Improved Application of Gas Reservoir Parameters

ACARP Project C10008

May 10th 2002

Mackay

GeoGAS

The Team….

- Applicant Organisation - GeoGAS Systems Pty. Ltd.
  Ray Williams, Eugene Yurakov
- Supporting Organisations –
  - CSIRO Energy Technology North Ryde
    Abou Saghafi
  - Multiphase Technologies Pty. Ltd.
    David Casey
  - James Cook University
    Peter Crosdale
- $141,159
- 1 Year

Objectives

- Improving the quality of input data in key areas.
- Obtaining a clearer understanding of the combined effects of sets of gas reservoir parameters.
- Producing a set of sensitivity matrices that can be used as an improved guide in modelling and in identification of the most important data to acquire.

From the ACARP Submission

"……… the importance of considering the gas implications is widely recognised. What is not generally recognised, is the variability in the gas reservoir and the processes and limitations of the tools available to undertake modelling assessments."

From GeoGAS/CSIRO SIMED Procedure Manual 1998

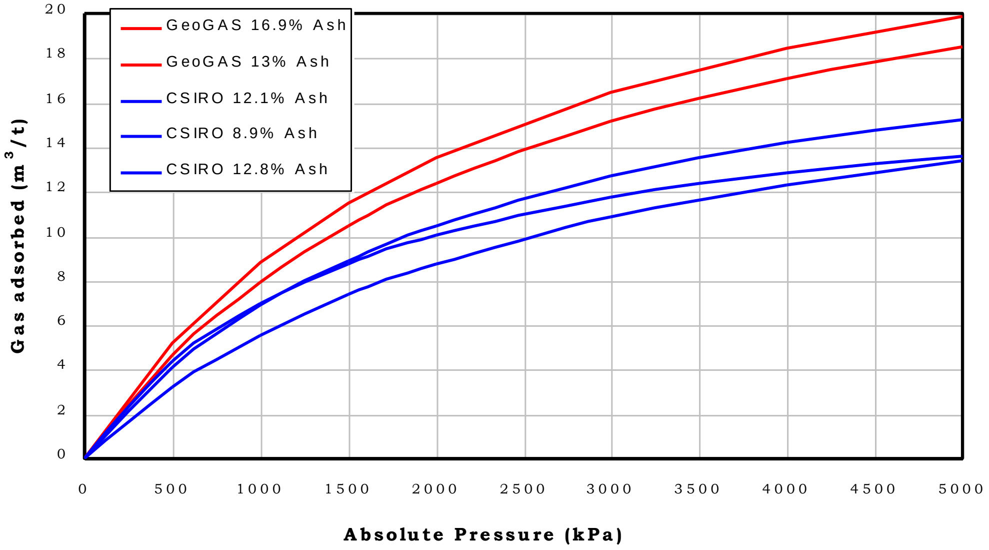
Parameter	Sensitivity of results to parameter			Obtaining likelihood		
	Low	Middle	High	Low	Middle	High
Seam dimensions						
Roadway dimensions						
Gas composition						
Porosity						
Permeability						
Langmuir isotherm						
Desorption time constant						
Desorption pressure						
Reservoir temperature						
Gas content						
Relative permeability						
Pore pressure						
Compressibility						
Matrix shrinkage						
Pore pressure						
Transmissibility						

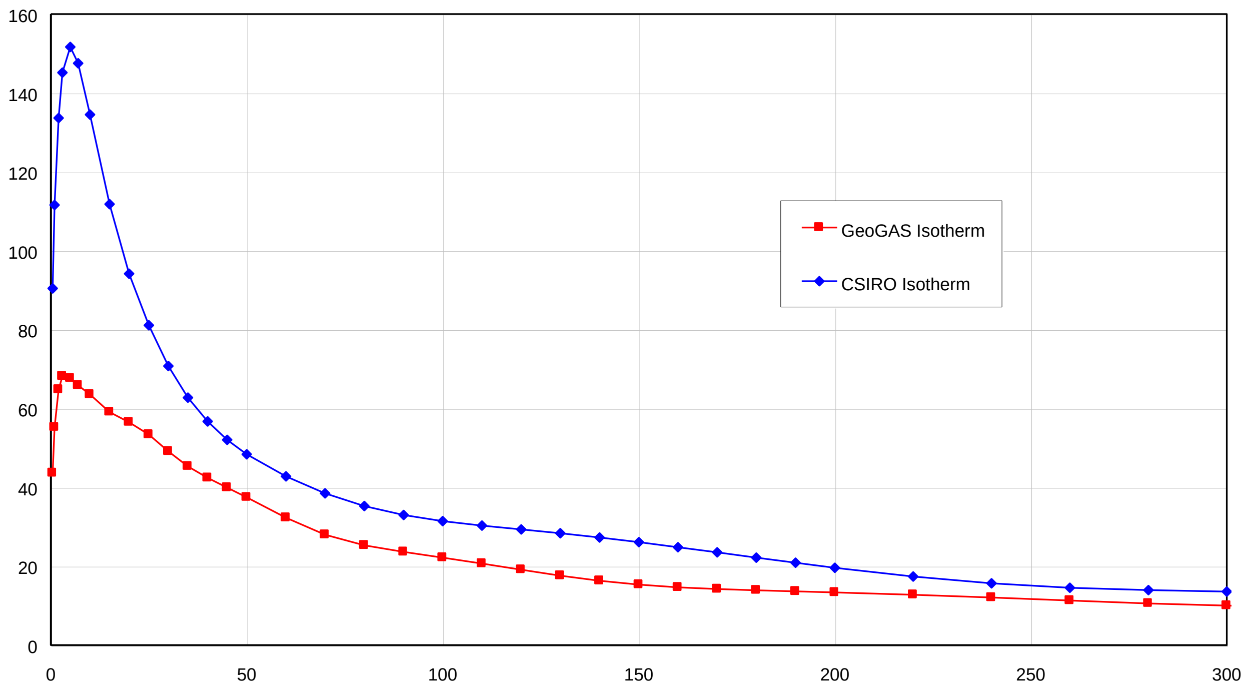
For this project we look mainly at:

- Gas sorption isotherms
- Use of multiphase testing to:
  - Validate gas sorption isotherms
  - Generate relative permeability curves
- Assess desorption time constant τ
- Gas drainage borehole recharge
- Other important stuff –
  Permeability, porosity, compressibility
- **Sensitivity analyses**

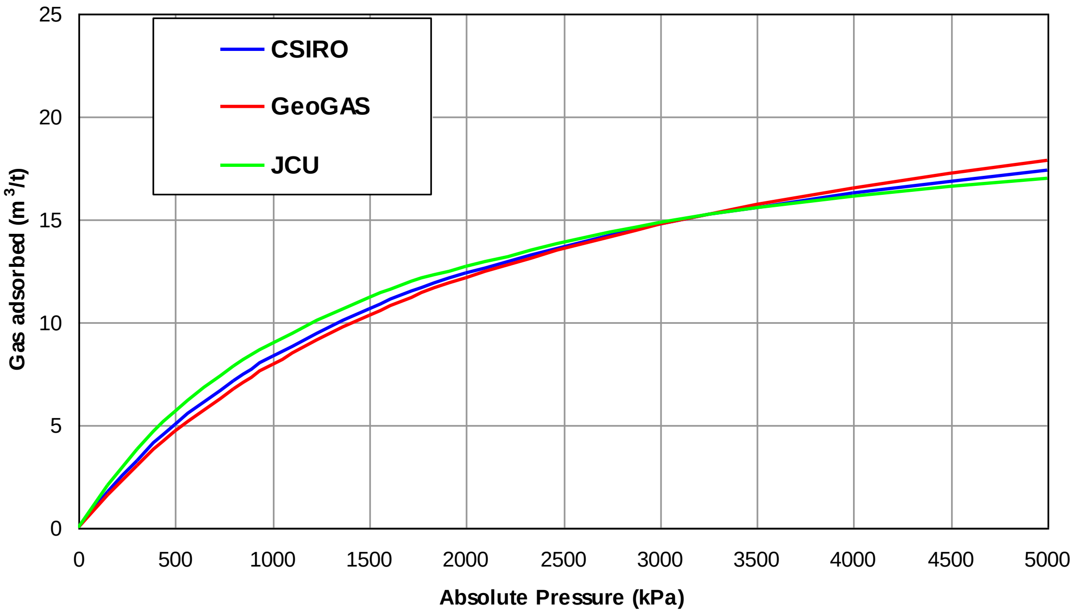
Gas Sorption Isotherms

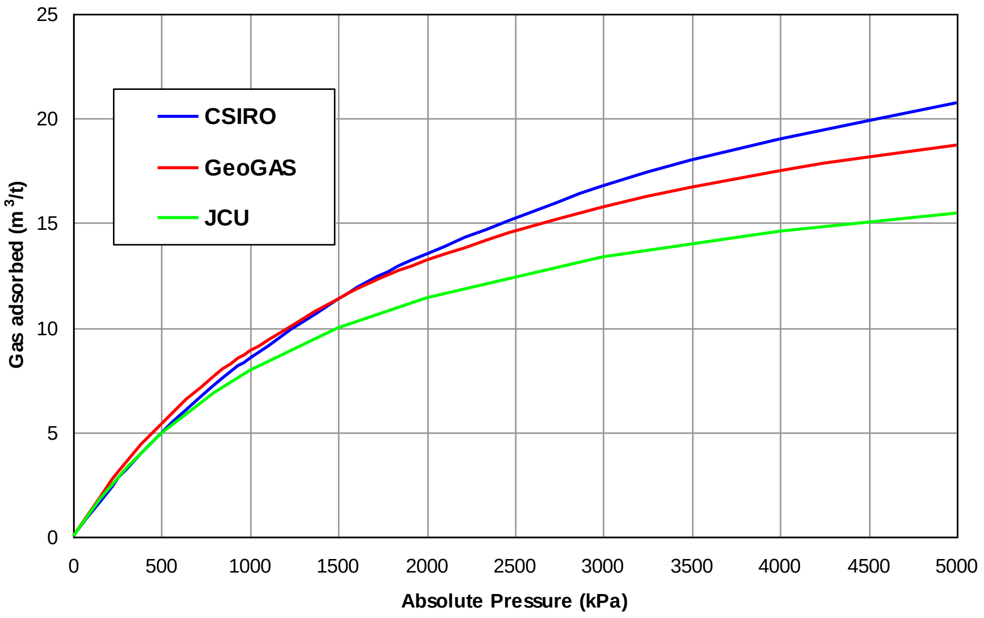
An Example – The Isotherm Shock





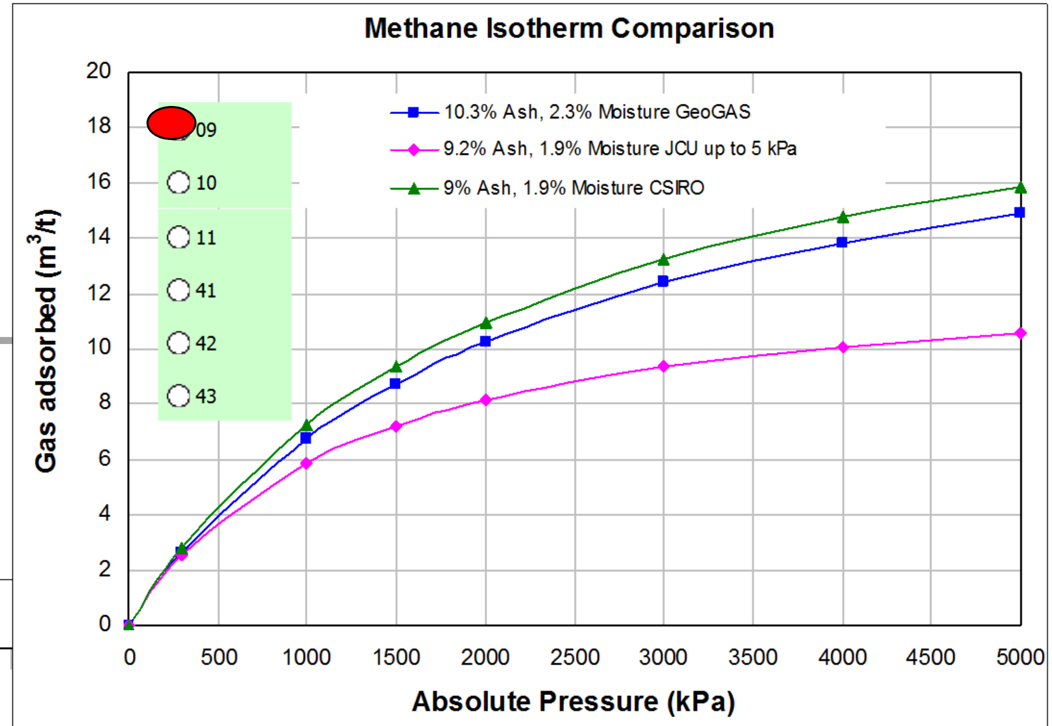
Start of Comparisons



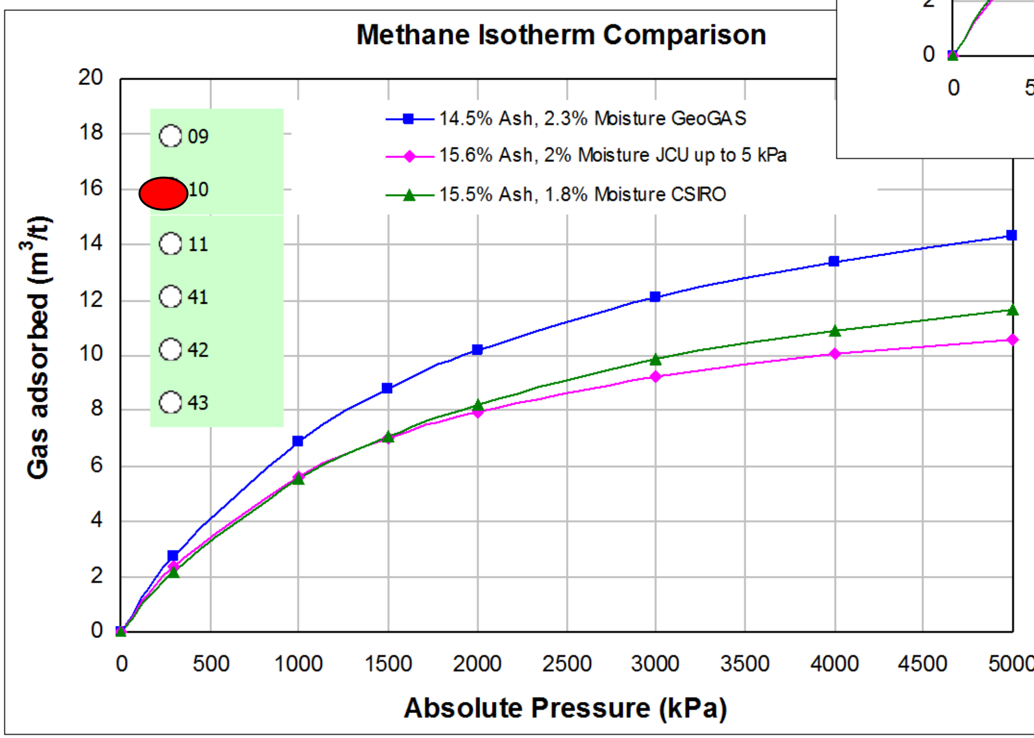


Isotherm Comparison Tests – Factors Considered

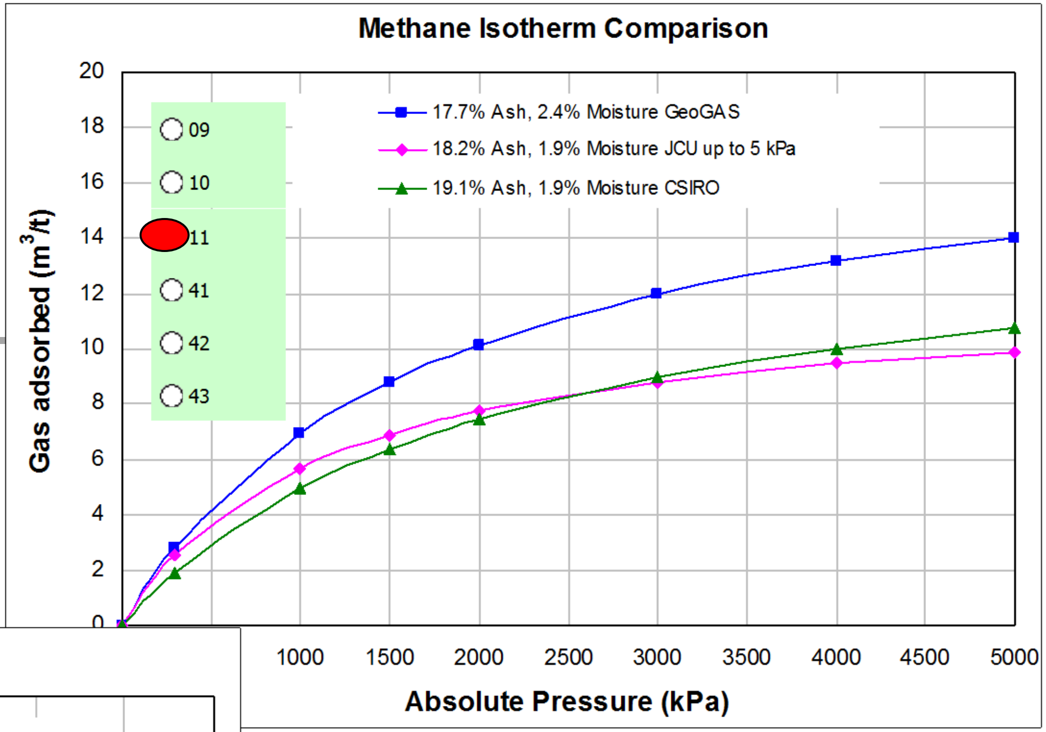
- Method – all essentially the same (gravimetric)
- Grainsize distribution of tested coal
- Moisture before during and after testing, including equilibrium moisture
- Consistency between distributed samples



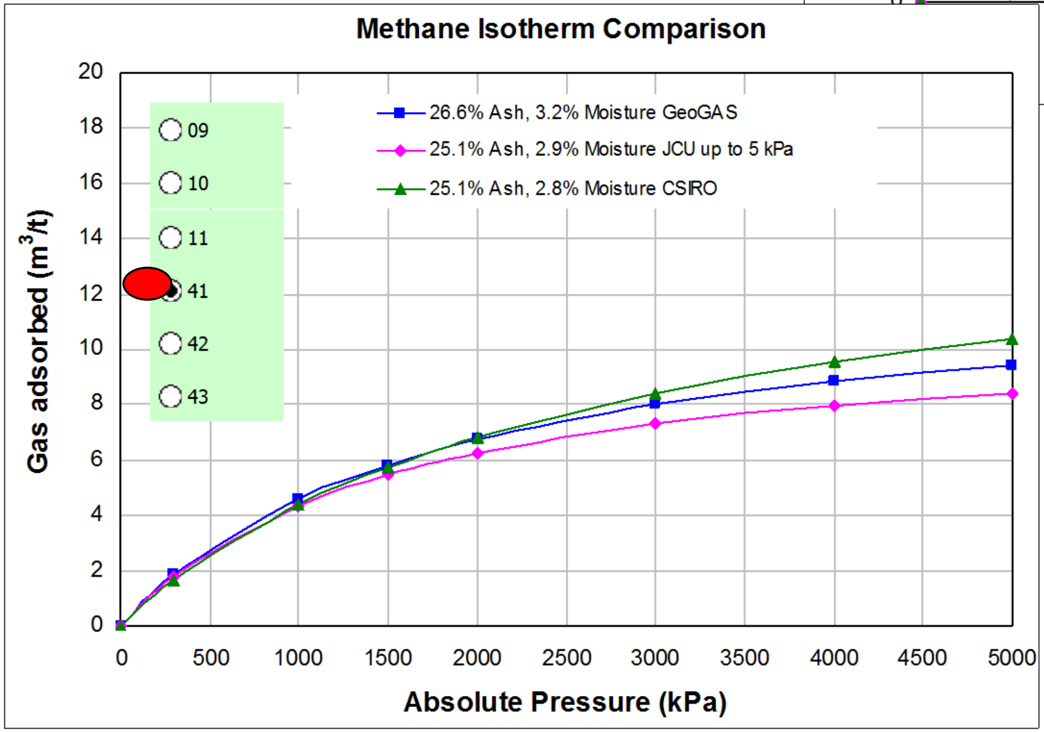
Methane Isotherm Comparison
Gas adsorbed (m³/t)
Absolute Pressure (kPa)
09
10
11
41
42
43
10.3% Ash, 2.3% Moisture GeoGAS
9.2% Ash, 1.9% Moisture JCU up to 5 kPa
9% Ash, 1.9% Moisture CSIRO



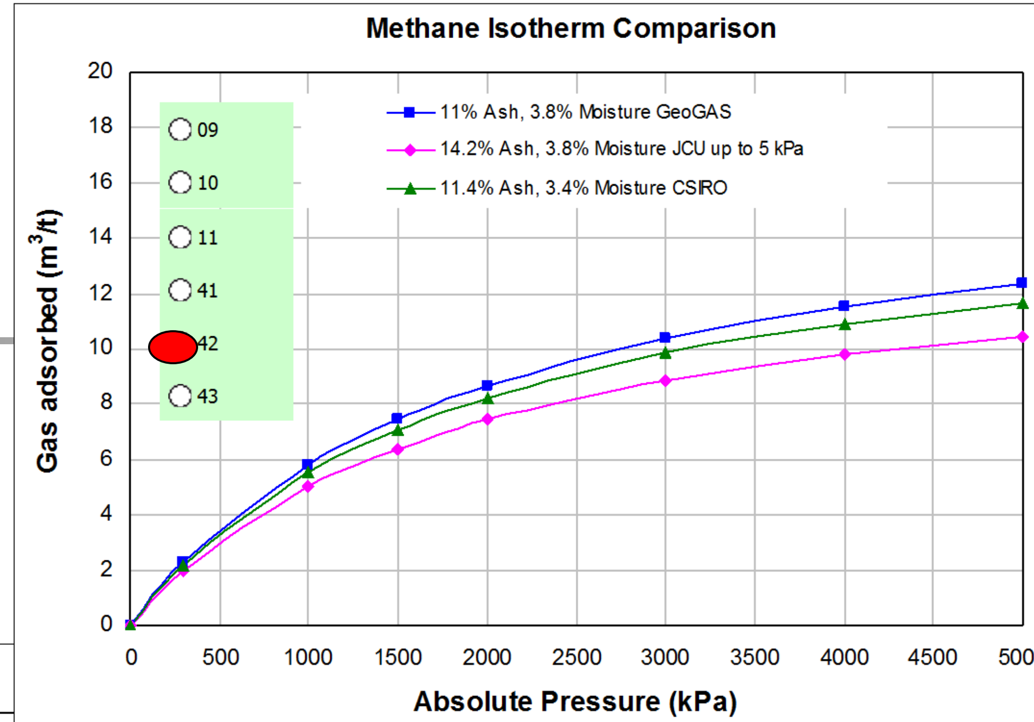
Methane Isotherm Comparison
Gas adsorbed (m³/t)
Absolute Pressure (kPa)
09
10
11
41
42
43
14.5% Ash, 2.3% Moisture GeoGAS
15.6% Ash, 2% Moisture JCU up to 5 kPa
15.5% Ash, 1.8% Moisture CSIRO

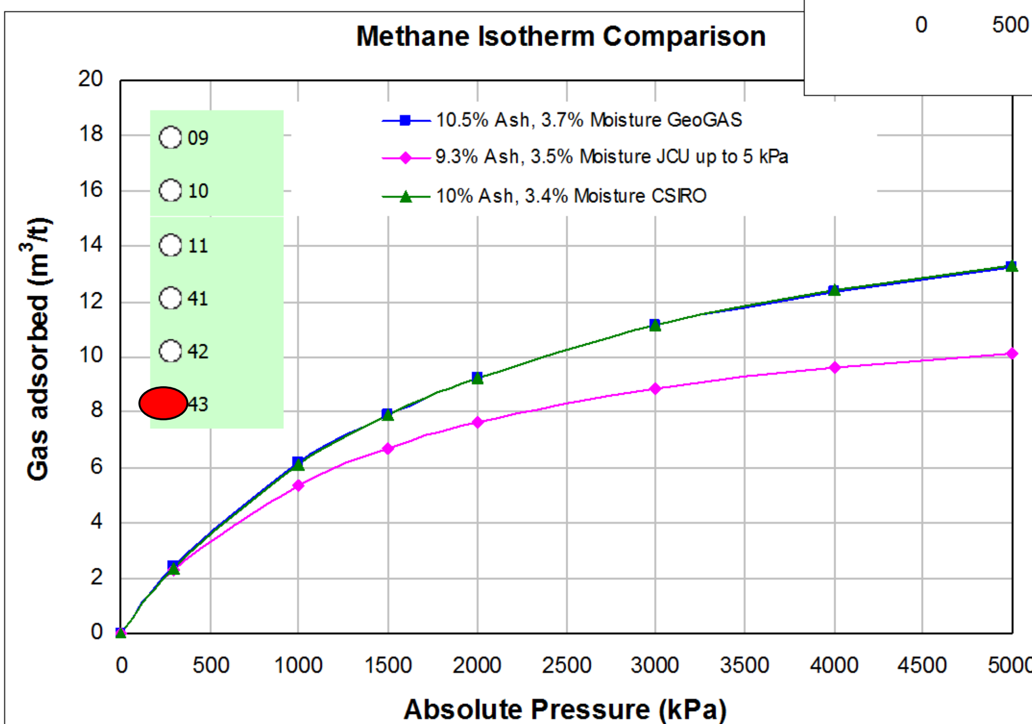


Methane Isotherm Comparison
Gas adsorbed (m3/t)
Absolute Pressure (kPa)
09
10
11
41
42
43
17.7% Ash, 2.4% Moisture GeoGAS
18.2% Ash, 1.9% Moisture JCU up to 5 kPa
19.1% Ash, 1.9% Moisture CSIRO



Methane Isotherm Comparison
Gas adsorbed (m3/t)
Absolute Pressure (kPa)
09
10
11
41
42
43
26.6% Ash, 3.2% Moisture GeoGAS
25.1% Ash, 2.9% Moisture JCU up to 5 kPa
25.1% Ash, 2.8% Moisture CSIRO


Methane Isotherm Comparison
Gas adsorbed (m³/t)
Absolute Pressure (kPa)
11% Ash, 3.8% Moisture GeoGAS
14.2% Ash, 3.8% Moisture JCU up to 5 kPa
11.4% Ash, 3.4% Moisture CSIRO
09
10
11
41
42
43
0 2 4 6 8 10 12 14 16 18 20
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000


Methane Isotherm Comparison
Gas adsorbed (m³/t)
Absolute Pressure (kPa)
10.5% Ash, 3.7% Moisture GeoGAS
9.3% Ash, 3.5% Moisture JCU up to 5 kPa
10% Ash, 3.4% Moisture CSIRO
09
10
11
41
42
43
0 2 4 6 8 10 12 14 16 18 20
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

Density Comparisons of Sub Samples

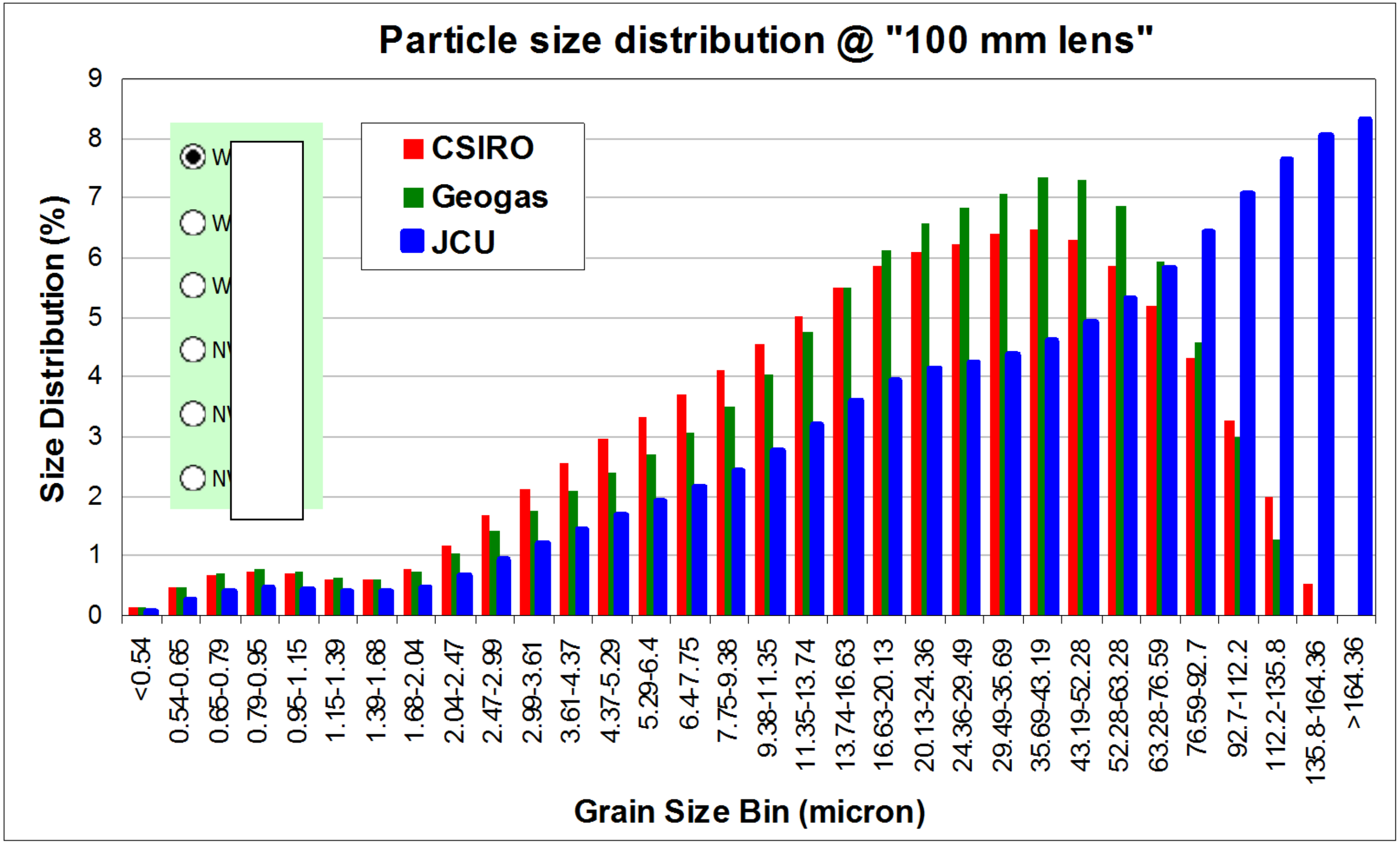
Adsorbed CH4 Densities
CSIRO 0.415 g/cc
GeoGAS 0.6189 g/cc
JCU 0.3196 g/cc

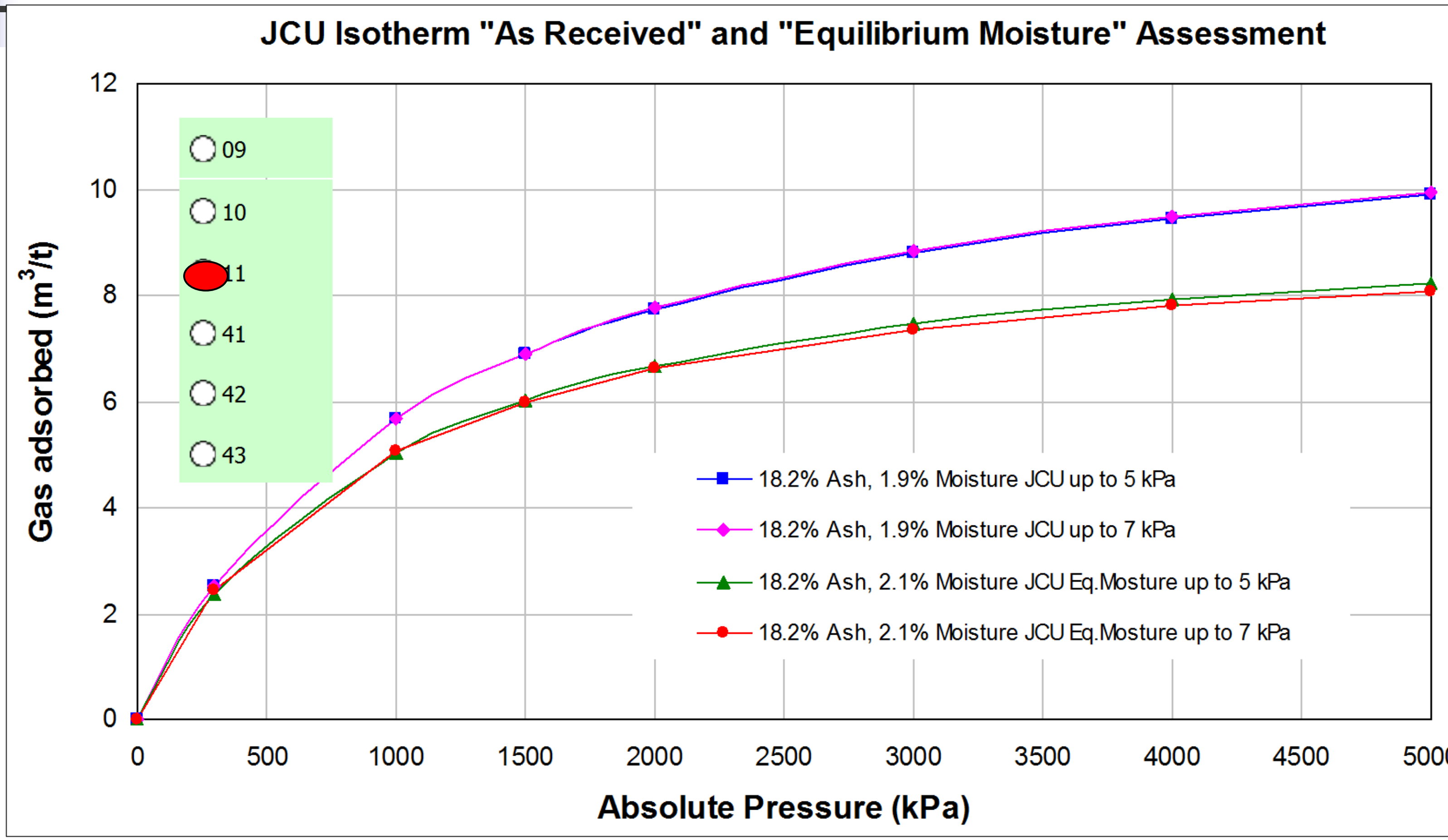
Relative Densities (g/cc)

Laboratory	9	10	11	41	42	43	Average
GeoGAS	1.39	1.40	1.32	1.64	1.41	1.41	1.43
JCU	1.45	1.50	1.52	1.59	1.47	1.46	1.50
CSIRO	1.35	1.41	1.40	1.59	1.41	1.37	1.42

Isotherms shown to be quite sensitive to density. A change of 0.1 g/cc results in around 6-18% change in sorption capacity. Replots by Crosdale and Yurakov showed reduced scatter using the same density.
Coal density inconsistencies identified as probably the most significant contributor to isotherm differences.

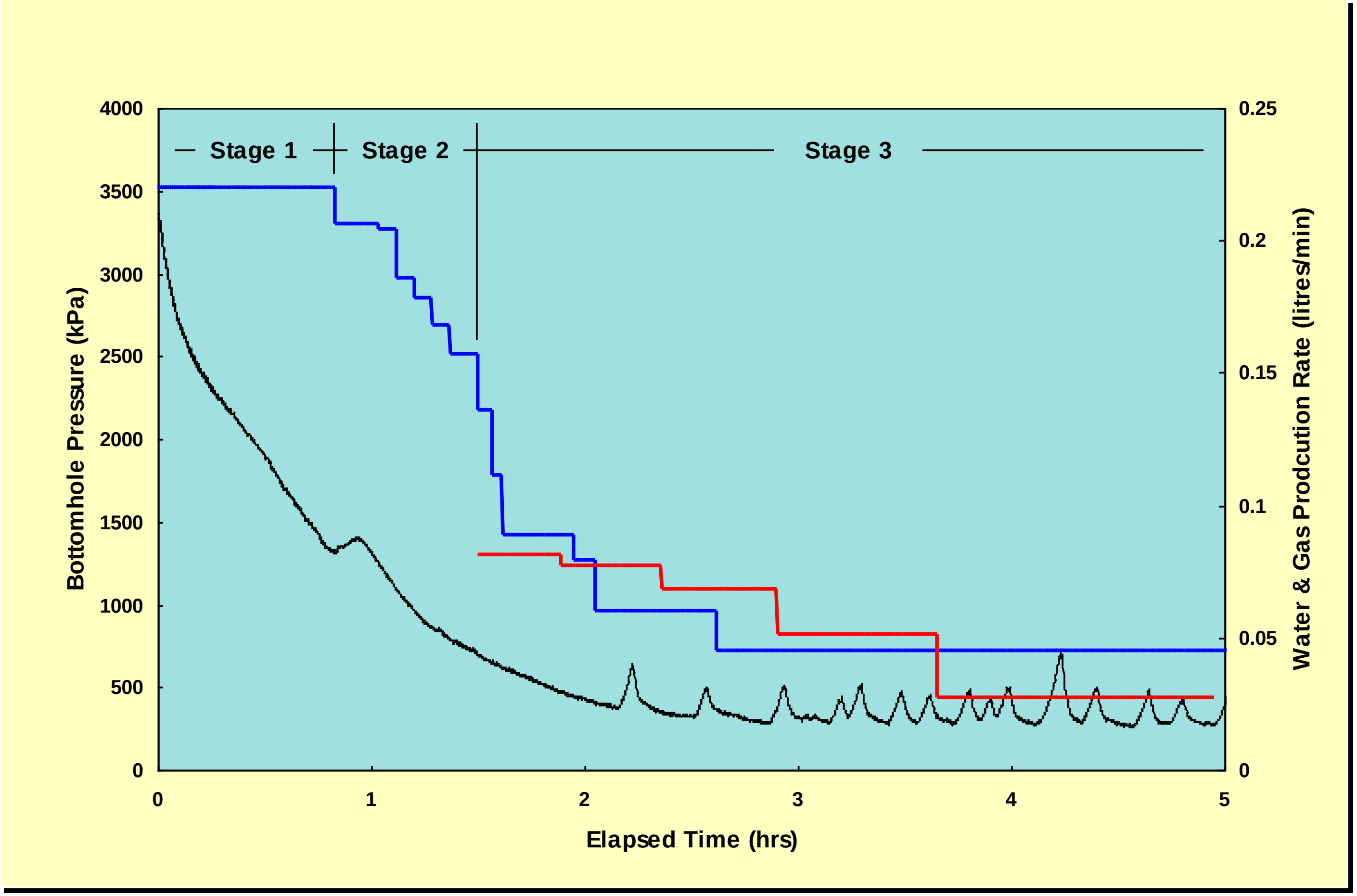
Grainsize Comparison



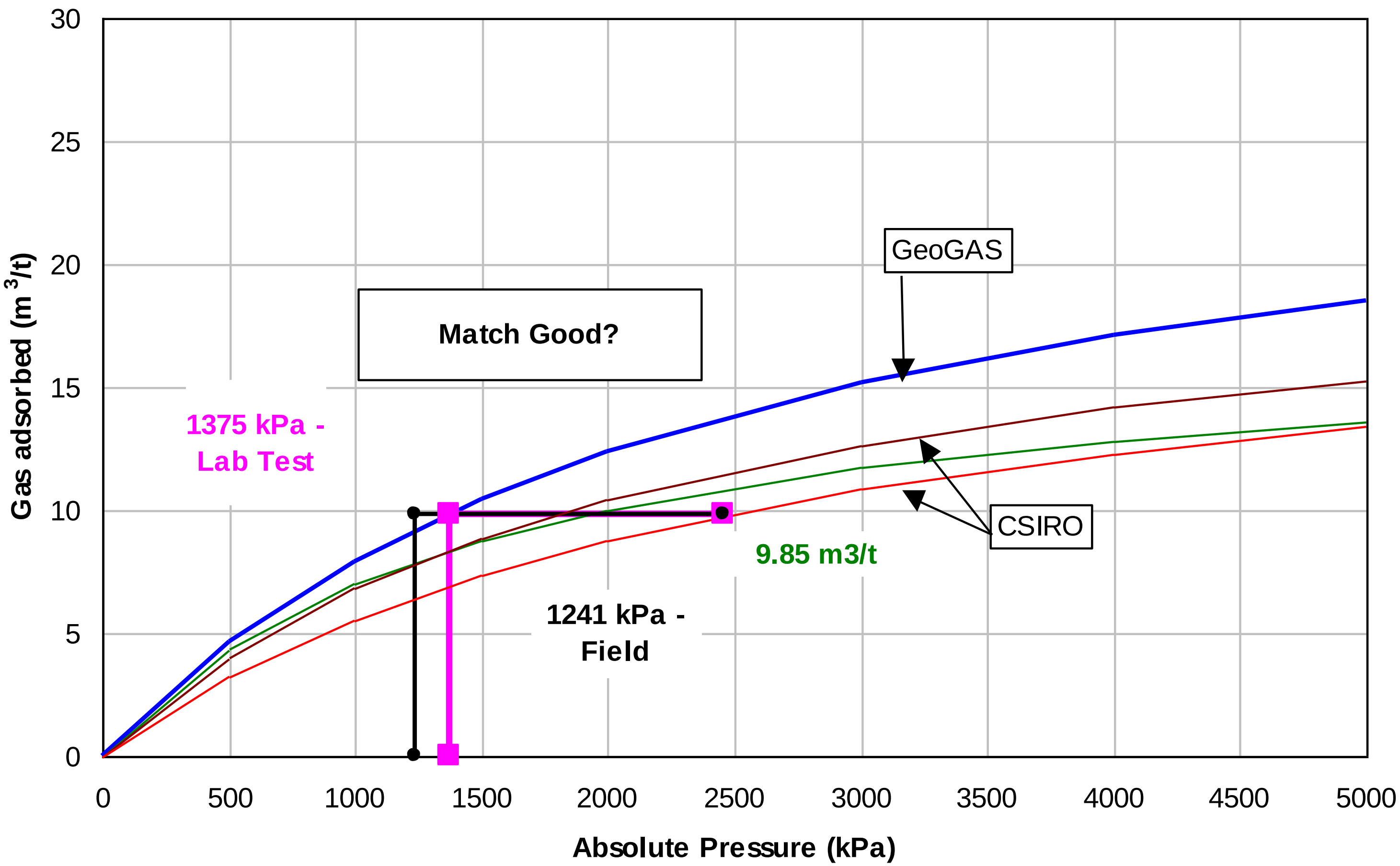

JCU Isotherm "As Received" and "Equilibrium Moisture" Assessment
Gas adsorbed (m^3/t)
Absolute Pressure (kPa)
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
09
10
11
41
42
43
18.2% Ash, 1.9% Moisture JCU up to 5 kPa
18.2% Ash, 1.9% Moisture JCU up to 7 kPa
18.2% Ash, 2.1% Moisture JCU Eq.Mosture up to 5 kPa
18.2% Ash, 2.1% Moisture JCU Eq.Mosture up to 7 kPa

Isotherms

Field-Lab Desorption Pressure Comparisons

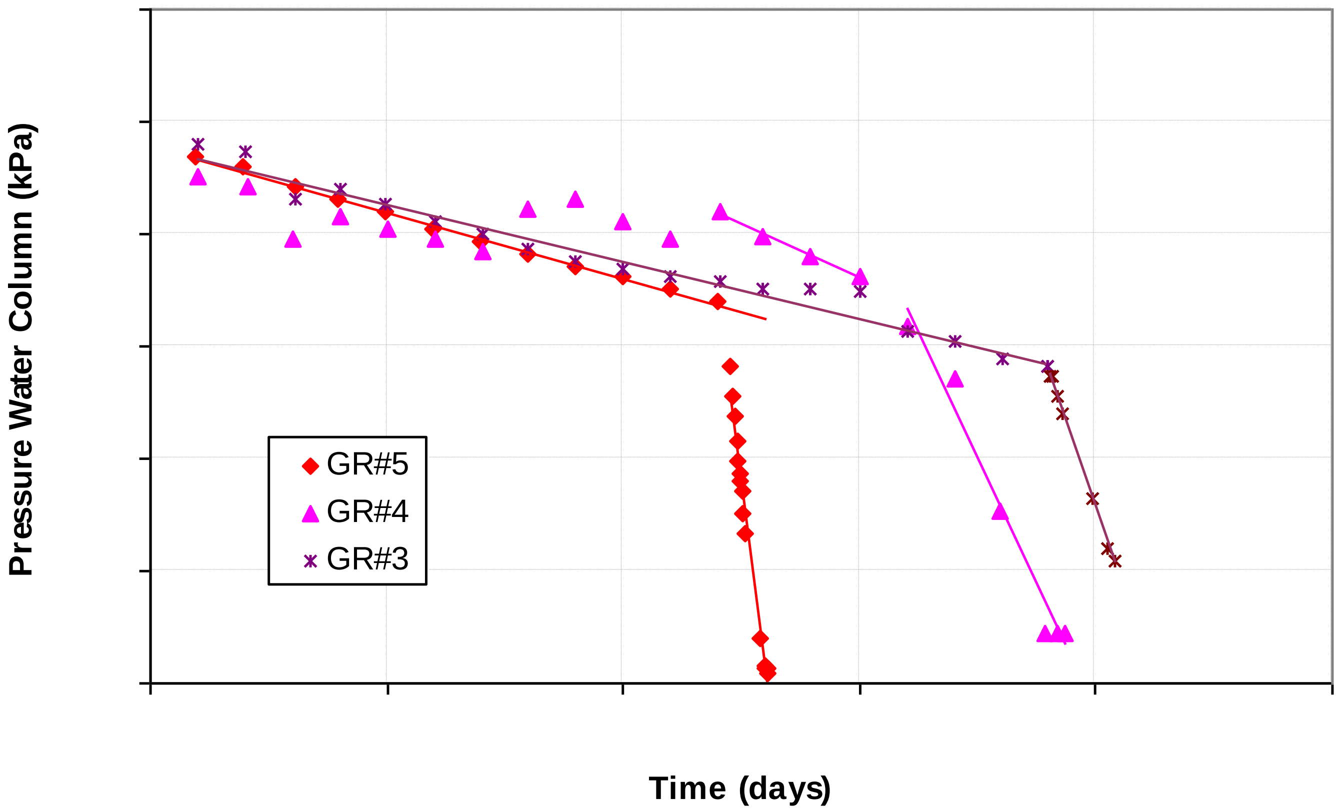


From Multiphase Technologies Pty. Ltd. David Casey

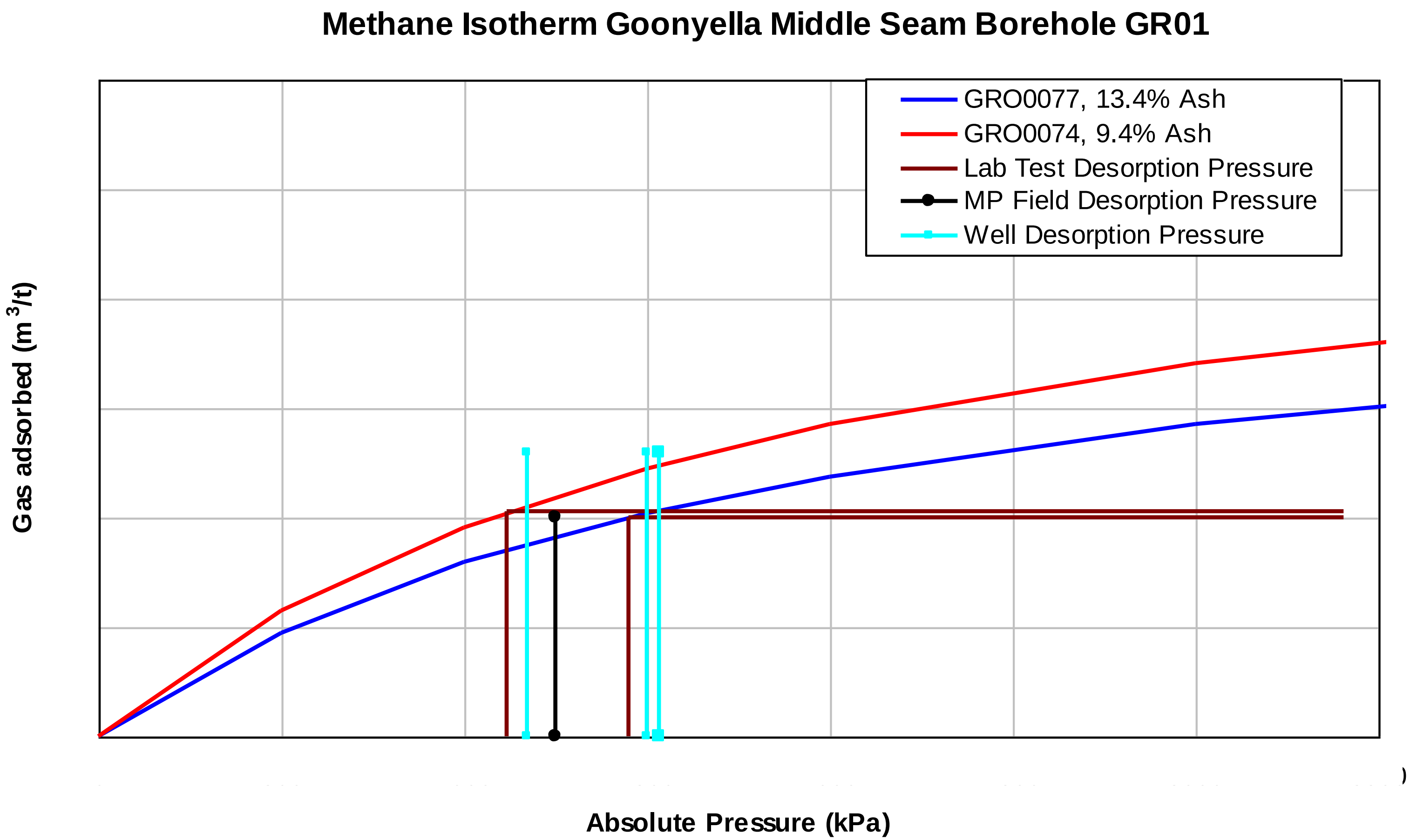


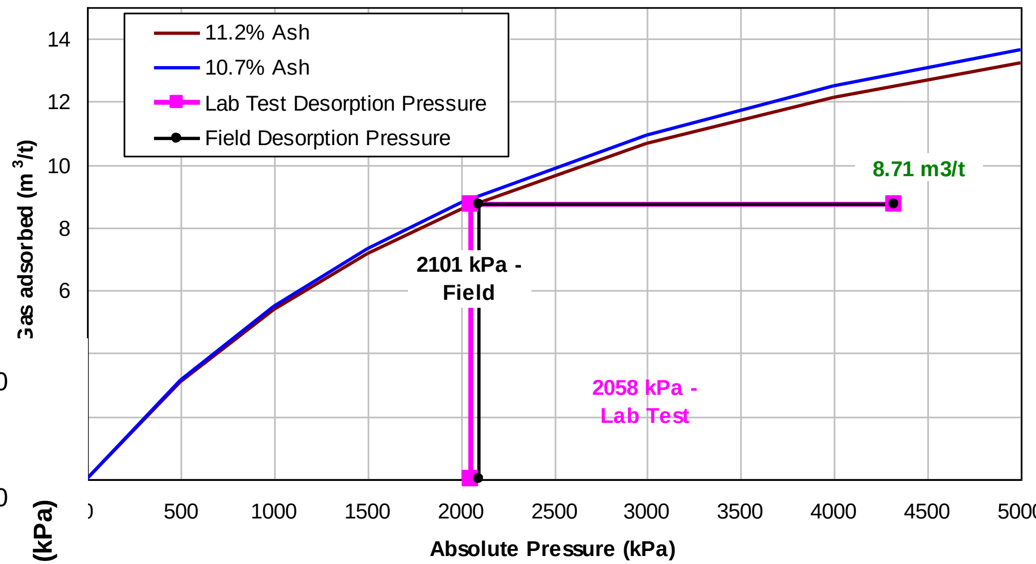
Match Good?
GeoGAS
CSIRO
1375 kPa - Lab Test
9.85 m3/t
1241 kPa - Field
Gas adsorbed (m3/t)
Absolute Pressure (kPa)
0
5
10
15
20
25
30
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

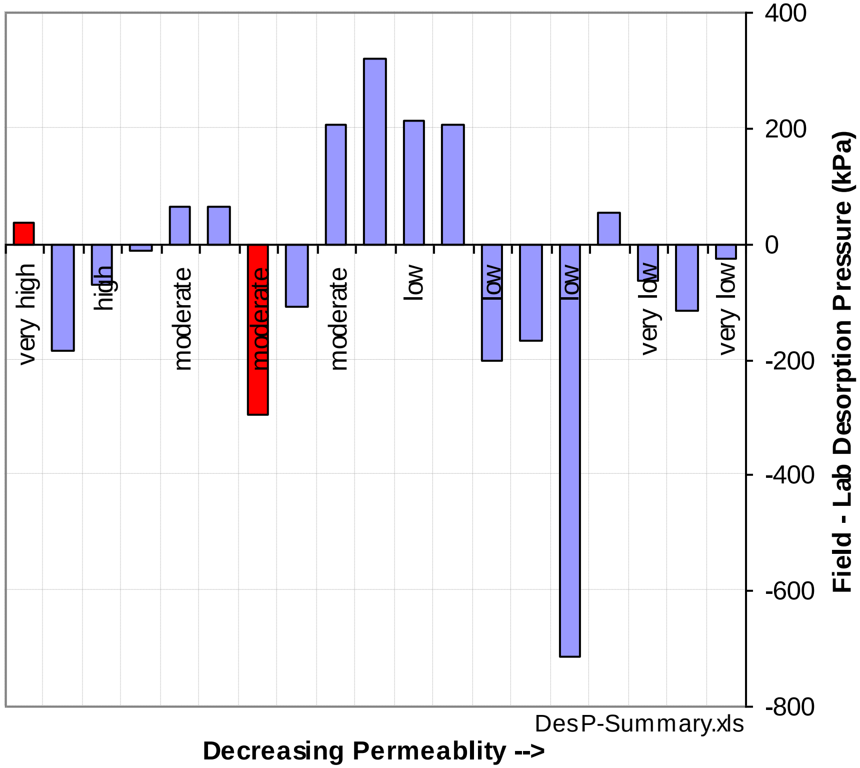
CH4 Grosvenor Desorption Pressure During Well Production

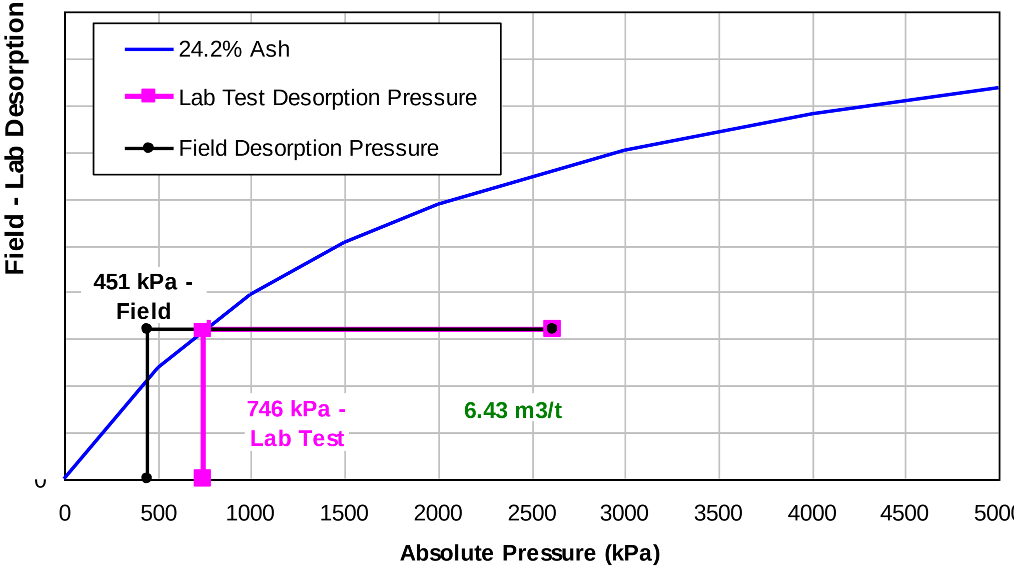


Comparison Desorption Pressures – Well, Multiphase, Laboratory




14
12
10
8
6
Gas adsorbed (m 3/t)
11.2% Ash
10.7% Ash
Lab Test Desorption Pressure
Field Desorption Pressure
8.71 m3/t
2101 kPa -
Field
2058 kPa -
Lab Test
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Absolute Pressure (kPa)


400
200
0
-200
-400
-600
-800
Field - Lab Desorption Pressure (kPa)
very high
high
moderate
moderate
moderate
low
low
low
very low
very low
DesP-Summary.xls
Decreasing Permeablity -->

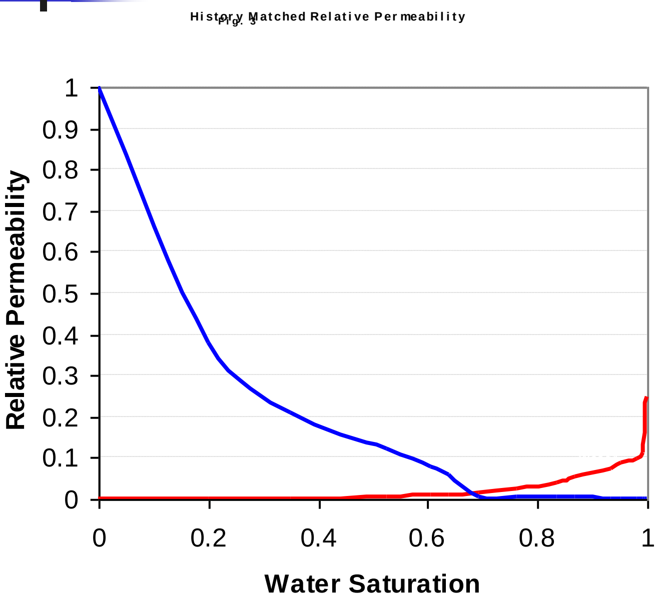

24.2% Ash
Lab Test Desorption Pressure
Field Desorption Pressure
451 kPa -
Field
746 kPa -
Lab Test
6.43 m3/t
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Absolute Pressure (kPa)

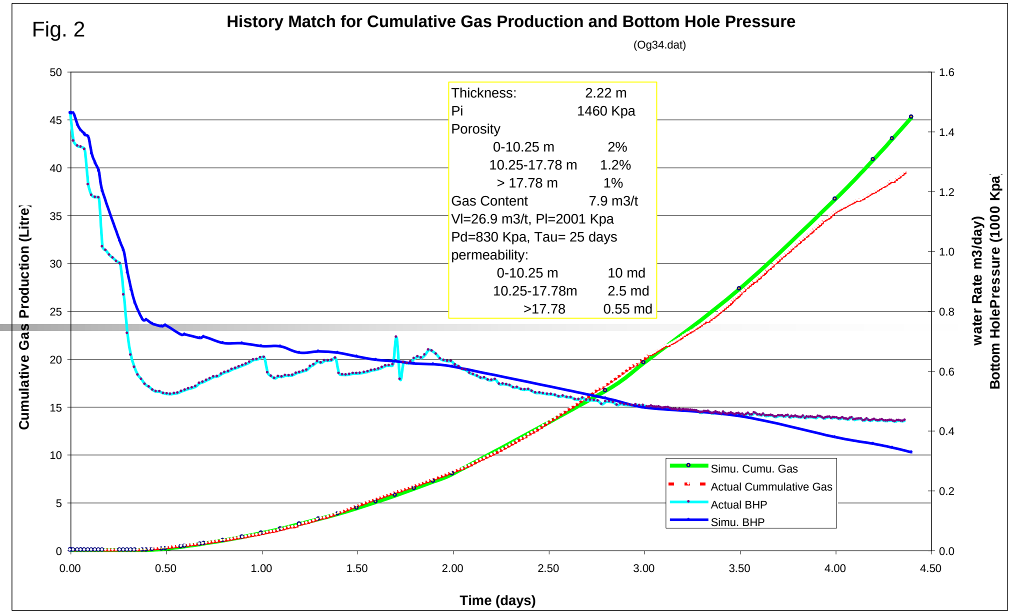
Relative Permeability from Multiphase Testing

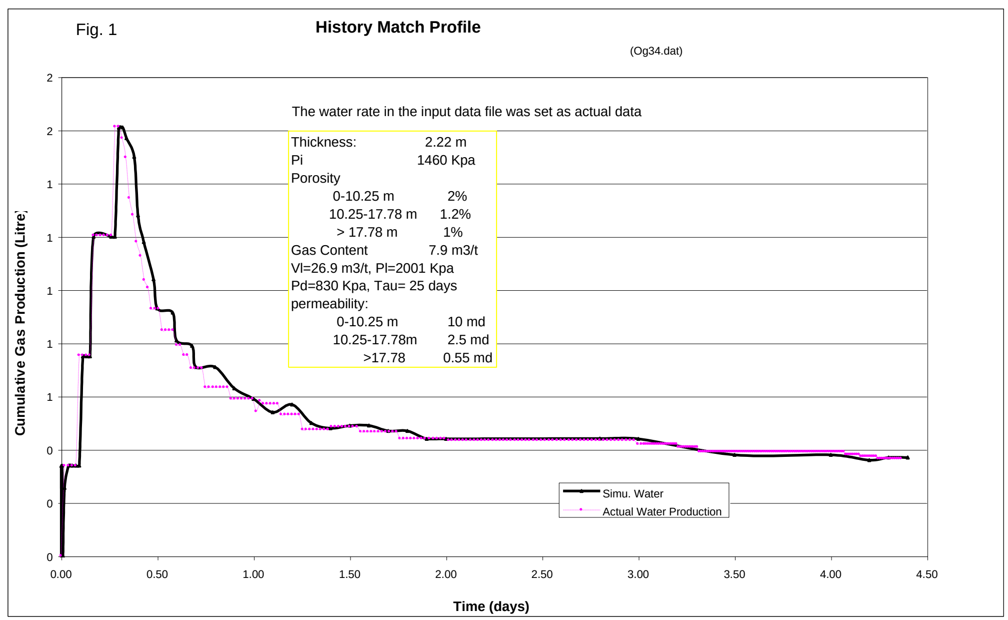
Idea is to back out relative permeability curves from history matching water and gas production

- Have had difficulty doing this with SIMED in moderate to high permeability coal.
- Same problem using EclipseCBM
- Have contracted Molopo (Wang Xingjin) to further SIMED curve matching

Matching per se is not the problem, it is getting a match using sensible parameters that is proving difficult…….







Parameters varied are:
- porosity
- permeability
- sorption time constant
- relative permeability

Desorption Time Constant - Tau

What is tau?

- Supposedly, the time taken for 63.2% of gas to desorb from a slow desorption gas content test

$$\tau = \frac{1}{\sigma D}$$

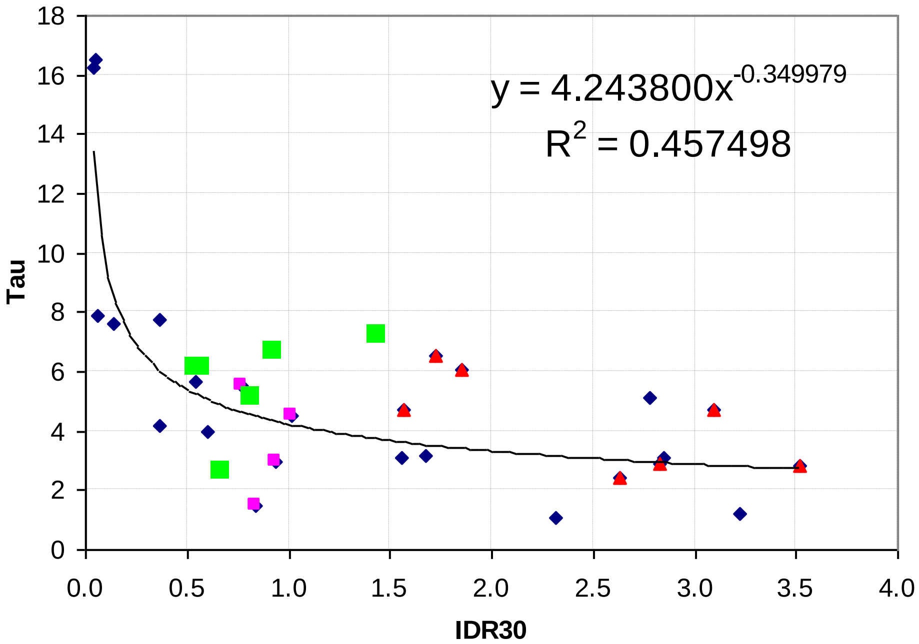
Where τ = desorption time constant

σ = coal matrix shape factor

D = diffusion coefficient

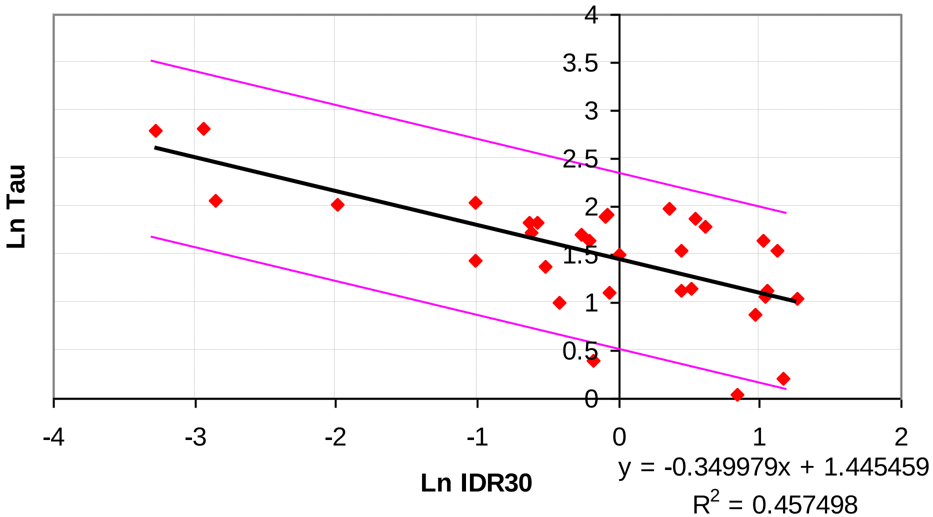
$$\frac{\Delta Q}{Q_0} = 1 - e^{-\sigma D t} \qquad \frac{\Delta Q}{Q_0} = 1 - e^{-1} = 0.632$$

- But is it 63.2% of Qm, Q1+Q2 or just Q2?
- We have related tau (from Qm) to IDR30.



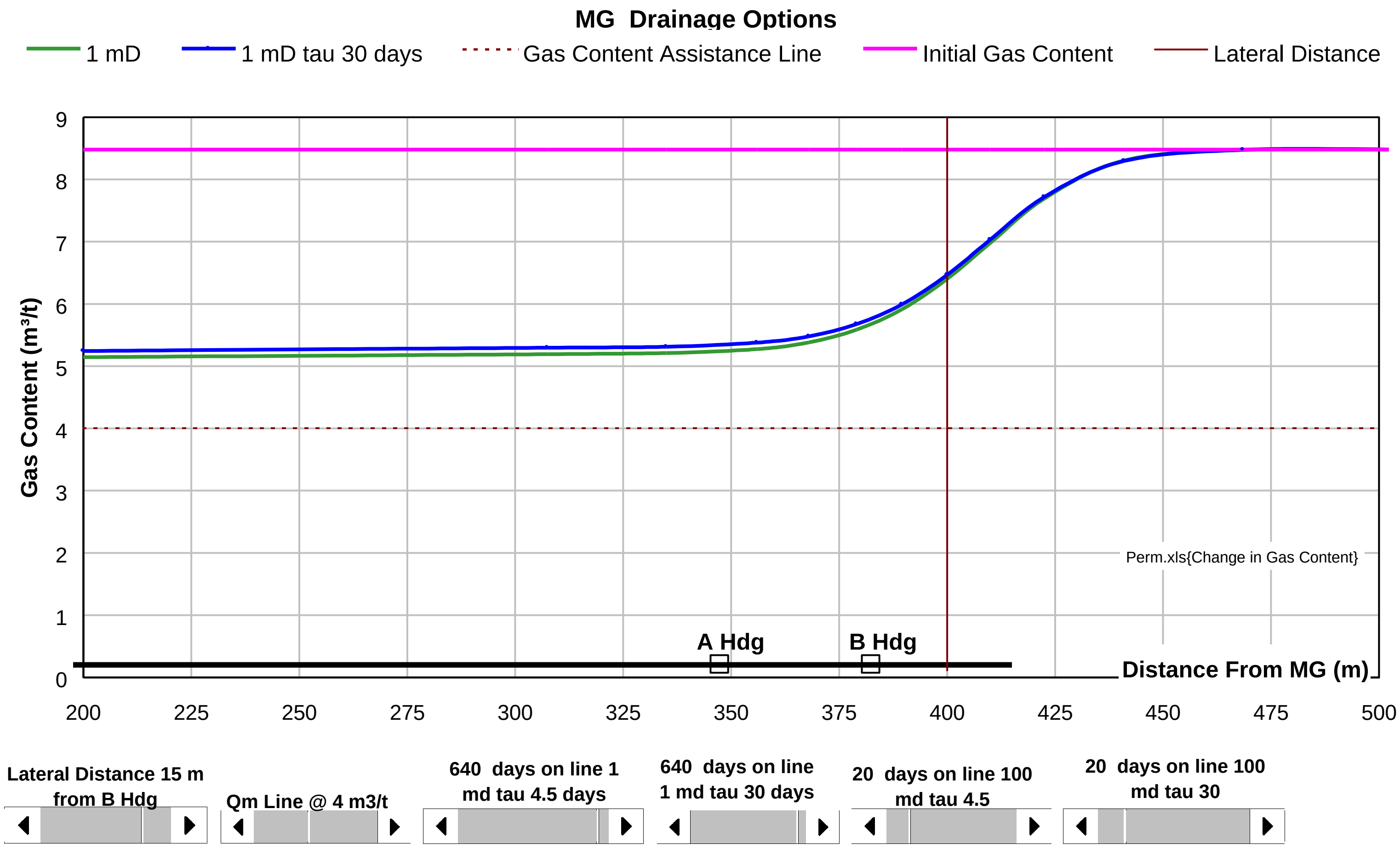
- Assessed the variability

- For a particular study area, define a range of tau’s applicable to the gas content magnitude for that deposit for use in sensitivity assessments

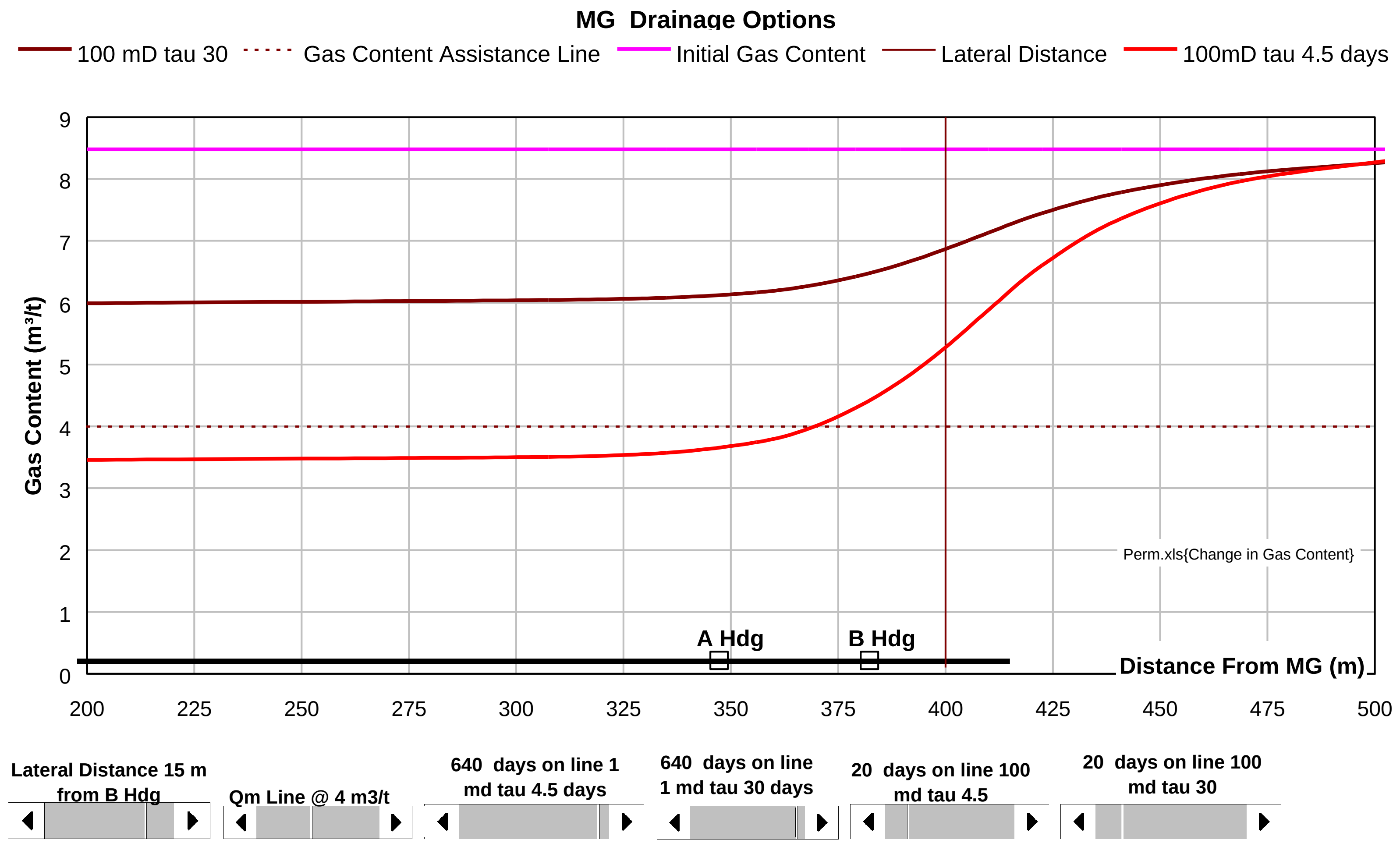


Qm mean	Tau hi	Tau mean	Tau low
3.36	23.8	9.5	3.8
4.58	18.7	7.5	3.0
6.81	13.5	5.4	2.2
8.50	10.7	4.3	1.7
9.47	9.2	3.7	1.5
10.01	8.3	3.3	1.3
10.38	7.7	3.1	1.2
10.63	7.2	2.9	1.2
10.83	6.9	2.7	1.1

At low perm (1mD, almost no difference between tau 4.5 and tau 30 days (8.5 m3/t)



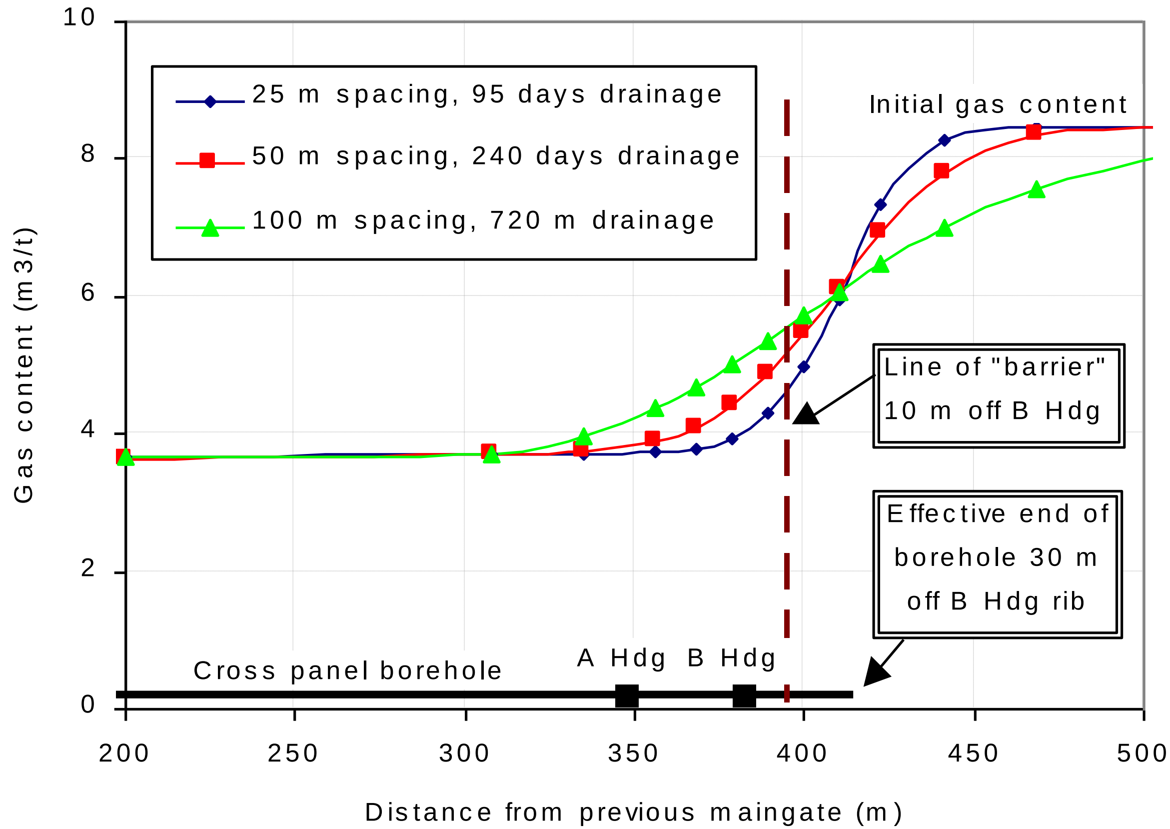
At high perm (100 mD, big difference between tau 4.5 and tau 30 days (8.5 m3/t)

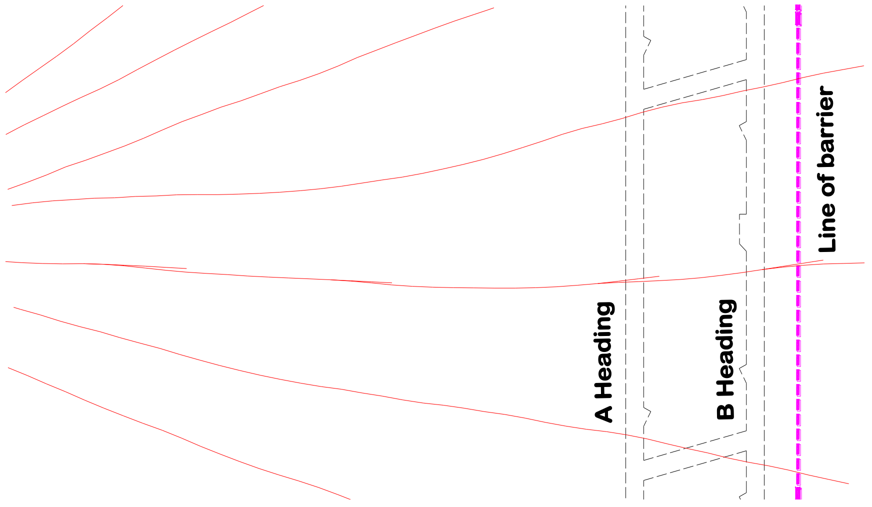


Gas Drainage Borehole Recharge

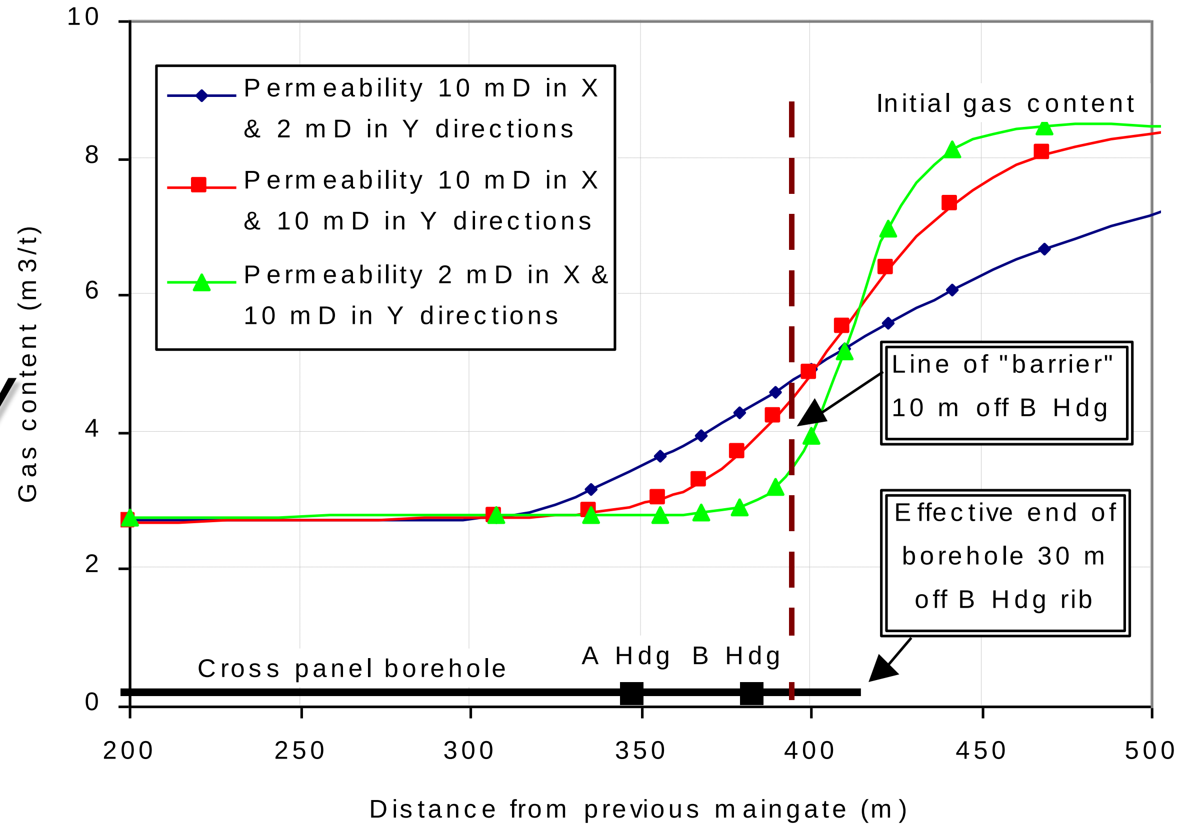
Gas drainage efficiency diminishes toward the end of boreholes,
Not from the end…

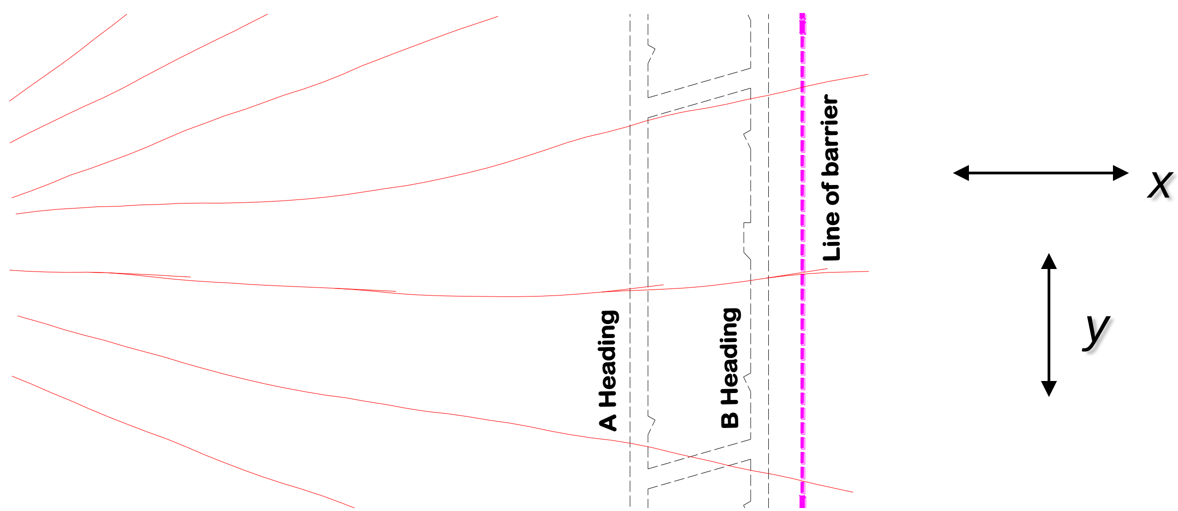
Effect Of Hole Spacing



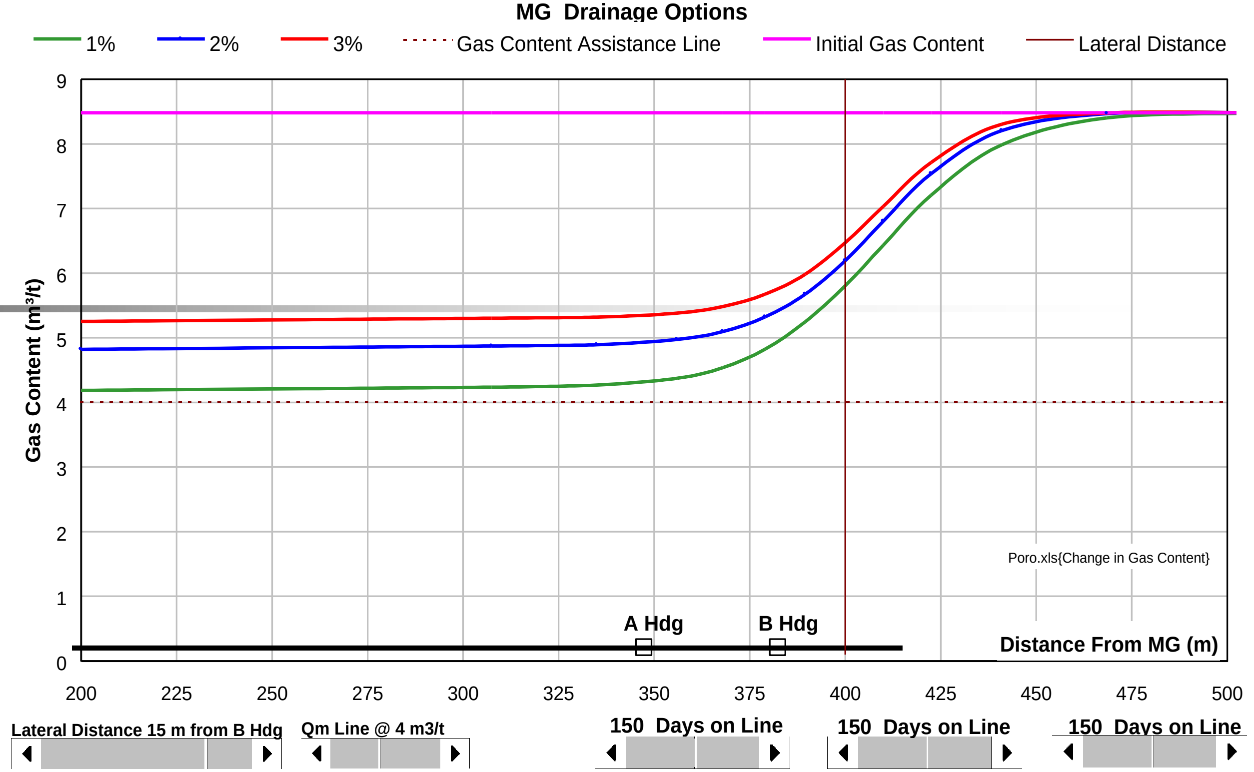


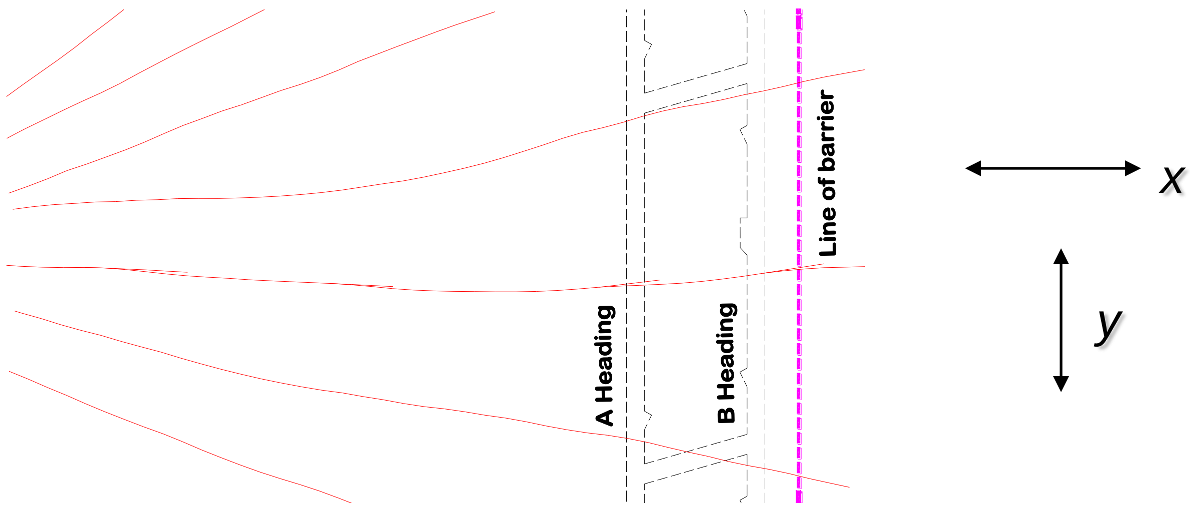
Effect Of Directional Permeability





Effect Of Porosity





Conclusions

- Hope to bring project to a close in next couple of months
- Scope to improve understanding and standardisation between labs on isotherm testing.
- Need to evaluate combinations of parameters eg as we did for ranges of tau at low and high permeabilities.
- A wider range of field measurements is important to lock down parameters. Eg measurement of both water and gas flow from in-seam boreholes greatly improves the robustness of the modelling.
- The bottom line is to create more robust modelling that is relevant. That means:
  - better input data
  - good modelling packages.
  - defining the approach to modelling that includes being critical every inch of the way, quantifying uncertainty……..