole horizontal and multilaterals

Surat Basin Stratigraphy



Surat Basin

- Intracratonic basin with Jurassic-Cretaceous fluvial, lacustrine sediments with minor marine influence
- Walloon Jurassic Coal Measures: Juandah, Tangalooma and Taroom

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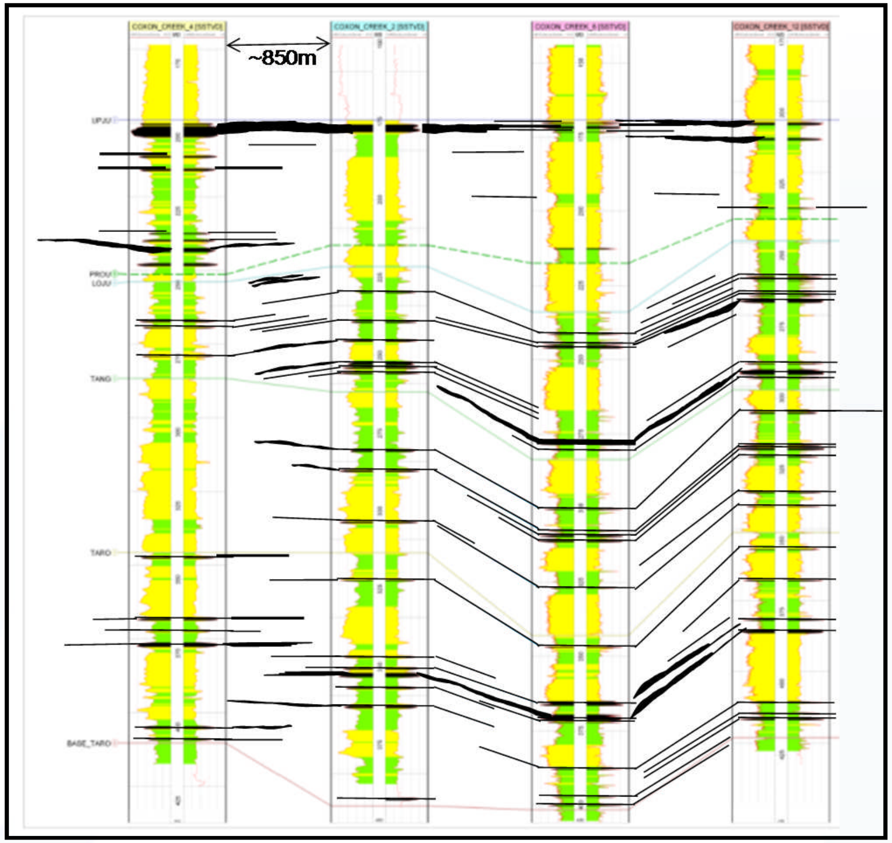
Surat Basin Coal Seam Gas Reservoirs



Three Main Coal Measures

- Depth range: 150-1000 m
- Av. Group Thickness: 200-230 m with ~35 thin seams
- Seam thickness: 10-390cm, average 0.2 m
- Net Pay ~ 6-15 m, the rest is shale, siltstone and sandstone

Typical Completion Design

- Vertical or low angled wells, under reamed to 12.25",
- Artificial lift: PCP
- Only viable completion options are:
- Either Open Hole accepting non-pay > 90%
  - high risk of solids production
  - conventional solids control methods may not work
- Or cased and stimulate;
  - challenging with numerous small seams
  - expensive relatively

Effects of Solids on Wells & Dewatering

- Field Economics are based on ONE workover per well (change-out from water to free-flow)
- Most of openhole pilot wells produce solids,
- PCP reliability and failure due to solids production
  - Solids producing wells require frequent, monthly, separator clean-outs
- Workover costs & resources issue when many wells are online (100s of CSG wells)
- Solids may be coming from a number of zones, mostly non-coal,
  - production monitoring, solids and water sampling and geo-mechanical work was carried out to identify the source(s) of solids.

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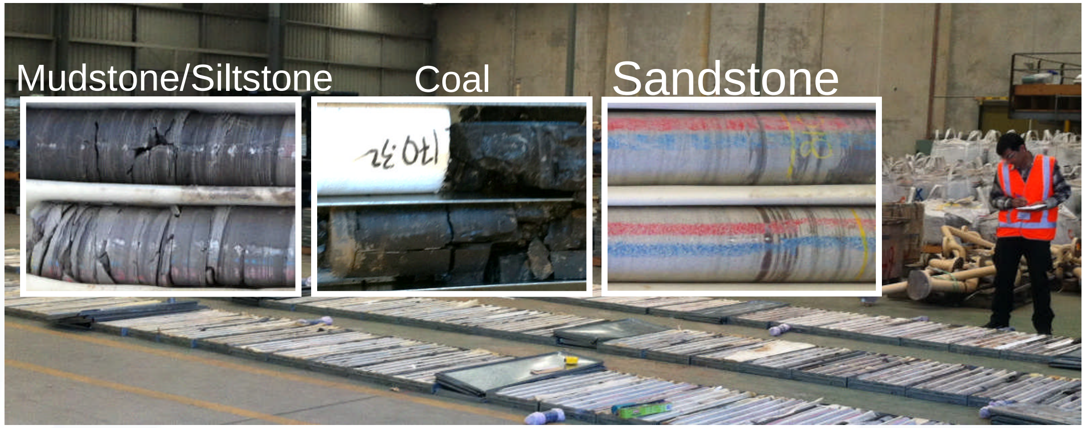
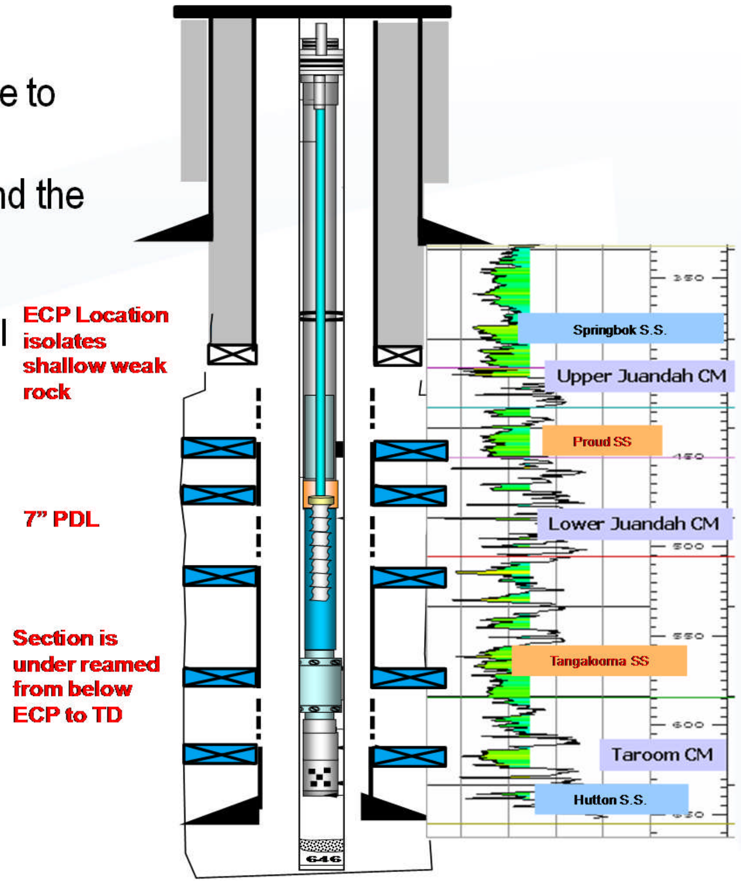
Downhole Isolation of Solids Prone Zones

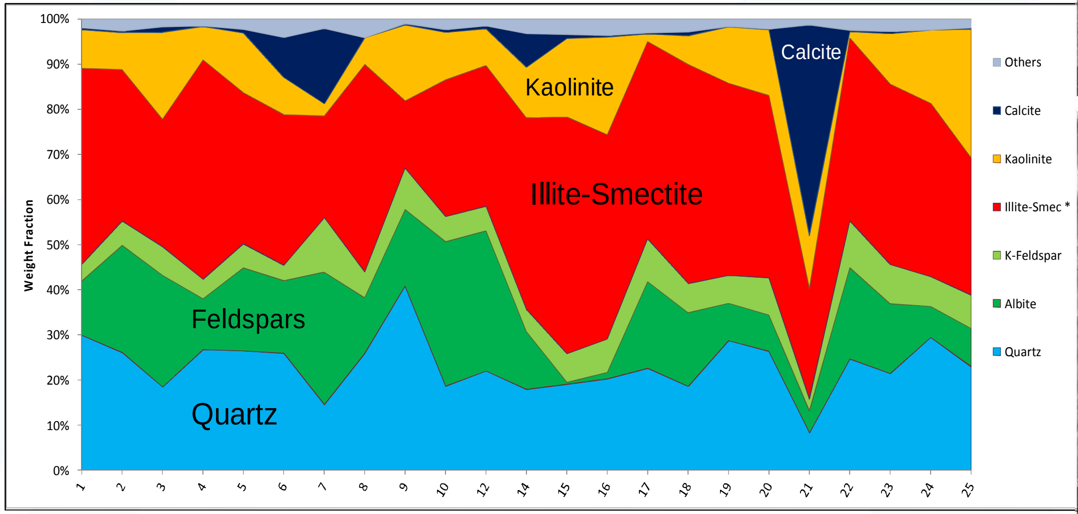
- Use of Swell Packers, "How many packers??
  - 3 coal measures/36 coal seams, weak inter-burden zones, prone to swelling
- Geomechanics work conducted to identify weak zones for isolation and the packer placement.
  - Comprehensive and systematic rock mechanics testing to characterise the interbedded siltstone/sandstone of the Coal Measures in the CSG field.

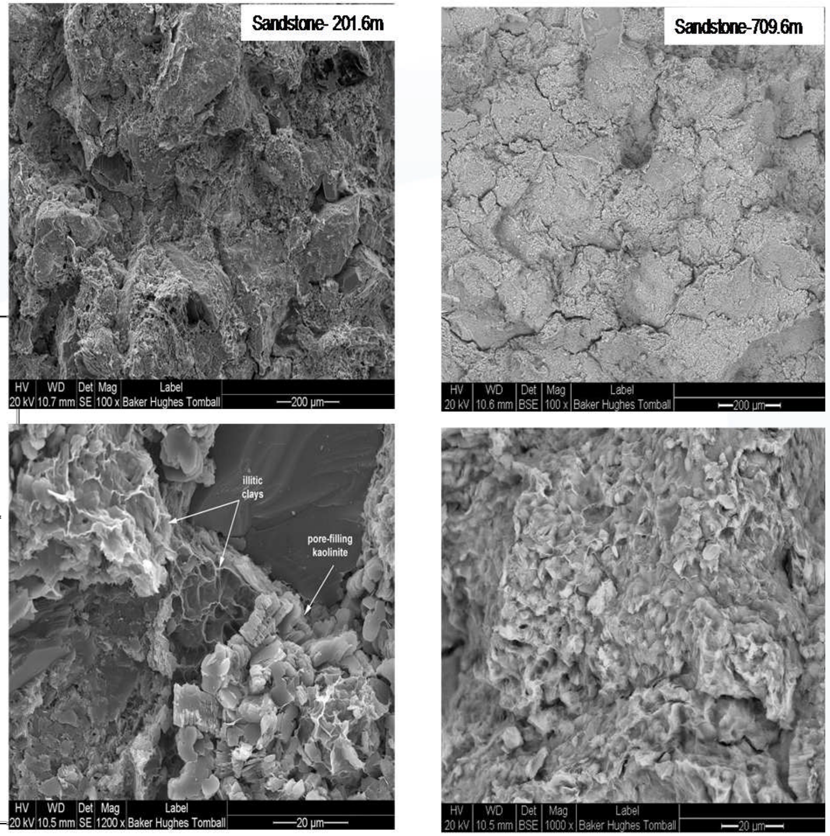




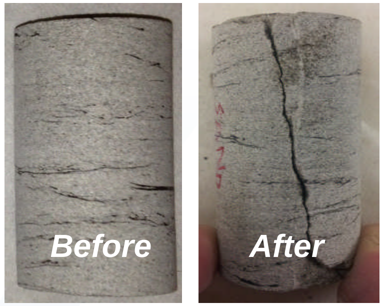
Petrography: XRD and SEM

- XRD results: quartz & feldspar (ave 47%), clay minerals (ave 49%) with dominant mixed-layer illite-smectite and 70% to 80% smectite layers.
- SEM analyses: MLIS clay-rich sandstone and siltstone with fair to poor intergranular porosity, pores clogged up by MLIS and kaolinite. Clays provide the primary intergranular cement





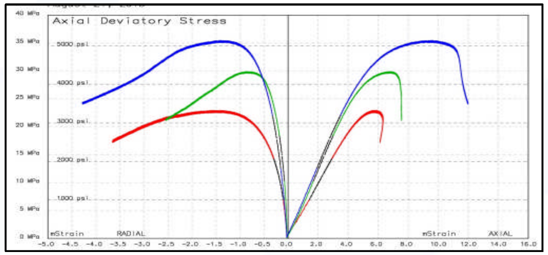
Rock Mechanical Properties

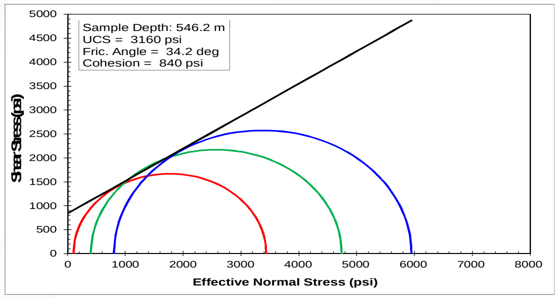


Triaxial compressive tests on dry samples indicate generally competent rocks with unconfined compressive strength (UCS) generally above 4000 psi.

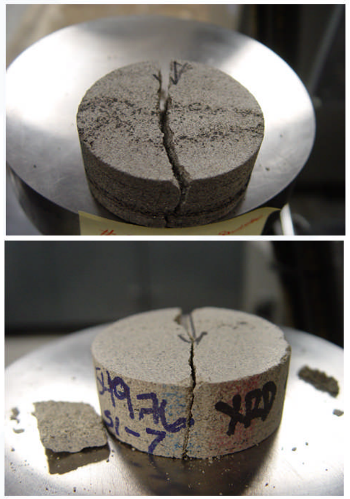
Measured TWC range ~7040 to 8280 psi. With a TWC/UCS ratio ~ 2.0, typical of moderately strong to competent rocks.

Tensile strength (T_0) shows UCS/ T_0 ~ 8.0 which is typical for sedimentary rocks

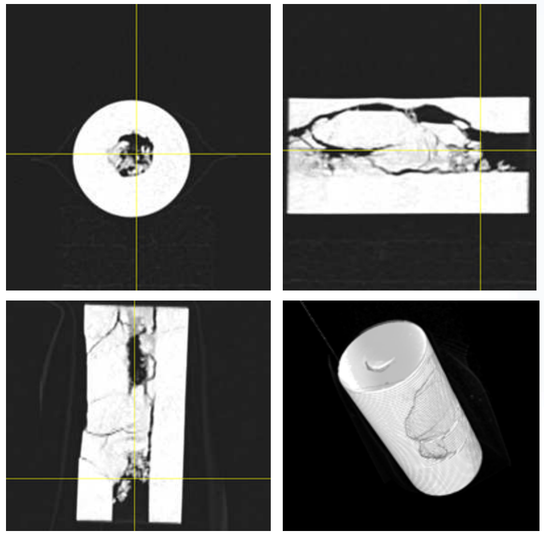




Tensile strength tests



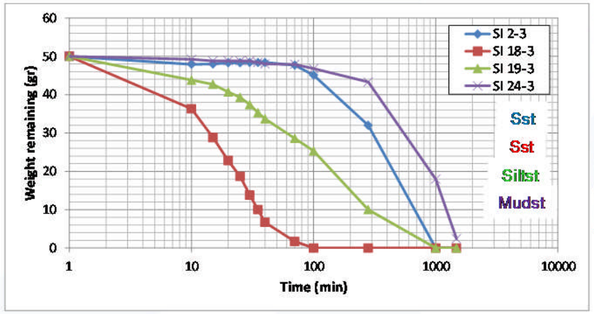
CT Scan of TWC Sample after test

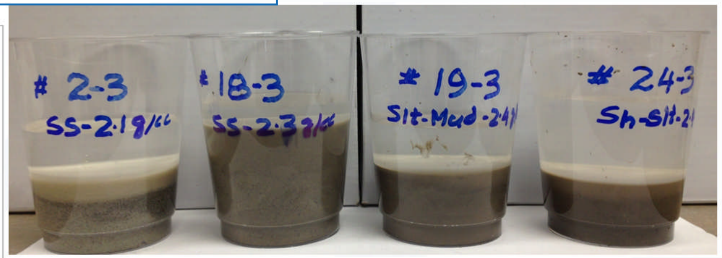


Water Sensitivity and Rock Weakening

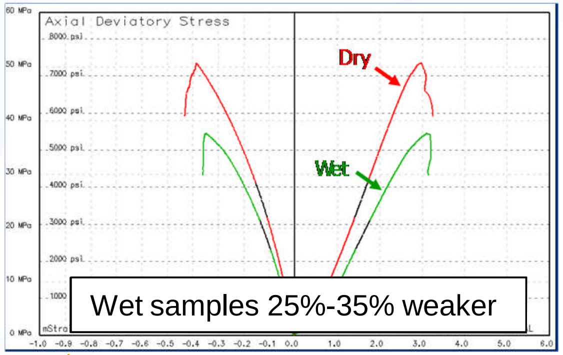
- Rock strength sensitivity to brackish produced water was investigated using immersion, indentation and triaxial tests.

Samples fully dissolved after few hours immersion in the simulated water



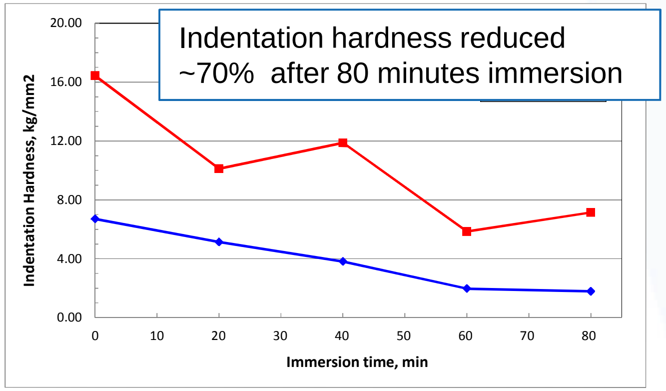


Immersion test after 4 Hrs | Immersion test after 30 minutes | Immersion test after 4 Hrs | Immersion test after 16 Hrs



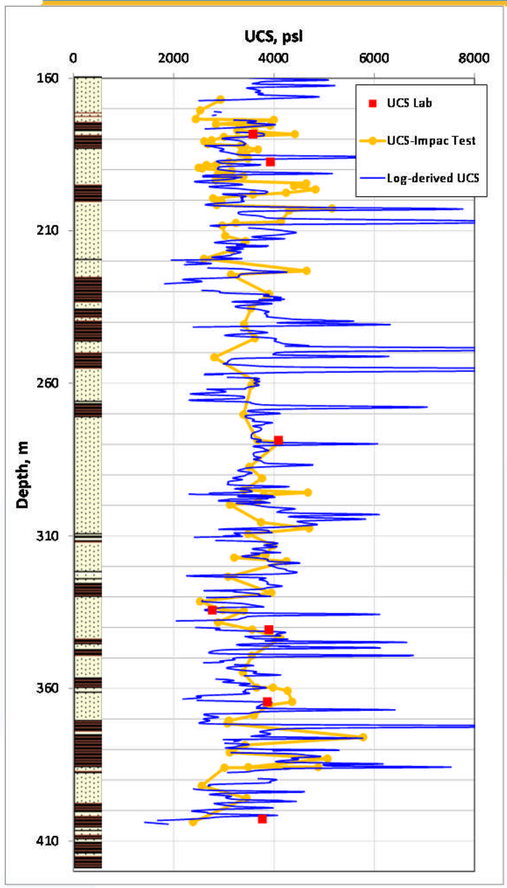
Wet samples 25%-35% weaker

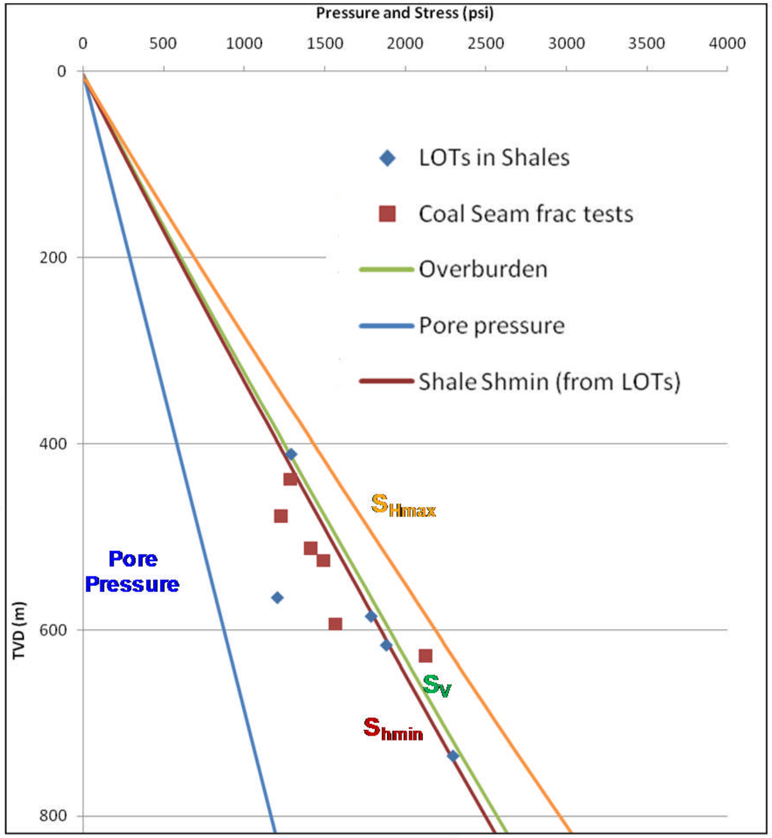
Weakening of wet samples is due to the clay swelling and the loss of cementation of MLIS clays with the simulated water

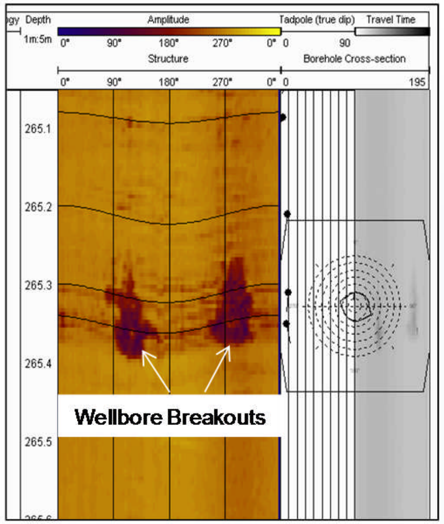


Indentation hardness reduced ~70% after 80 minutes immersion

Geomechanical Evaluation: Rock Strength, Pore Pressure & Stress Profile







$S_{hmin} < S_V < S_{Hmax}$

S_{Hmax} ~ 1.10 psi/ft

S_v ~ 0.98 psi/ft

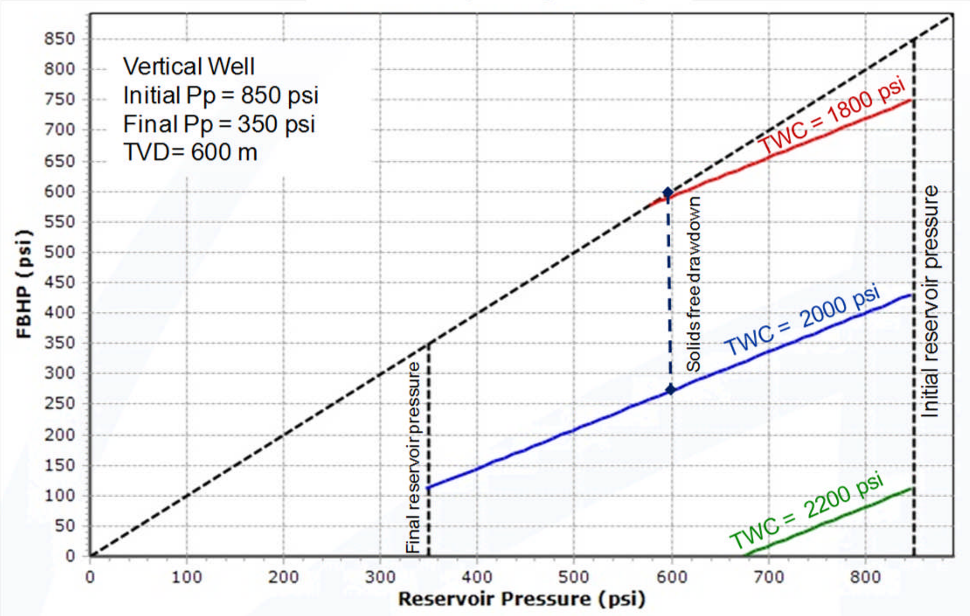
S_{hmin} ~0.85 psi/ft

P_p ~ 0.43 psi/ft

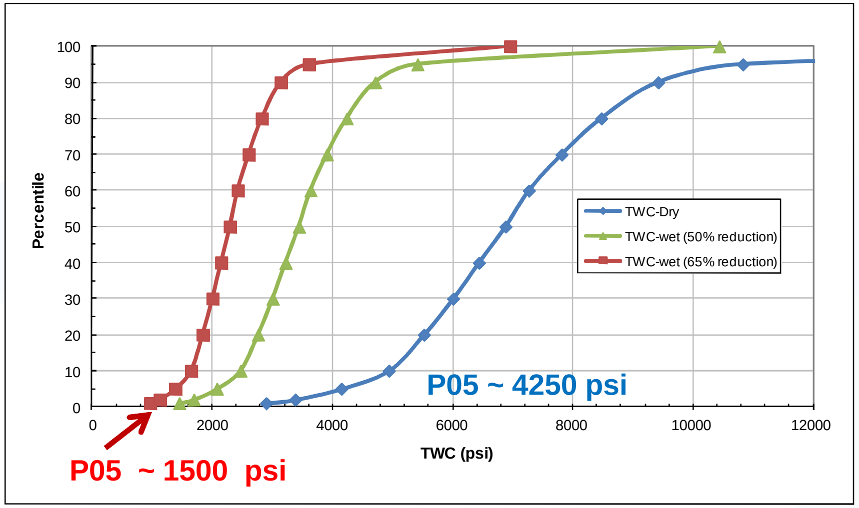
S_{Hmax} azimuth ~020°N

Geomechanical Evaluation: Rock Failure Assessment & Solids Production

Solids Free Operating Envelope



Rock Strength (Dry, Wet)



Rocks with TWC >2200 psi (most of native rocks) should stay stable but weakening due to the exposure to brackish water from coals poses a high risk. Solids production from interburden rocks during coal dewatering and production will be very likely if the interburden is kept open.

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Implications for Solids Management:
Isolation of Non-Pay Zones

- Isolation of non-pay solids prone zones by swellable packers may be successful only if the weak and smectite-rich zones are limited to very few sections or depth intervals

- Low chance of success in mitigating solids production in long open holes with numerous individual thin coal seams and the presence of thick, water-reactive non-pay zones across the target coal measures.

- These findings are consistent with field trials of OH pilot wells completed with packers with no or very limited success in mitigating solids production.

Implications for Solids Management:
Open hole vs Cased hole Completion?

- Field data to date show solids-free dewatering and gas production from few pilot well completed as cased hole with coal seams only perforation
  - This is consistent with the results of rock mechanics study and its recommendations for solids mitigation problem in the study area.

- Production monitoring of pilot wells is in progress and subject to further evaluation
  - The initial assessment suggest C&P completion with small scale stimulation for skin removal may the likely completion option in the study area.

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THANK YOU!