# Reserves Estimation and Influences on Coal Seam Gas Productivity in Eastern Australian Basins*

**Bruce McConachie[1], Peter Stanmore[1], Michael Creech[1], Lucas McLean Hodgson[1], Anargul Kushkarina[1], and Edward Lewis[1]**

Search and Discovery Article #10749 (2015)**
Posted July 13, 2015

*Adapted from oral presentation given at AAPG Asia Pacific Region, Geoscience Technology Workshop, Opportunities and Advancements in Coal Bed Methane in the Asia Pacific, Brisbane, Queensland, Australia, February 12-13, 2015


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## Abstract

SRK Consulting has undertaken many unconventional gas estimation projects in Australia plus China, USA, Canada, Botswana and South Africa. Our experience with projects indicates many potential pit falls in the estimation of both Resources and Reserves can lead to either overstating or underestimating potential. Geology is a significant control and the context of gas estimations is critical to ensure their delivery as economic Reserves.

SRK Consulting has experience of coal seam gas (CSG/CBM) Reserve and Resource in most eastern Australian basins and we have observed that the impact of coal quality and depositional environments are commonly underestimated and some potential gas upside is not necessarily captured from other aspects associated with coal seam gas analysis. The coal seam environment is complex comprising fluvial deposition in upper to lower delta plain settings where the complex interaction of sedimentary deposition is compounded by variations relating to the original peat swamp environment.

The nature of the peat-forming environment and the genesis of the contained methane in shallow CSG reservoirs often results in highly variable gas saturations. By understanding these processes and identifying the geological features responsible for high-frequency variations in gas contents, exploration can be better targeted. Individual coal seam reservoirs typically split and coalesce within hundreds of metres but seam characteristics such as ash content can also vary over similar distances. The thin nature of the CSG reservoir also provides the potential for common relatively small faults (<5 metres) to fully displace the coal seam and effectively compartmentalise the reservoir.

It is important to have a good understanding of the origin of the methane and how it has been stored in the reservoir. SRK has undertaken several projects in the Surat Basin where shallow coals are often highly gas productive. Deeper coals can be significantly undersaturated resulting in lower gas contents and significant dewatering requirements to achieve first gas. Lack of meteoric influx due to geometry and permeability barriers can result in minimal biogenic gas enhancement resulting poor permeabilities that require lateral wells to achieve reasonable productivity.

## Selected References

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Creech, M., and B. McConachie, 2014, Reserve estimation and the influence of coal seams on coal seam gas productivity: AusIMM Bulletin, Issue 1 (Feb 2014).

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U.S. Department of Energy, 2009, Modern Shale Gas Development in the United States: A Primer: Web Accessed June 27, 2015, http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf.

AAPG Geosciences Technology Workshop 2015
12-13 February 2015, Brisbane

# RESERVES ESTIMATION AND INFLUENCES ON COAL SEAM GAS PRODUCTIVITY IN EASTERN AUSTRALIAN BASINS

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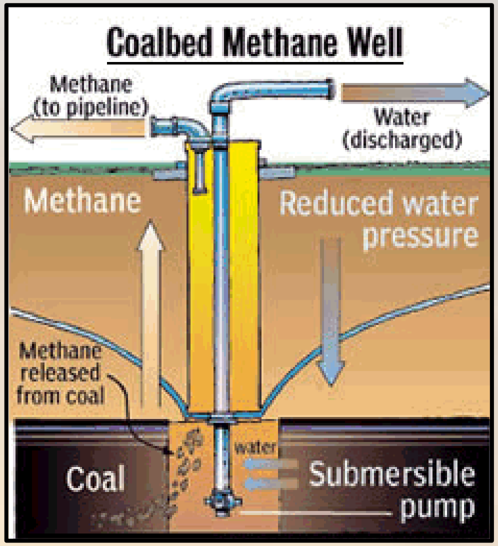
# Coal Seam Gas/ Coal Bed Methane

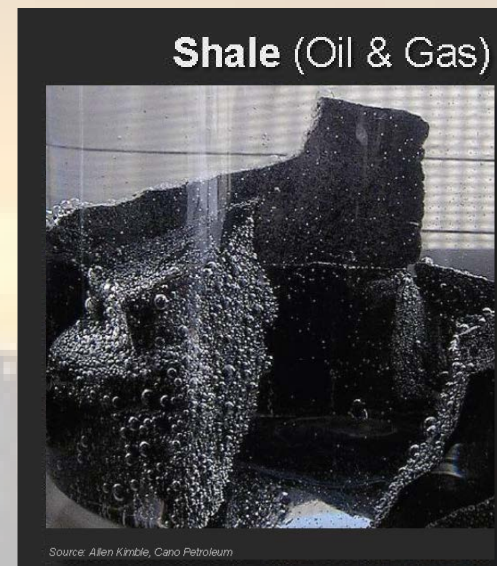


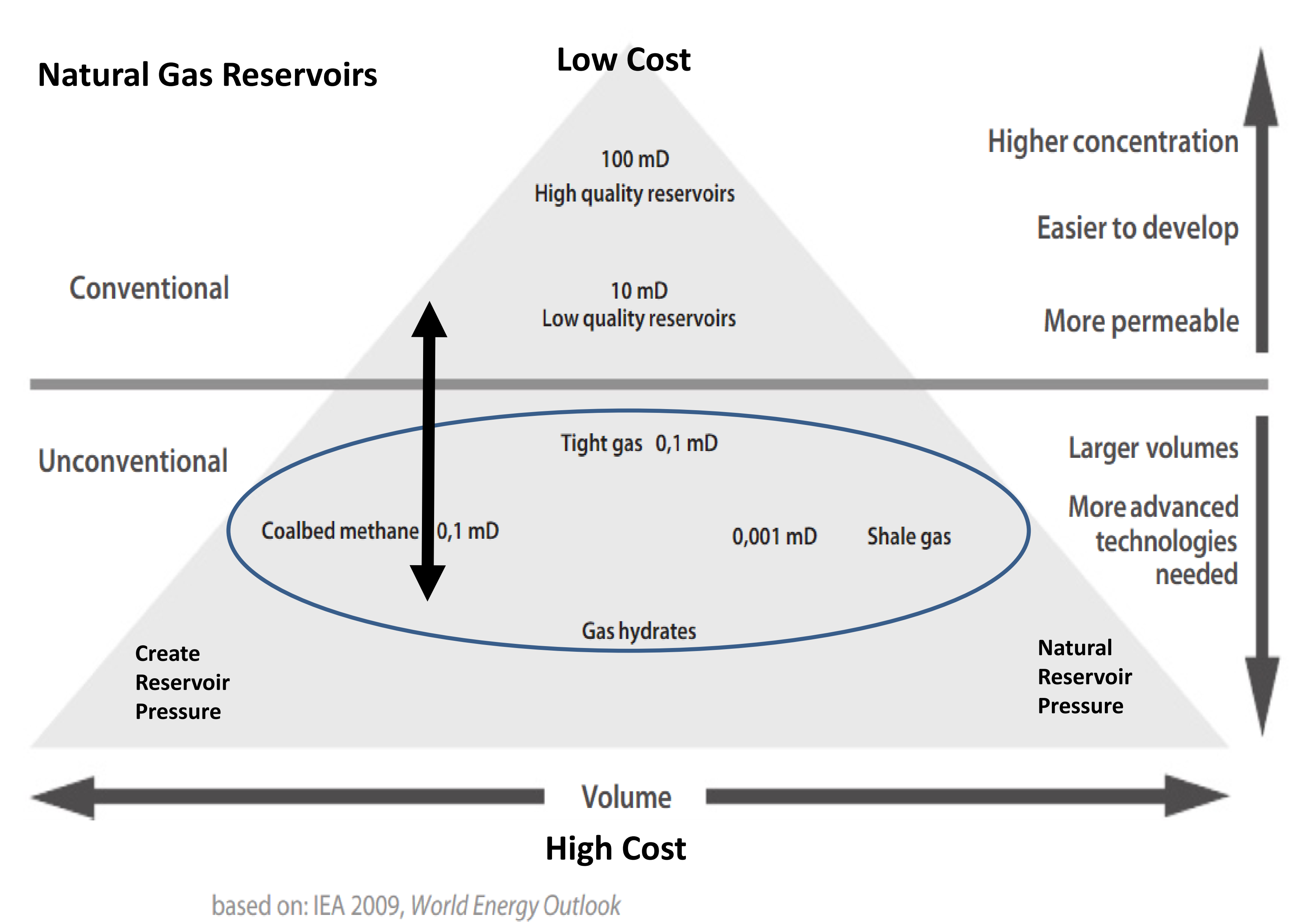

Topics to Cover

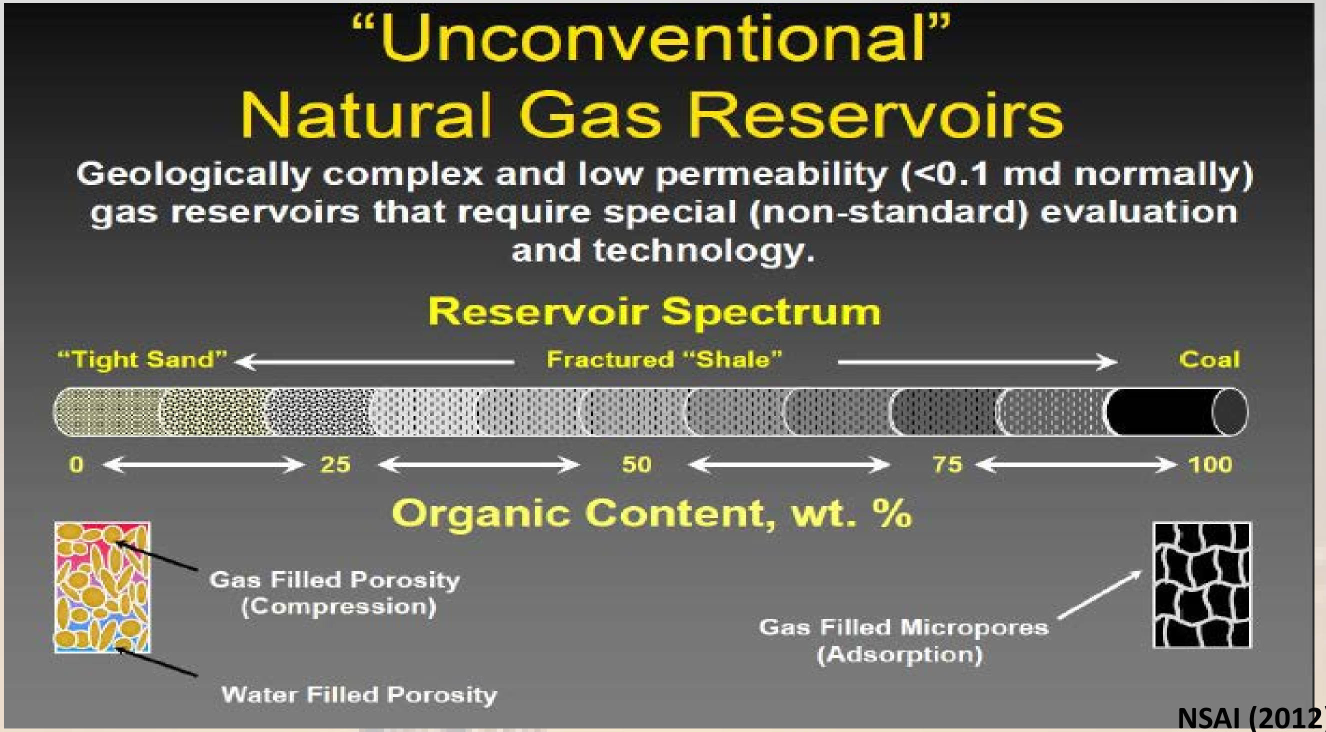
- Unconventional Gas and Coal
- Fracking
- Associated Gas and Reserves
- Surat Basin
- Clarence Moreton Basin
- Bowen Basin
- The Place of Unconventional Gas in the World

**Coal Seam Gas** is produced from coal and storage is dominantly adsorption

**Shale Gas** is derived from petroleum source rocks

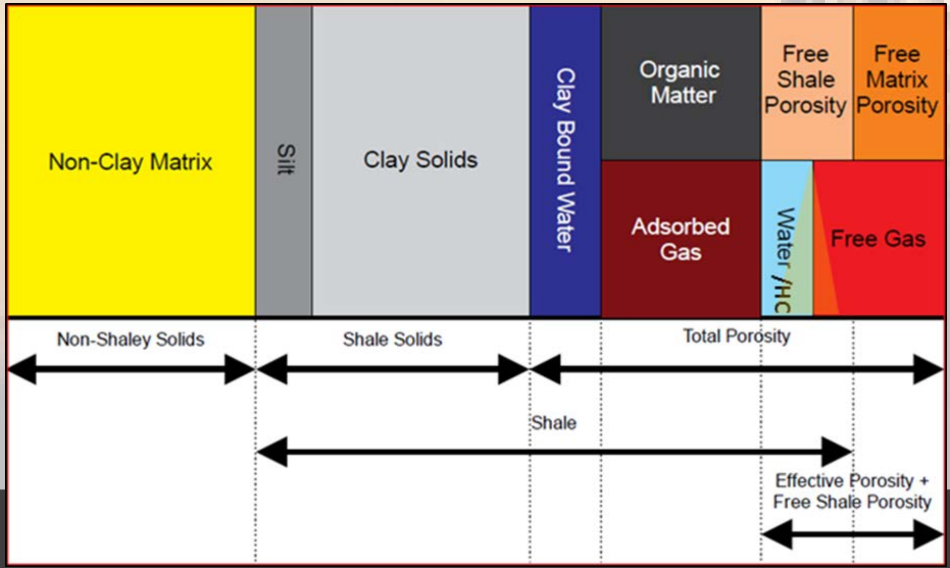



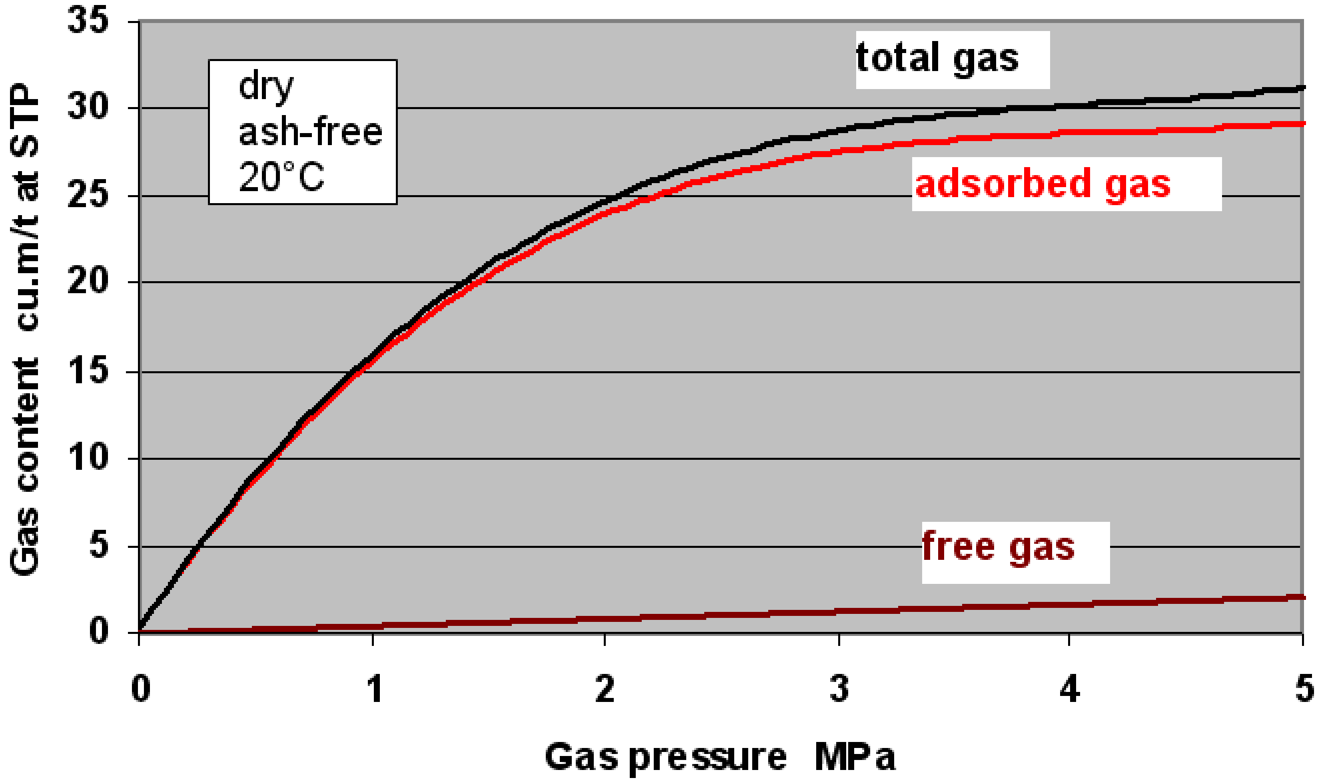

Natural Gas Reservoirs
Low Cost
100 mD
High quality reservoirs
10 mD
Low quality reservoirs
Conventional
Higher concentration
Easier to develop
More permeable
Unconventional
Tight gas 0,1 mD
Coalbed methane 0,1 mD
0,001 mD
Shale gas
Gas hydrates
Larger volumes
More advanced technologies needed
Create Reservoir Pressure
Natural Reservoir Pressure
Volume
High Cost
based on: IEA 2009, World Energy Outlook




NSAI (2012)

**Organic Content**

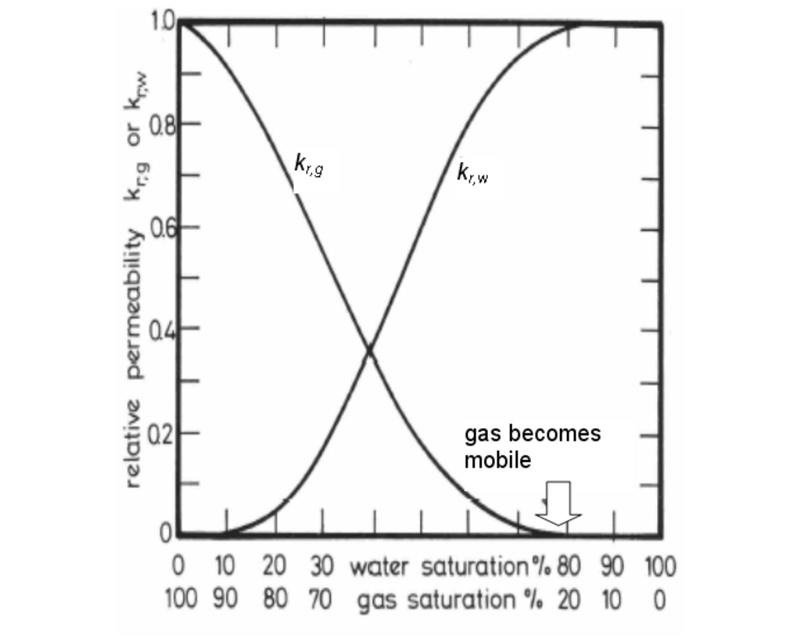





adsorbed, free and total gas isotherms for methane in coal

# Coal seam gas containment versus Pressure

# Imbibition is a function of Coal Type

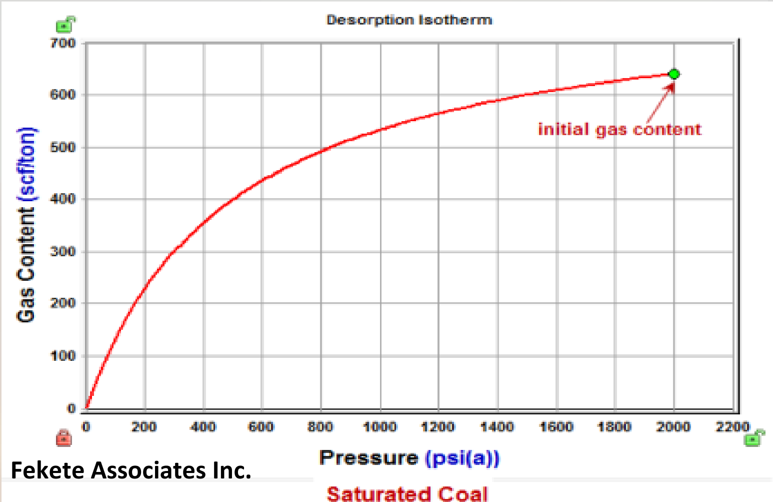


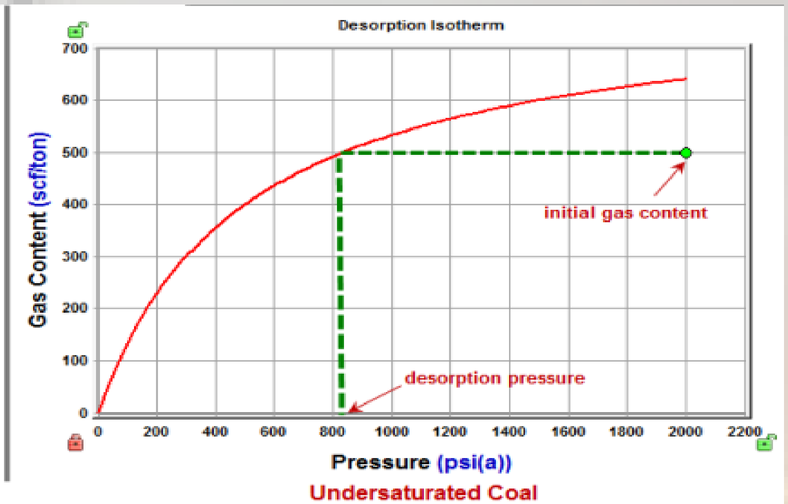

Illustrates a typical behaviour of relative permeabilities with respect to saturations of water and gas. The actual loci of the relative permeability curves depend upon whether the coal substance is wetted preferentially by the water or the gas. This, in turn, varies with the proportion of coal constituents, **vitrain and clarain tending to prefer the gas** while **durain and fusain are more easily wetted by water**

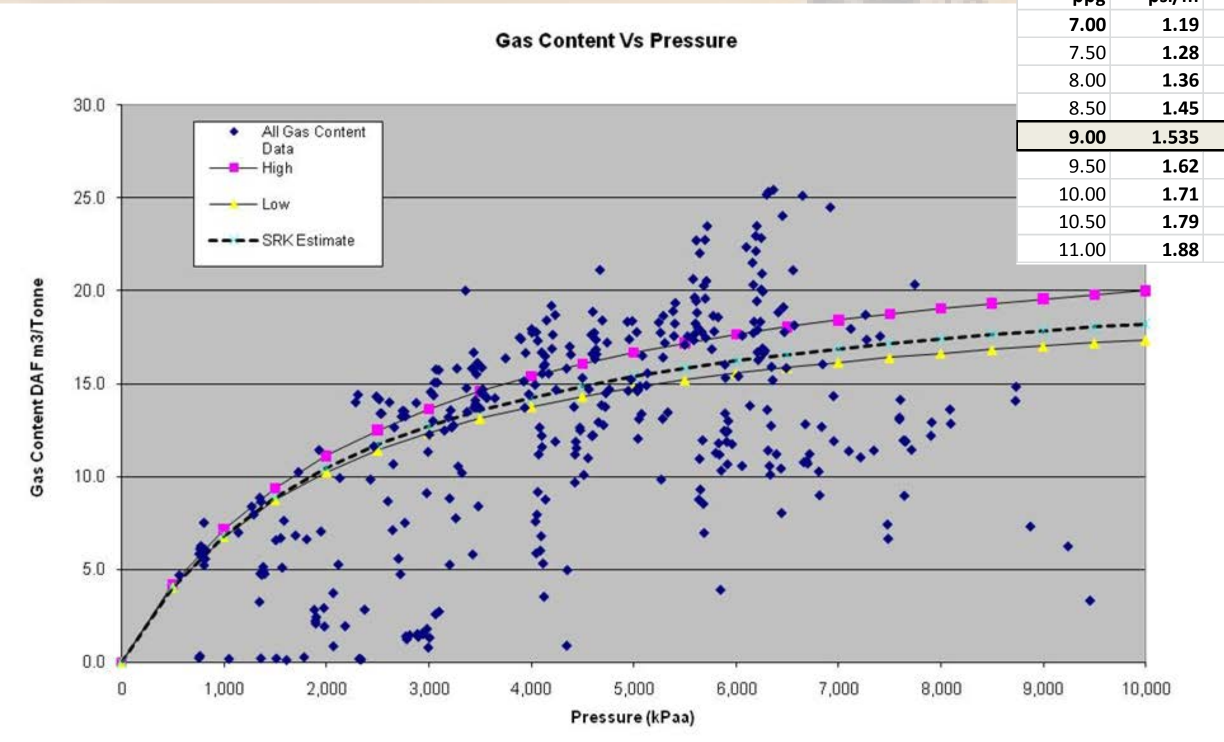
The curves suggest a net hydrophobic coal, i.e. the gas is the preferred wetting phase. The water will, therefore, tend to reside in the larger openings within the matrix and inhibit migration of the gas which exists in the smaller interstices. Hence, the gas will not become mobile until the water saturation has fallen significantly below 100%. This saturation explains why considerable volumes of water may be produced from a borehole before gas flows appear.

Saturated Coal Reservoir

Undersaturated Coal Reservoir




| ppg | psi/m | psi/ft | MPa/100m | Mpa/km | atm/100m | |
|---|---|---|---|---|---|---|
| **7.00** | **1.19** | **0.364** | **0.824** | **8.24** | **8.13** | |
| 7.50 | **1.28** | 0.390 | 0.882 | 8.82 | **8.71** | |
| 8.00 | **1.36** | 0.416 | 0.941 | 9.41 | **9.29** | fresh water 0.433 psi/ft |
| 8.50 | **1.45** | 0.442 | 1.000 | 10.00 | **9.87** | |
| **9.00** | **1.535** | **0.468** | **1.059** | **10.589** | **10.451** | sea water 0.465 psi/ft |
| 9.50 | **1.62** | 0.494 | 1.118 | 11.18 | **11.03** | |
| 10.00 | **1.71** | 0.520 | 1.177 | 11.77 | **11.61** | |
| 10.50 | **1.79** | 0.546 | 1.235 | 12.35 | **12.19** | |
| 11.00 | **1.88** | 0.572 | 1.294 | 12.94 | **12.77** | |

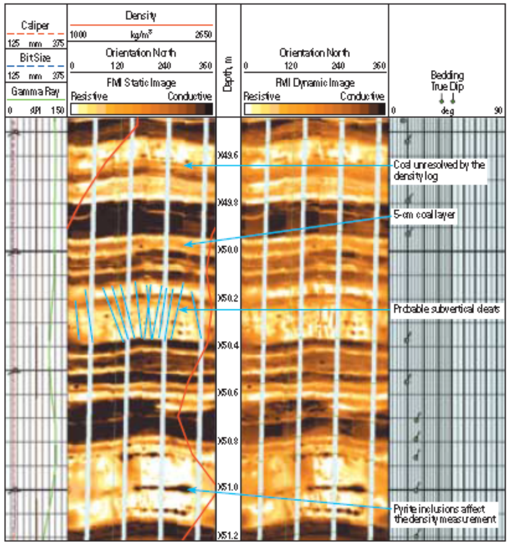
# Gas Saturations and pressure are important

**Undersaturation**

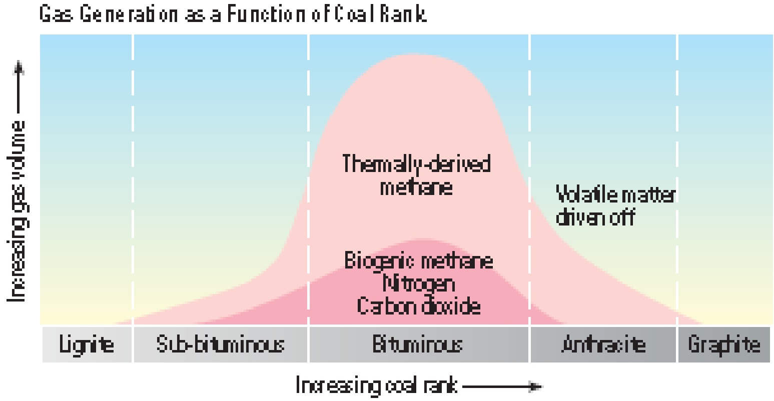
**May or may not be a problem depending on the amount and type of potential water production**

# CSG/CBM Criteria

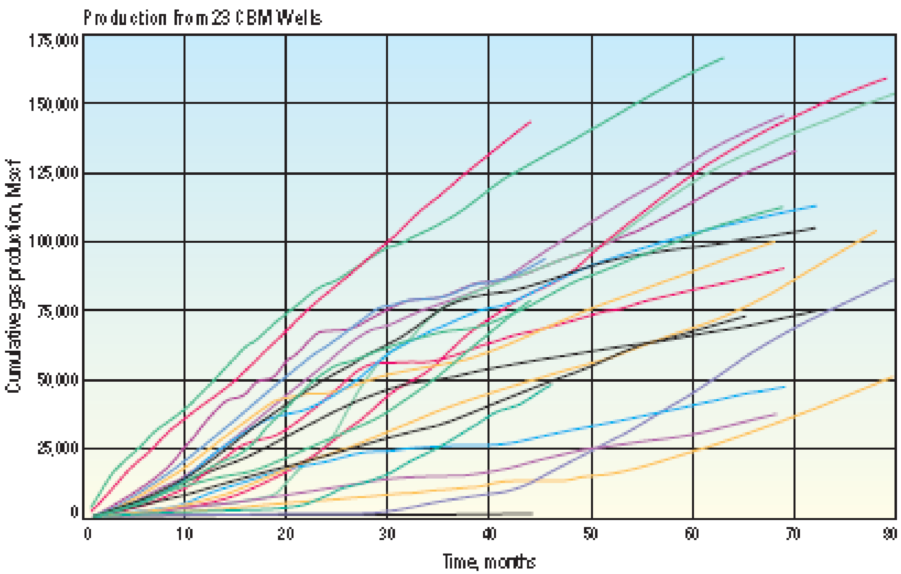
## Gas adsorbed in CSG



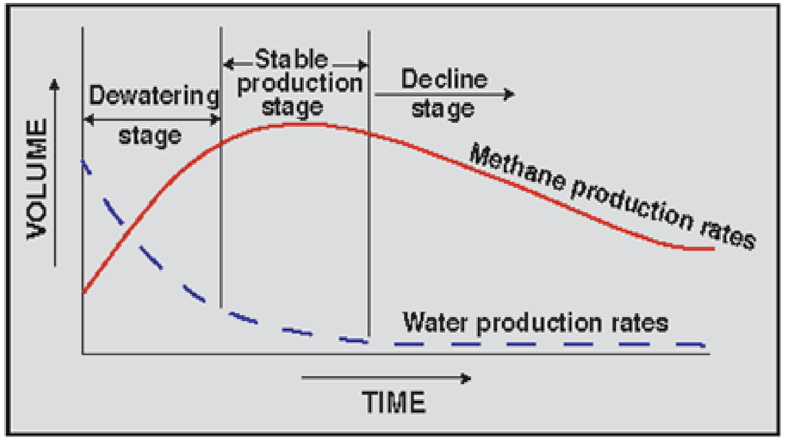

High-resolution measurements in thin-bedded coals. Many coals are thin-bedded and may not be identified with standard measurements. The FMI Fullbore Formation MicroImager tool has a vertical resolution of 0.2 in. [0.5 cm], which allows analysts to image thin coals. Track 1 contains gamma ray, caliper and borehole orientation data. A comparison between the density log and the FMI static image is displayed in Track 2. The FMI tool clearly identifies the thin coal at X50.0 m, where the density log does not. Pyrite inclusions that dramatically affect the density at X51.0 m appear as dark spots on the FMI image. Track 3 contains the FMI dynamic image, and Track 4 displays dip information.




Gas generation in coal. As temperature and pressure increase, coal rank changes along with its ability to generate and store methane. Through time, dewatering and devolatization occur, causing shrinkage of the coal matrix and creation of endogenetic cleats.

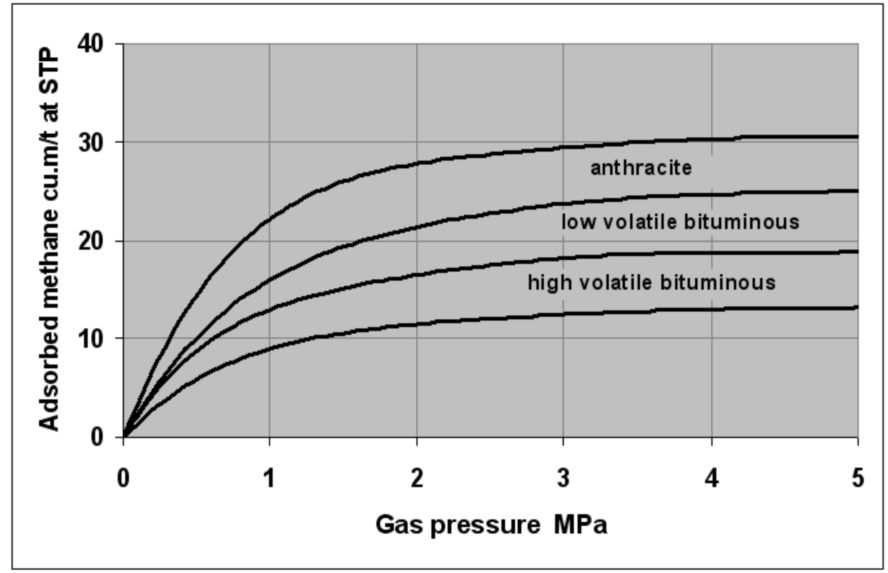



Local well-performance variations in a group of 23 similar wells in a field in the Black Warrior basin, USA. In this area, the differences are attributed to local changes in cleat and natural-fracture permeabilities. The plot shows cumulative gas production through time for each of the 23 wells.

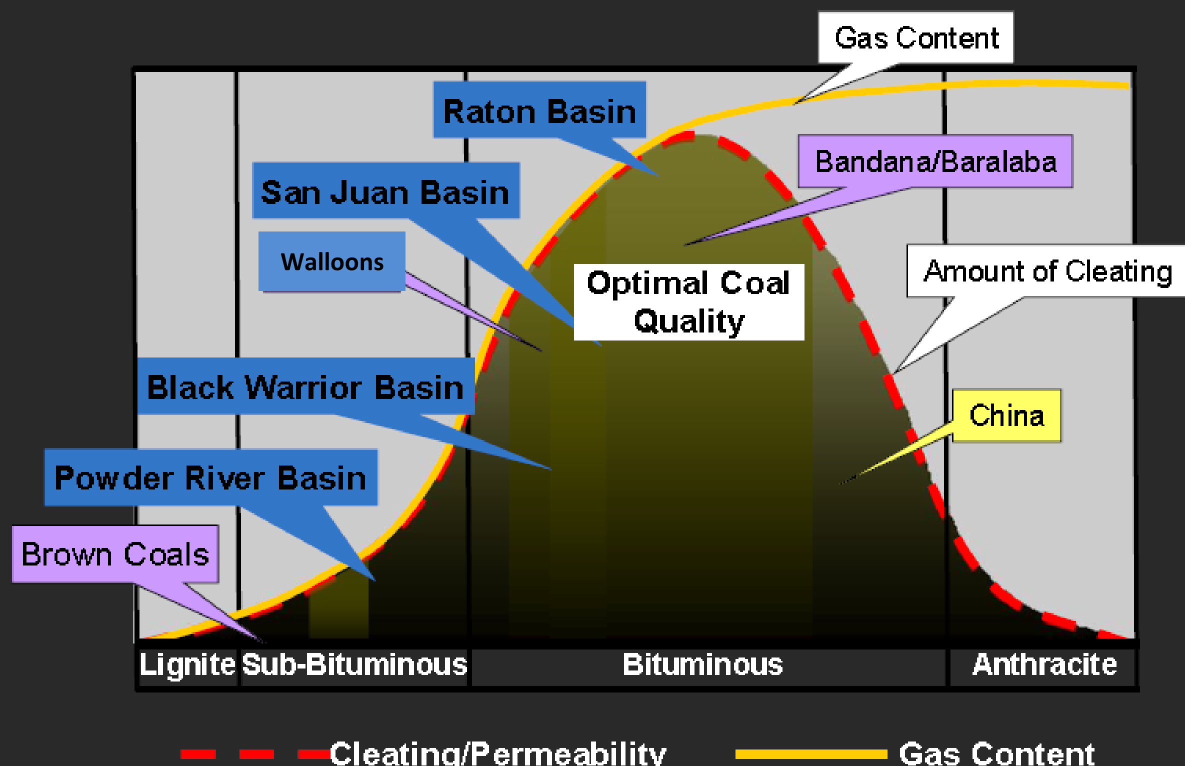



Typical production curves for a coal-bed methane well showing relative volumes of methane and water through time. Modified from Kuuskraa and Brandenberg (1989).

# Gas content is a function of coal rank
# But so is permeability




Examples of adsorption isotherms for methane in coal. The amount of gas adsorbed increases with the carbon content of the coal.



## Hydraulic Fracturing Issues - Social License

**Engelder, AAPG Explorer (2014)**
**Identified 6 Key mistakes made by companies**

- ❑ **Failure to establish baseline water chemistry before drilling campaigns**

**Traditionally oil wells were first drilled in places where oil was leaking to the surface, gas similarly leaks**

**It is common for water wells to produce gas (spring water commonly effervesces)**

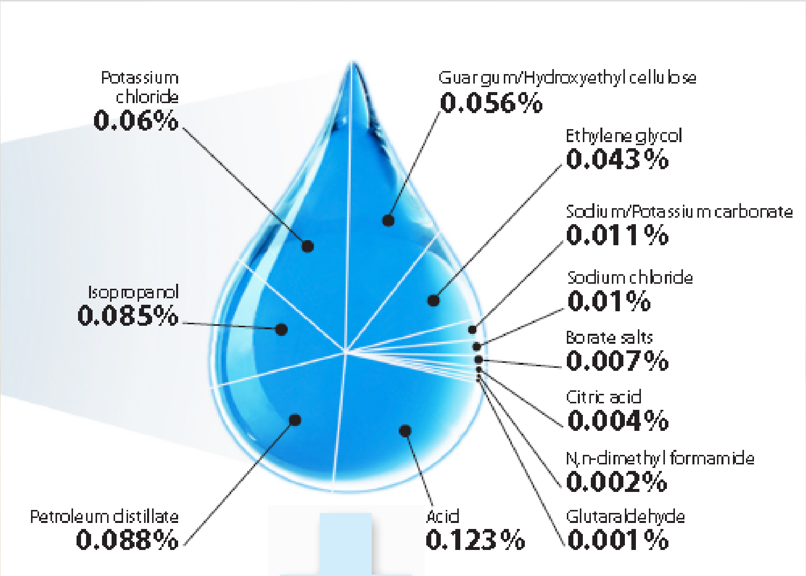
- ❑ **Use of cemented casing to cover the reservoir levels is important**

- ❑ **Use of air drilling to penetrate reservoirs in shallow aquifer settings**

- ❑ **Supporting Energy Policy that allowed hydraulic fracturing companies to keep their additives proprietary**

- ❑ **Disposing of flow back in large enough volumes to trigger earthquakes**

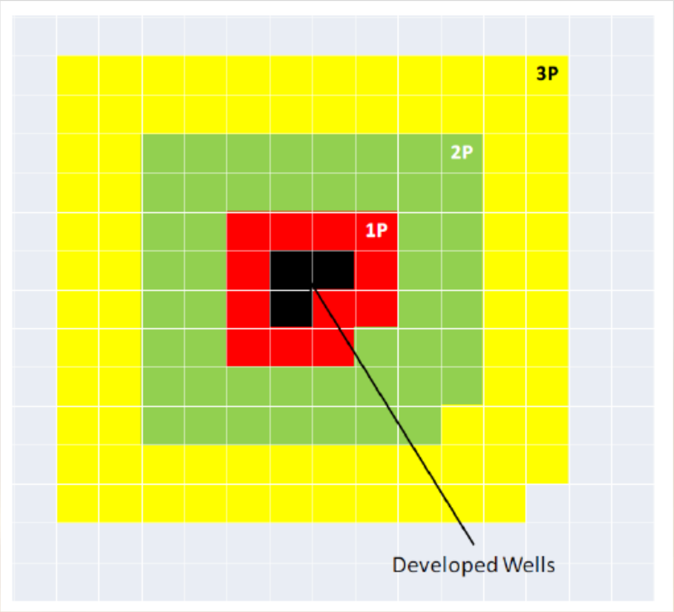
- ❑ **Water management associated with potential open pit leakage**

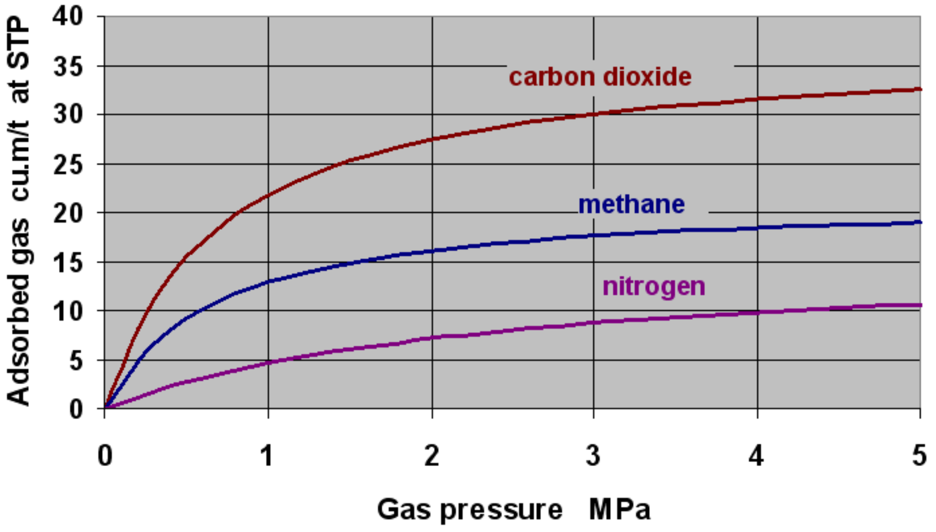



**The dilute 0.49%**

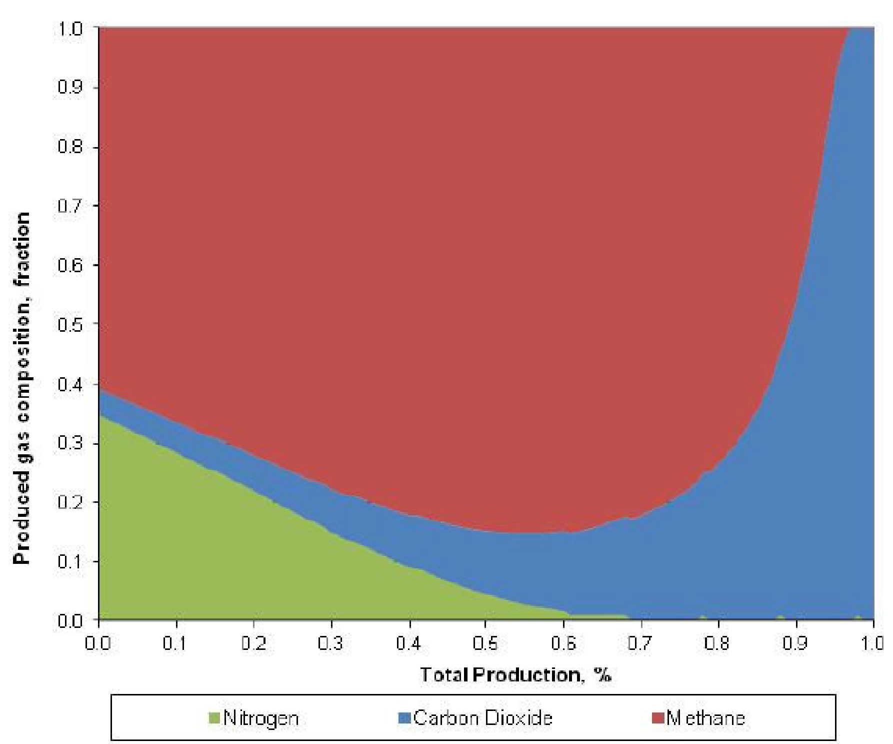
Source: DOE, GWPC: Modern Gas Shale Development In the United States:
A Primer (2009)

| Compound* | Purpose | Common application |
|---|---|---|
| Acids | Helps dissolve minerals and initiate fissure in rock (pre-fracture) | Swimming pool cleaner |
| Glutaraldehyde | Eliminates bacteria in the water | Disinfectant; Sterilizer for medical and dental equipment |
| Sodium Chloride | Allows a delayed break down of the gel polymer chains | Table Salt |
| N, n-Dimethyl formamide | Prevents the corrosion of the pipe | Used in pharmaceuticals, acrylic fibers and plastics |
| Borate salts | Maintains fluid viscosity as temperature increases | Used in laundry detergents, hand soaps and cosmetics |
| Polyacrylamide | Minimizes friction between fluid and pipe | Water treatment, soil conditioner |
| Petroleum distillates | "Slicks" the water to minimize friction | Make-up remover, laxatives, and candy |
| Guar gum | Thickens the water to suspend the sand | Thickener used in cosmetics, baked goods, ice cream, tooth-paste, sauces, and salad dressing |
| Citric Acid | Prevents precipitation of metal oxides | Food additive; food and beverages; lemon juice |
| Potassium chloride | Creates a brine carrier fluid | Low sodium table salt substitute |
| Ammonium bisulfite | Removes oxygen from the water to protect the pipe from corrosion | Cosmetics, food and beverage processing, water treatment |
| Sodium or potassium carbonate | Maintains the effectiveness of other components, such as crosslinkers | Washing soda, detergents, soap, water softener, glass and ceramics |
| Proppant | Allows the fissures to remain open so the gas can escape | Drinking water filtration, play sand |
| Ethylene glycol | Prevents scale deposits in the pipe | Automotive antifreeze, household cleansers, deicing, and caulk |
| Isopropanol | Used to increase the viscosity of the fracture fluid | Glass cleaner, antiperspirant, and hair color |



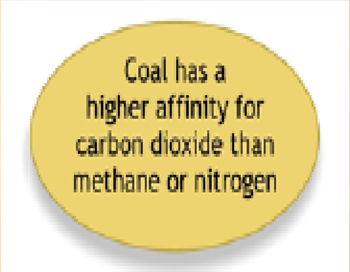




Adsorption isotherms for carbon dioxide, methane and nitrogen in a bituminous coal at 25°C.




**LNG FROM CSG—CHALLENGES AND OPPORTUNITIES**

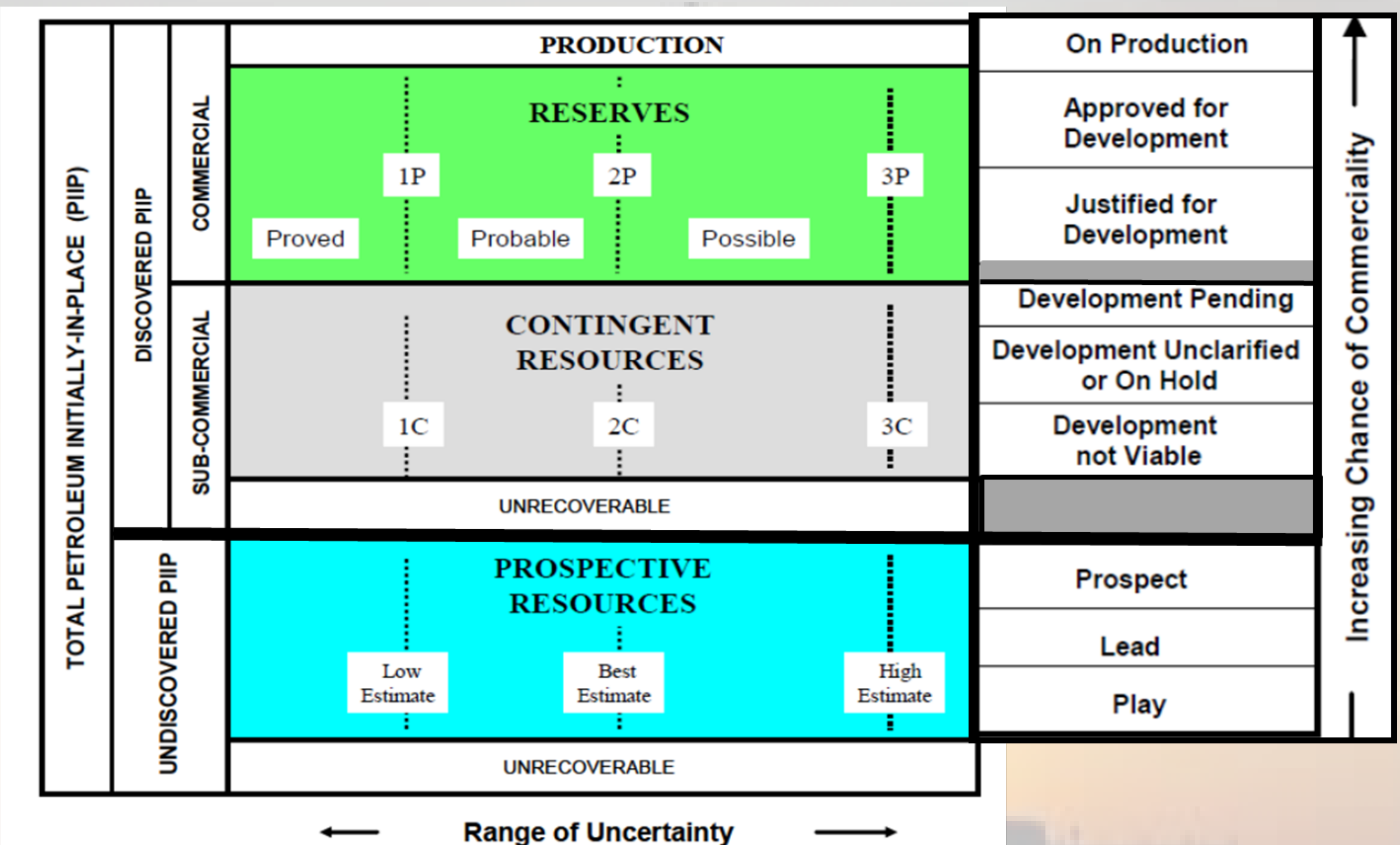
Nigel J. Unsworth
Project Process Manager
Foster Wheeler
Reading, UK



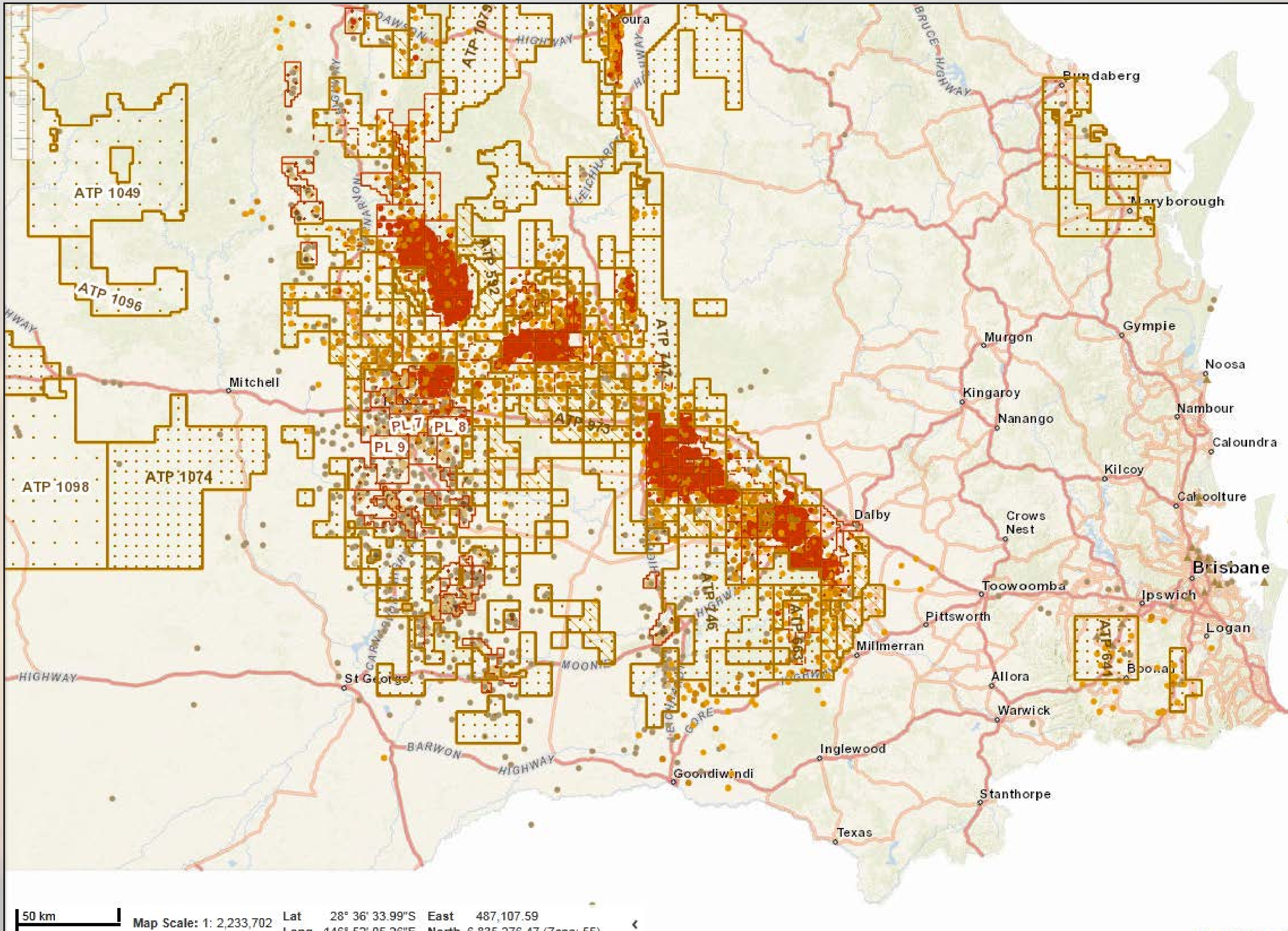

**CBM Geology & Well Design**

5 TH ANNUAL CBM & UNCONVENTIONAL GAS
WEDNESDAY 27 JUNE 2012
GEOFF BARKER

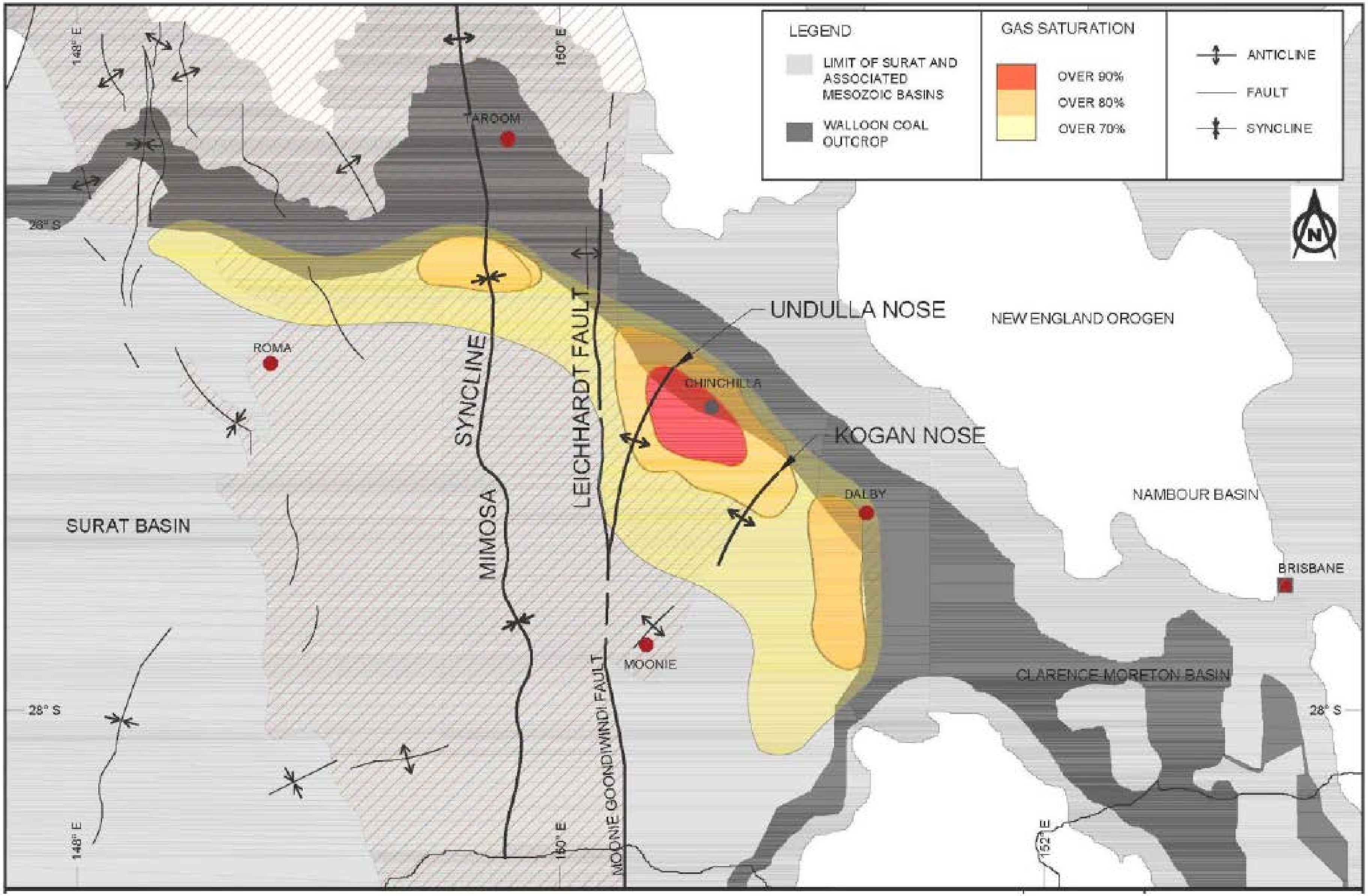
# Associated Gases in Coal and Reserves Designations

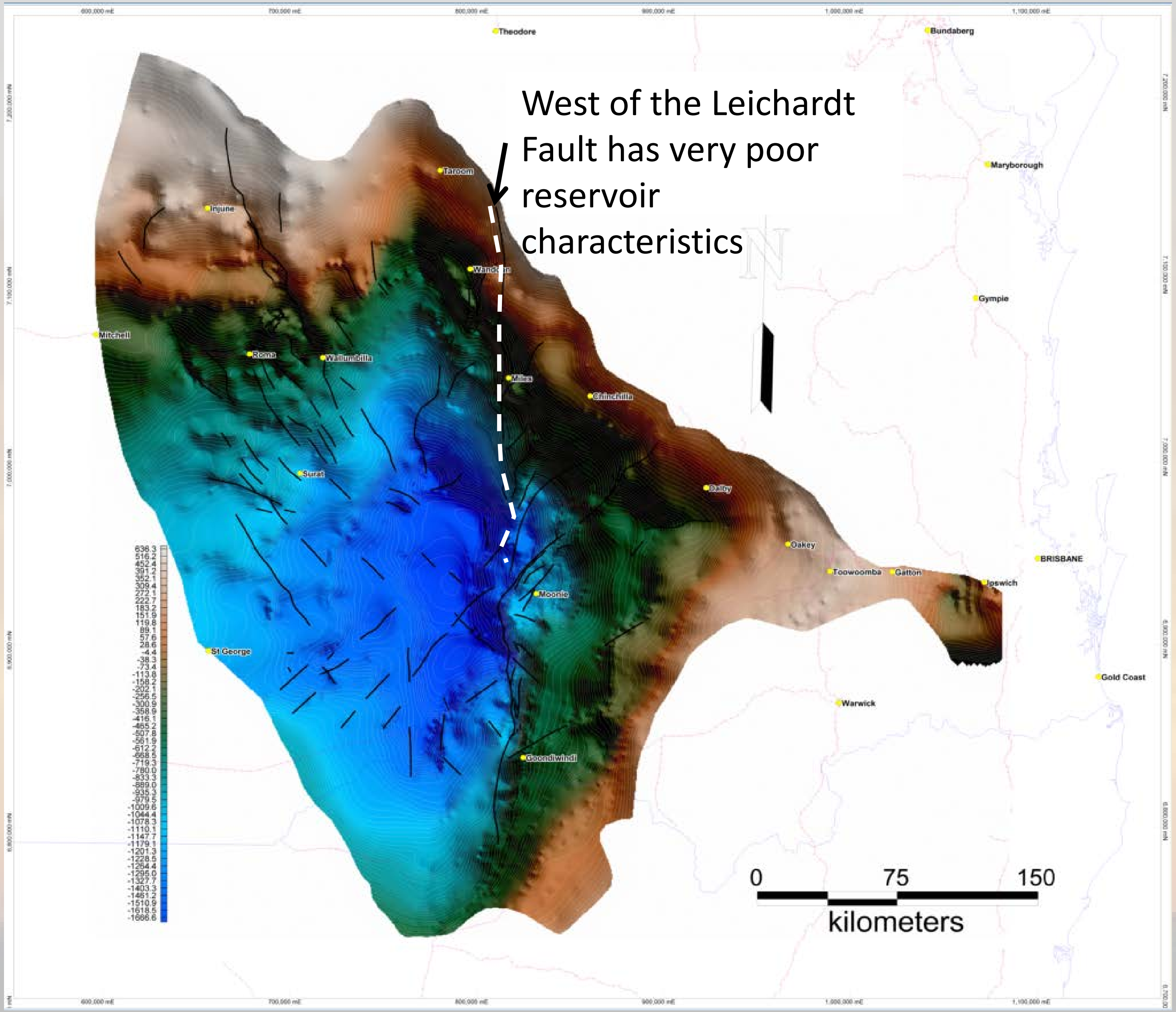


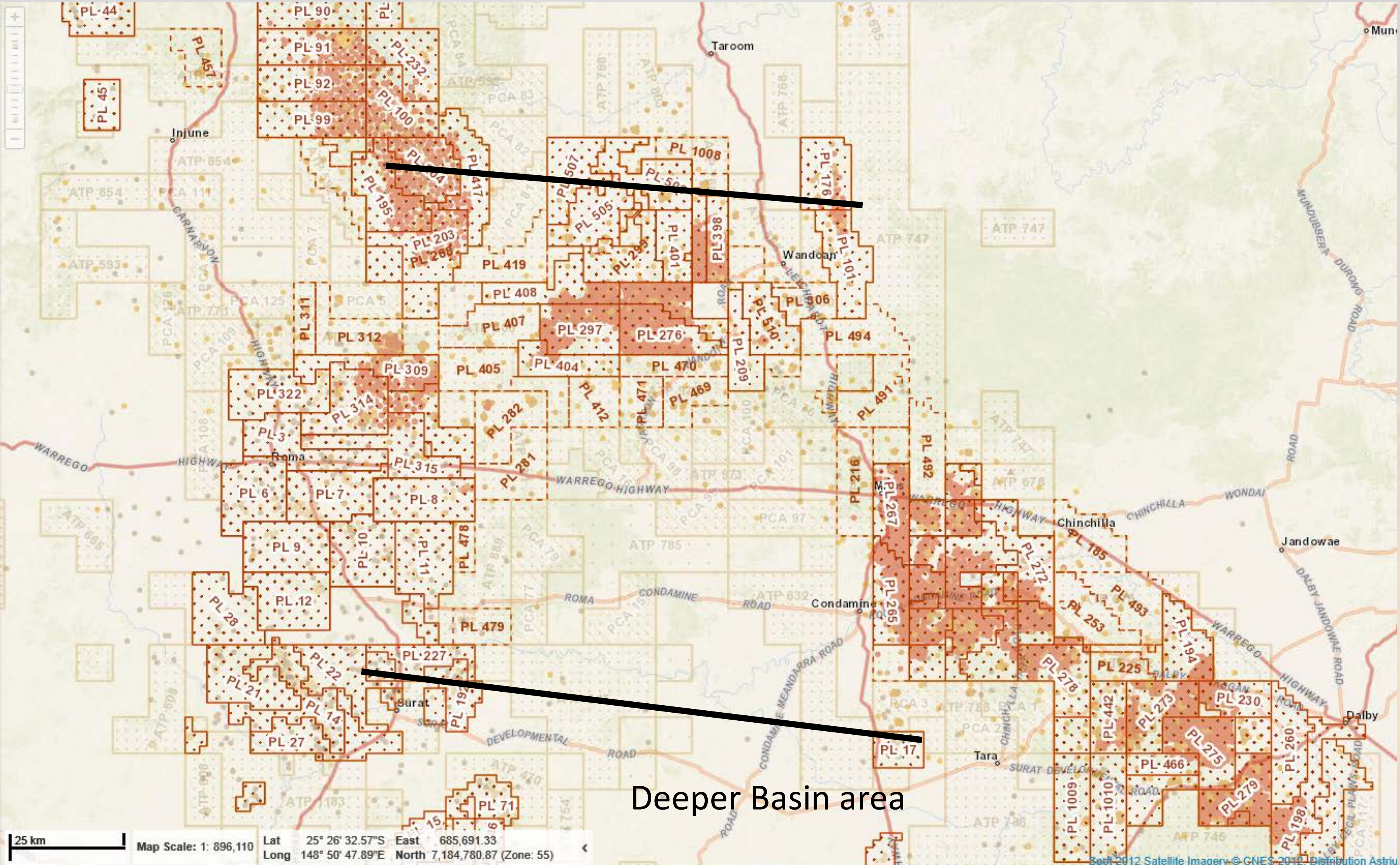

Reserves and Resources as classified by PRMS (not to scale)



ATP 1049
ATP 1096
ATP 1098
ATP 1074
ATP 746
PL 7
PL 8
PL 9
Bundaberg
Maryborough
Gympie
Murgon
Noosa
Kingaroy
Nambour
Nanango
Caloundra
Kilcoy
Caboolture
Mitchell
Dalby
Crows Nest
Brisbane
Toowoomba
Ipswich
Pittsworth
Logan
Millmerran
Allora
Warwick
St George
Inglewood
Goondiwindi
Stanthorpe
Texas
50 km
Map Scale: 1: 2,233,702
Lat 28° 36' 33.99"S East 487,107.59
Long 146° 52' 05.26"E North 6,835,276.47 (Zone: 55)

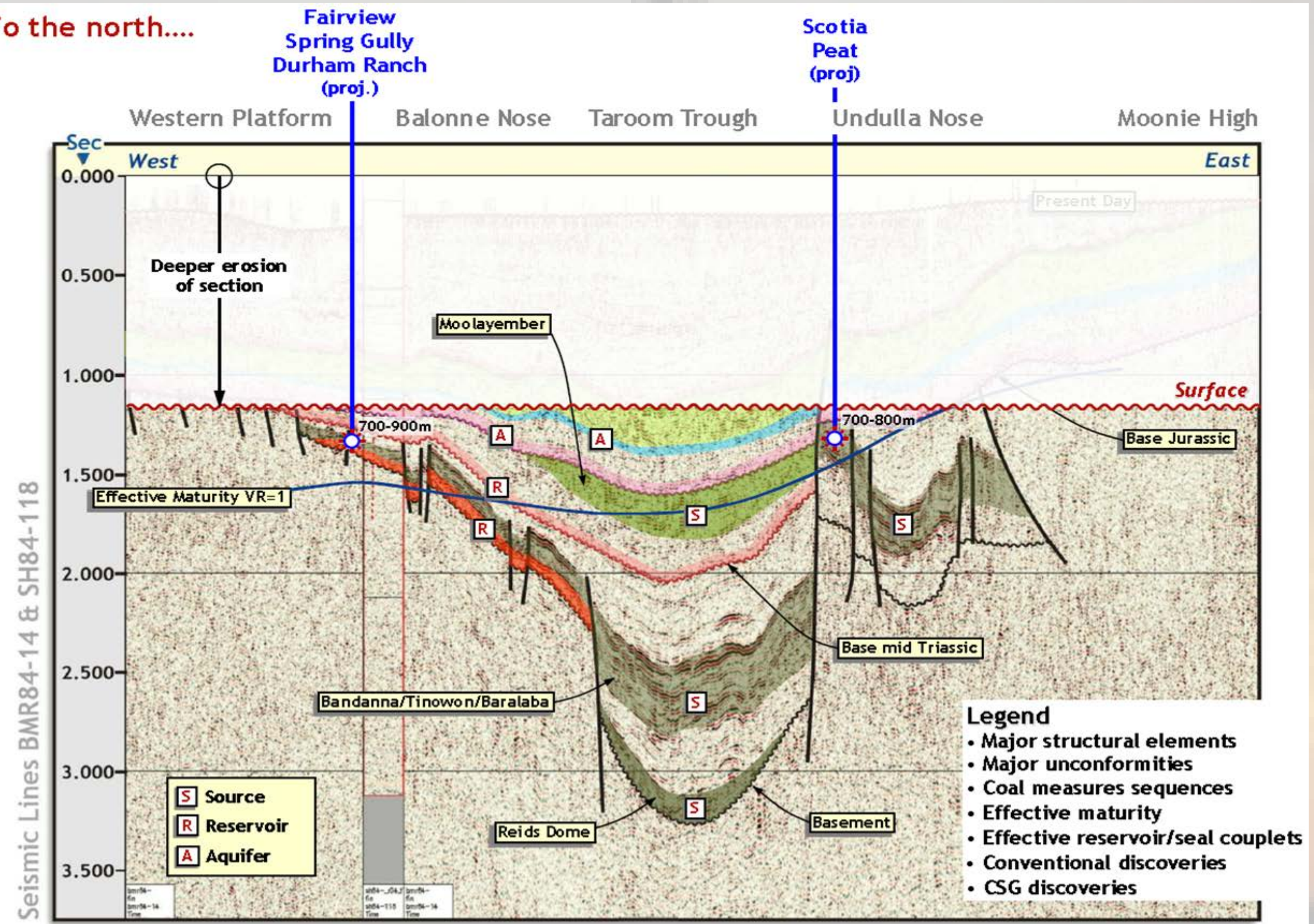

LEGEND
LIMIT OF SURAT AND ASSOCIATED MESOZOIC BASINS
WALLOON COAL OUTCROP
GAS SATURATION
OVER 90%
OVER 80%
OVER 70%
ANTICLINE
FAULT
SYNCLINE
N
TAROOM
ROMA
CHINCHILLA
DALBY
MOONIE
BRISBANE
UNDULLA NOSE
KOGAN NOSE
NEW ENGLAND OROGEN
NAMBOUR BASIN
SURAT BASIN
CLARENCE-MORETON BASIN
MIMOSA SYNCLINE
LEICHHARDT FAULT
MOONIE GOONDIWINDI FAULT
148° E
150° E
152° E
28° S


West of the Leichardt Fault has very poor reservoir characteristics
Theodore
Bundaberg
Taroom
Maryborough
Injune
Wandoan
Gympie
Mitchell
Roma
Wallumbilla
Miles
Chinchilla
Surat
Dalby
Oakey
BRISBANE
Toowoomba
Gatton
Ipswich
Moonie
St George
Gold Coast
Warwick
Goondiwindi
0
75
150
kilometers

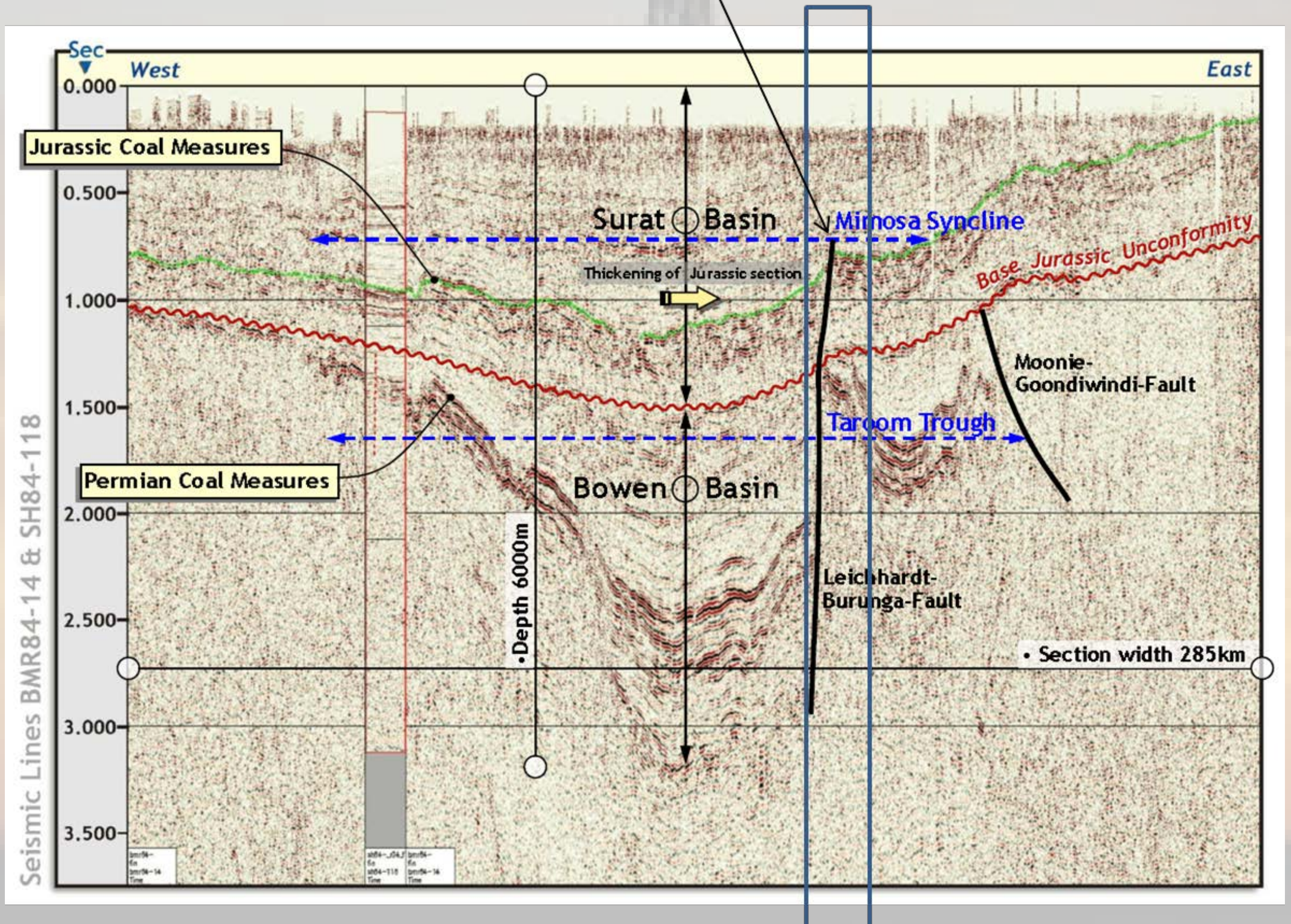


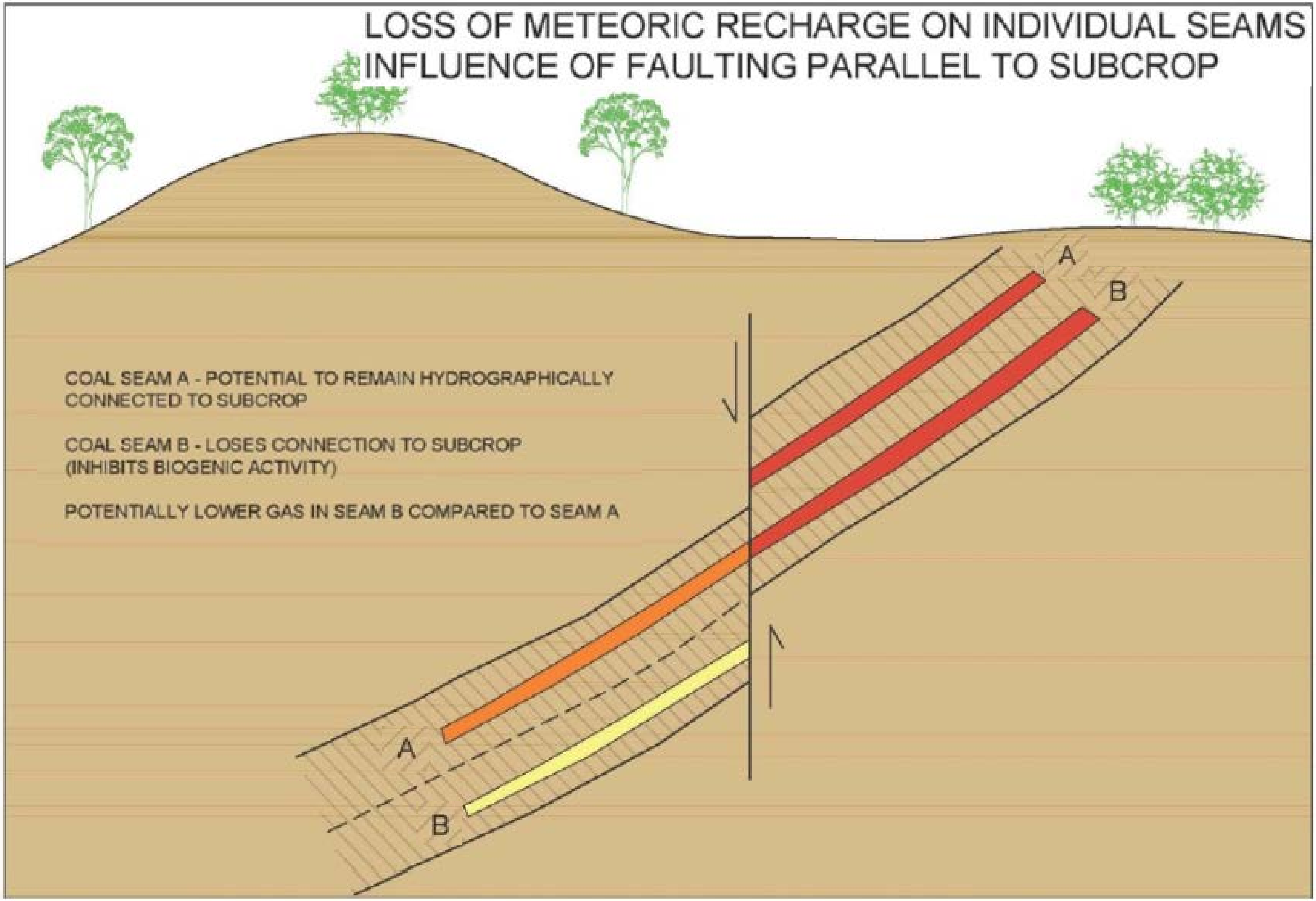
Deeper Basin area

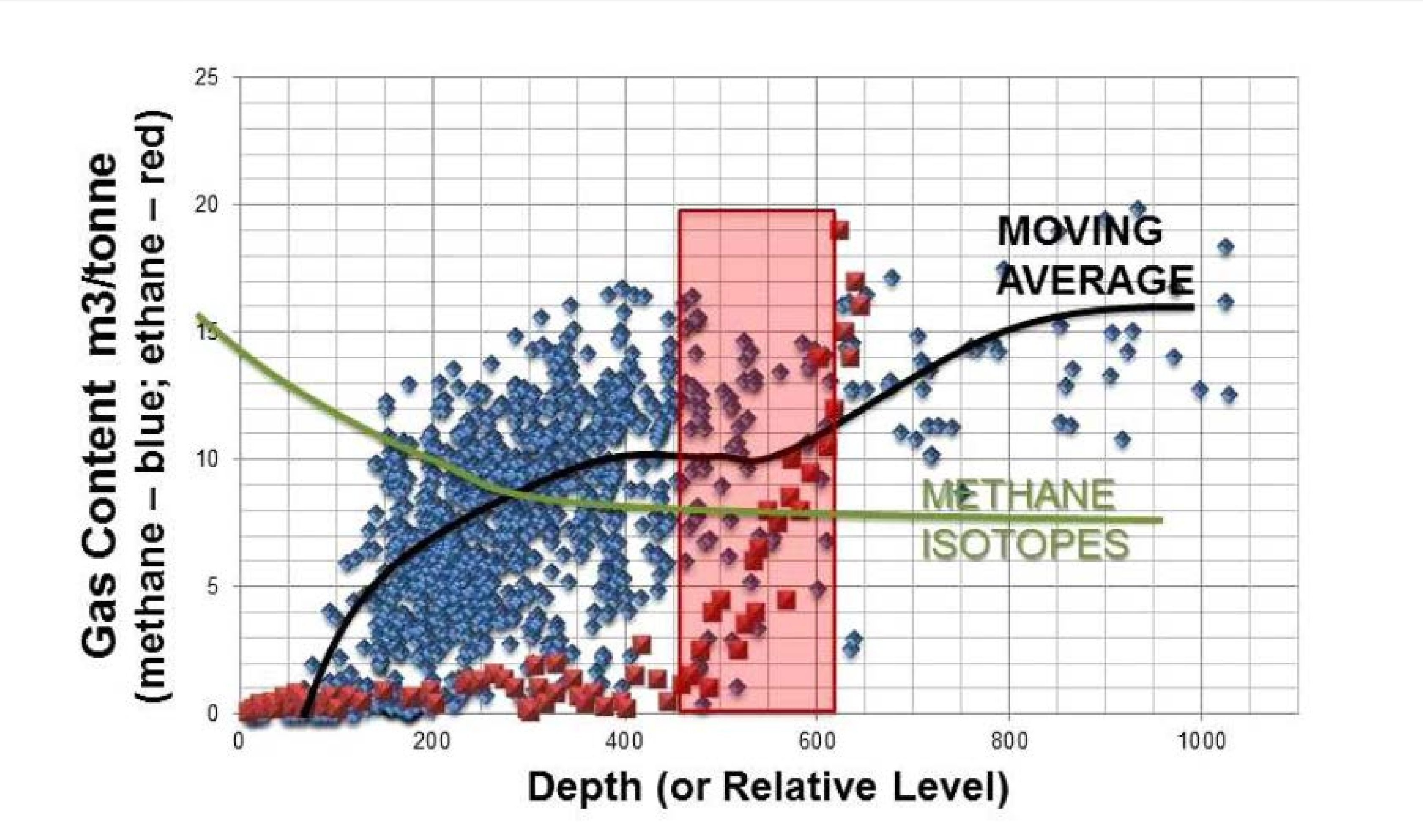
## To the north....


Fairview
Spring Gully
Durham Ranch
(proj.)
Scotia
Peat
(proj)
Western Platform
Balonne Nose
Taroom Trough
Undulla Nose
Moonie High
Sec
West
East
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
Deeper erosion of section
Present Day
Moolayember
Surface
700-900m
700-800m
Base Jurassic
Effective Maturity VR=1
Base mid Triassic
Bandanna/Tinowon/Baralaba
Reids Dome
Basement
S Source
R Reservoir
A Aquifer
Legend
• Major structural elements
• Major unconformities
• Coal measures sequences
• Effective maturity
• Effective reservoir/seal couplets
• Conventional discoveries
• CSG discoveries
Seismic Lines BMR84-14 & SH84-118

West of Leichardt fault is very poor CSG reservoir




LOSS OF METEORIC RECHARGE ON INDIVIDUAL SEAMS
INFLUENCE OF FAULTING PARALLEL TO SUBCROP
COAL SEAM A - POTENTIAL TO REMAIN HYDROGRAPHICALLY CONNECTED TO SUBCROP
COAL SEAM B - LOSES CONNECTION TO SUBCROP (INHIBITS BIOGENIC ACTIVITY)
POTENTIALLY LOWER GAS IN SEAM B COMPARED TO SEAM A
A
B
A
B




*Changes in gas characteristics with depth – Surat Basin*

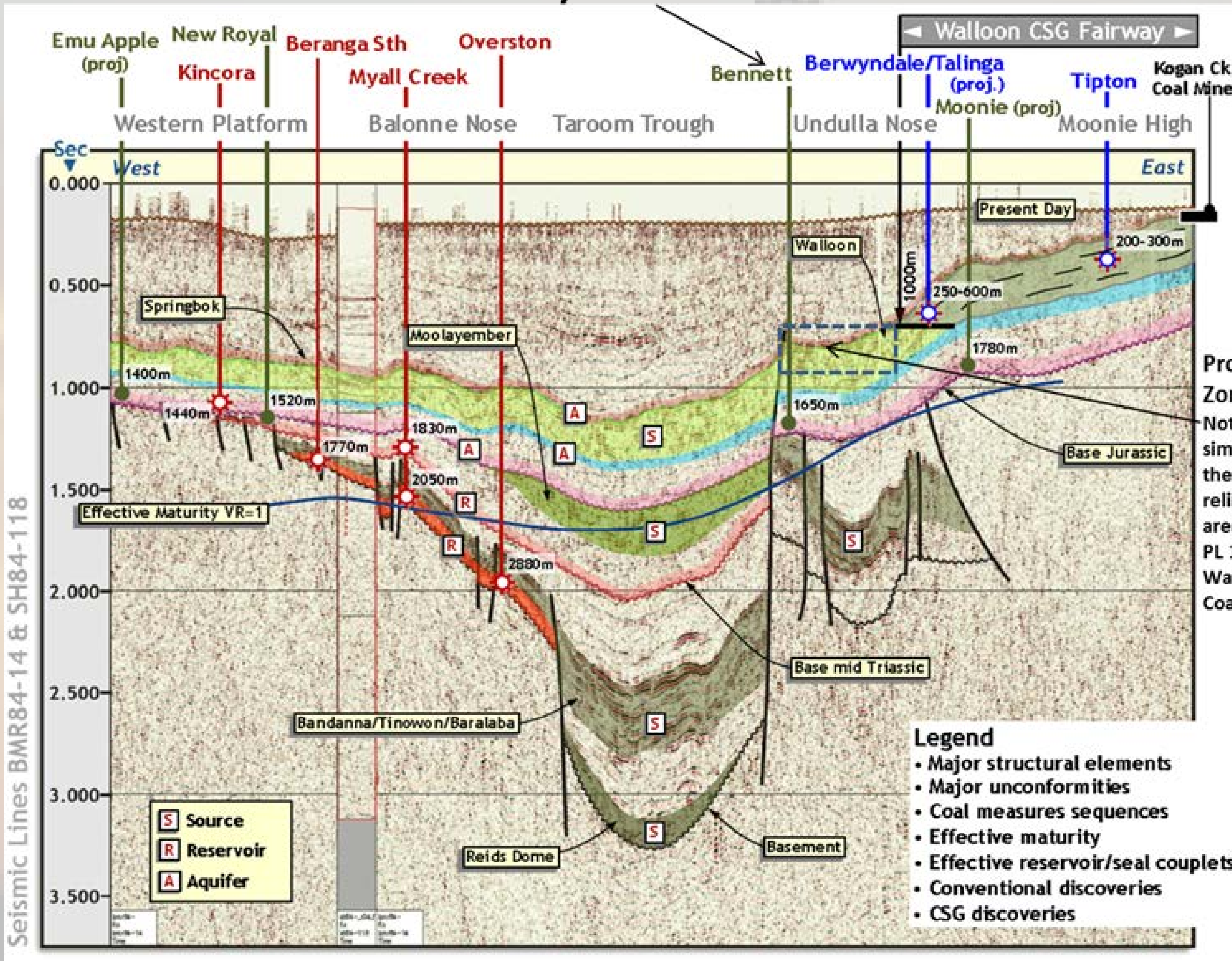
**Reserve estimation and the influence of coal seams on coal seam gas productivity**
Michael Creech, Bruce McConachie, SRK Consulting (AusIMM Bulletin, Feb, 2014)

| Location | Maximum distance from subcrop (km) | Maximum depth (m) | Estimate of general permeability (mD) |
|---|---|---|---|
| Surat Basin | 20-30 | 7-800 | <100 |
| Undulla Nose | 30-40 | 800 | 100s |
| Bowen Basin | 10-15 | 5-600 | <50 |
| Fairview | 10-15 | 1000 (steep dips) | <100 |
| Sydney Basin | 10-15 | 3-800 (variable) | <10 |
| Newcastle Coalfield | 5-10 | 4-500 | <5 |
| Gunnedah Basin | 15-20 | 6-800 | <10 |
| Ordos Basin, China | 5-10 | 6-700 | <5 |
| San Yuan Basin, USA | 50 | 1500 | 100s |
| General | 10-15 | 6-800 | Driven by permeability |

*Table 1. Influence of biogenic recharge – depth and distance from subcrop.*

**Reserve estimation and the influence of coal seams on coal seam gas productivity**
Michael Creech, Bruce McConachie, SRK Consulting (AusIMM Bulletin, Feb, 2014)

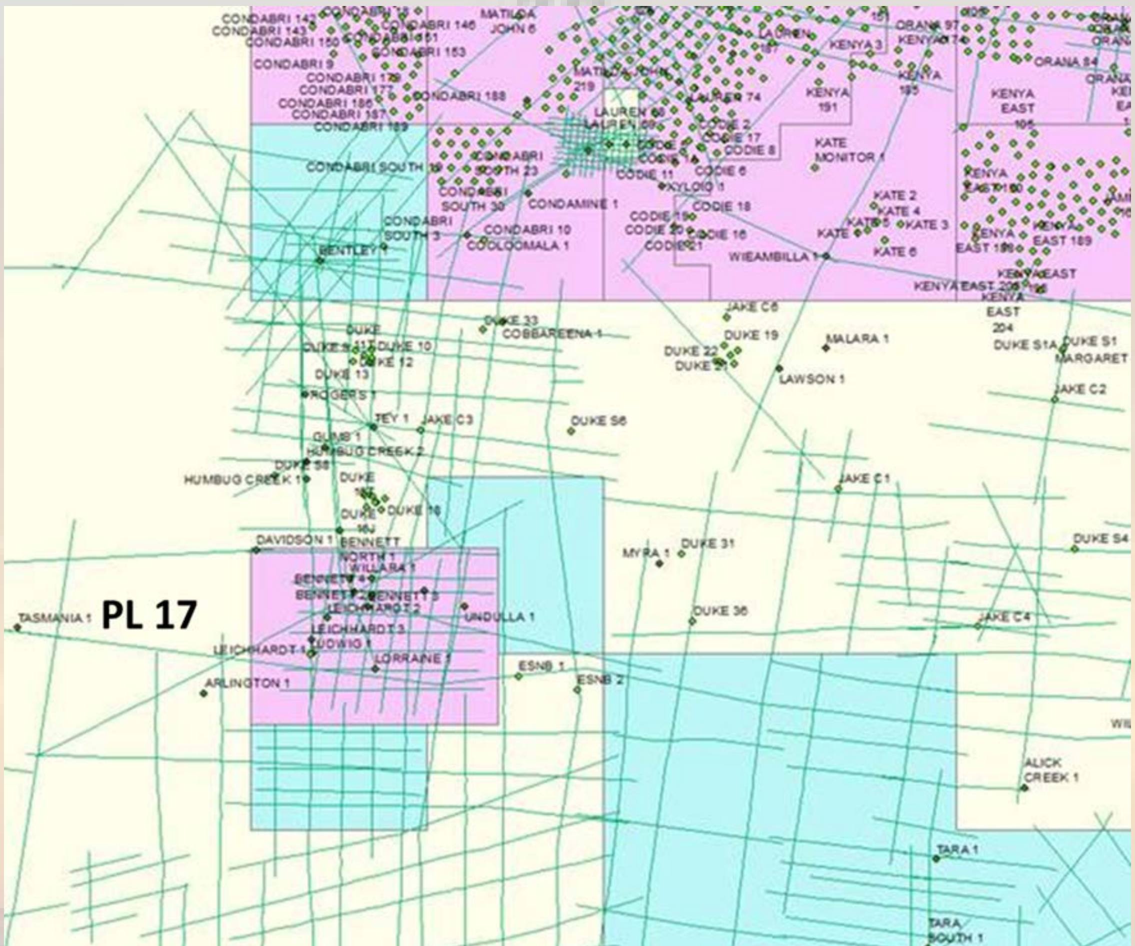
# Immediately north of PL17

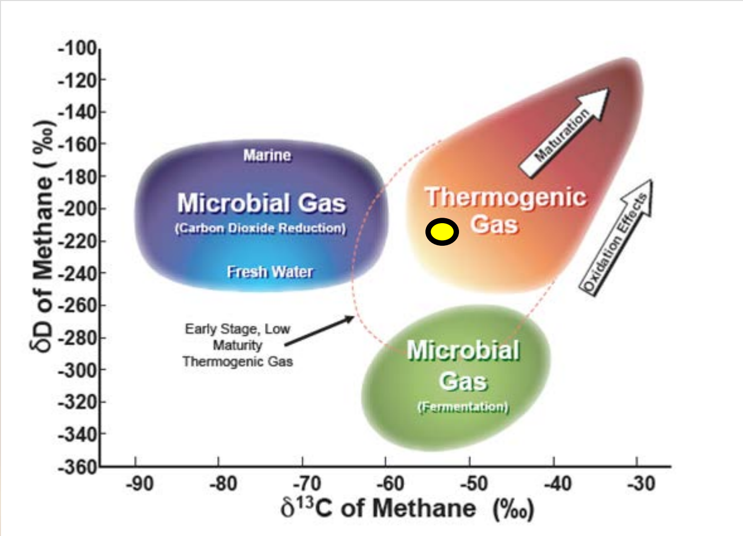



**Prospective Zone PL 17**

Note the similar depths for the Tru Energy relinquished area east of PL 17 at the Walloon Coal level

## Well locations in the Surat Basin








| Hydrogen | | | |
|---|---|---|---|
| *Run1* | *Run2* | *Average* | *Std dev* |
| -208 | -212 | -210 | 2.83 |
| -207 | -210 | -208 | 2.23 |
| -220 | -219 | -220 | 0.71 |

SANTOS QNT PTY LTD

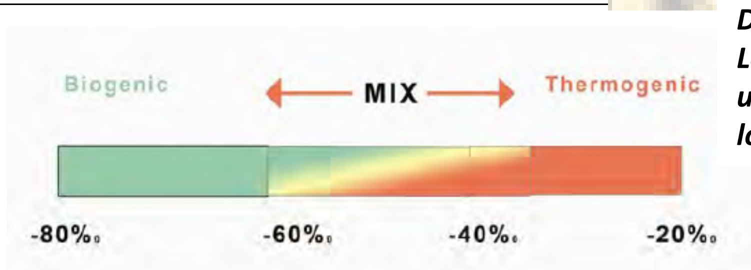
# LUDWIG 1

WELL COMPLETION REPORT

PL 17 - QUEENSLAND

**Company:** Santos Limited
**Well Name:** Ludwig-1
**Job Number:** 1132-06
**Date:** 7/07/2009

| Seam Name | δ13C Methane *Run1* | *Run2* | *Average* | *Std dev* |
|---|---|---|---|---|
| Upper Juandah | -54.5 | -54.1 | -54.3 | 0.28 |
| Lower Juandah | -51.9 | -52.0 | -52.0 | 0.07 |
| Taroom | -58.2 | -58.0 | -58.1 | 0.14 |



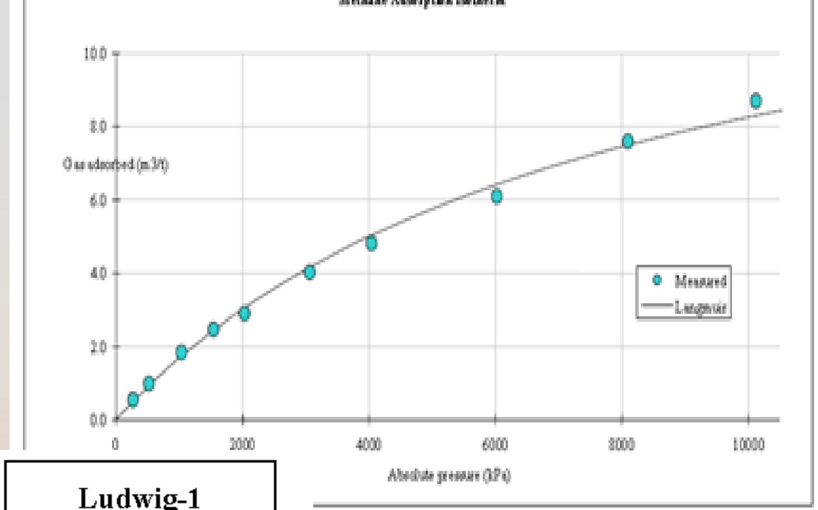

**Weatherford reported *"A total of five drill stem tests (DSTs) were run over the relevant coal seams. Water but no gas was recovered to surface during any of the DSTs indicating that the Upper Juandah, Lower Juandah and Taroom coals are under-saturated with respect to gas at this location".***


**Prepared by:**
GeoConsult
**Reviewed By:**
**A. Buck**

**For**
SANTOS QNT PTY LTD
A.B.N. 33 083 077 196
Level 14 Santos House
60 Edward Street
Brisbane Qld 4000
**October 2008**




Desorbed gas samples selected by the client were used for isotopic analyses. The results of the analysis for δ13CH$_4$ suggest a mixed biogenic and thermogenic origin for the gas in the coals which is common for sub-bituminous to bituminous ranked coals.




rm Parameters

| | | | |
|---|---|---|---|
| | Gas adsorbed (total gas) | | $V_L$(abs, daf) |
| quilbrium | $V_L$ (abs)= | 14.60 $m^3/t$ | 17.52 |
| | $P_L$ (abs)= | 7680 kPa | |
| | Gas content at 1 atm. | 0.19 $m^3/t$ | |

l gas ($m^3/t$)

| CH4 storage capacity of coal at seam depth (based on isotherm) |
|---|
| **8.16 $m^3/t$** |

# ACS Laboratories Pty Ltd

## GAS DESORPTION DATA SUMMARY

| Ludwig-1 |
|---|
| 5 |
| Upper Juandah |

**WELL NAME: Ludwig-1**

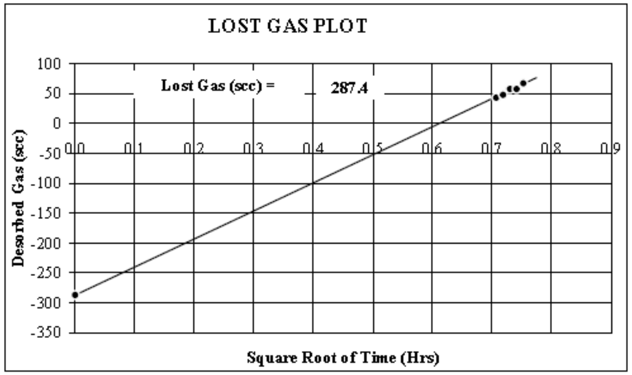
| SAMPLE DETAILS | | CAN DETAILS | | DESORBED GAS | | | |
|---|---|---|---|---|---|---|---|
| SAMPLE NO | 5 | CAN NO | D | USBM LOST GAS (scc) | 287.4 | RESIDUAL GAS (scc/g) | 0.07 |
| SEAM NAME | Upper Juandah | CAN LENGTH (m) | 0.5 | USBM LOST GAS (scc/g) | 0.16 | **TOTAL RAW GAS (scc/g)** | **1.81** |
| DEPTH FROM (m) | 1002.40 | CAN WEIGHT (kg) | 3.377 | | | | |
| DEPTH TO (m) | 1002.90 | CAN + SAMPLE WT (kg) | 5.228 | DESORPTION TEMP (°C) | 42.7 | DAF LOST GAS (scc/g) | 0.21 |
| THICKNESS (m) | 0.5 | SAMPLE WEIGHT (kg) | 1.851 | | | DAF DESORBED GAS (scc/g) | 2.10 |
| COAL LENGTH (m) | 0.5 | CAN VOLUME (cc) | 2200 | RAW DESORBED GAS (scc) | 2935 | DAF Q1 + Q2 (scc/g) | 2.31 |
| COAL WEIGHT (kg) | 1.851 | SAMPLE VOLUME(cc) | 1559 | RAW DESORBED GAS (scc/g) | 1.59 | | |
| CORE DIAM (mm) | 63 | CAN VOID SPACE (cc) | 641 | | | DAF RESIDUAL GAS Q3 (scc/g) | 0.09 |
| SAMPLE TYPE | Core | ESTIMATED VOID (cc) | 0 | RAW TOTAL DESORBED (scc/g) | 1.74 | DAF TOTAL GAS Q1+2+3 (scc/g) | 2.40 |

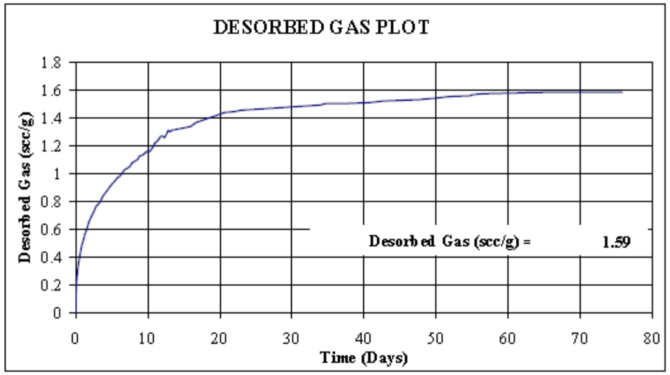
| CORE DETAILS | Date | Time |
|---|---|---|
| CORE PENETRATED | 5/13/2008 | 13:20:00 |
| CORE LEFT BOTTOM | 5/13/2008 | 15:30:00 |
| CORE AT SURFACE | 5/13/2008 | 15:48:00 |
| COAL IN CANISTER | 5/13/2008 | 16:05:00 |
| CORE ON TEST | 5/13/2008 | 16:08:00 |
| TIME ZERO | 5/13/2008 | 15:39:00 |

| COAL ANALYSIS DATA | |
|---|---|
| ASH % | 20.5 |
| VOLATILE MATTER % | 41.1 |
| INHERENT MOISTURE % | 4.0 |
| FIXED CARBON % | 34.4 |

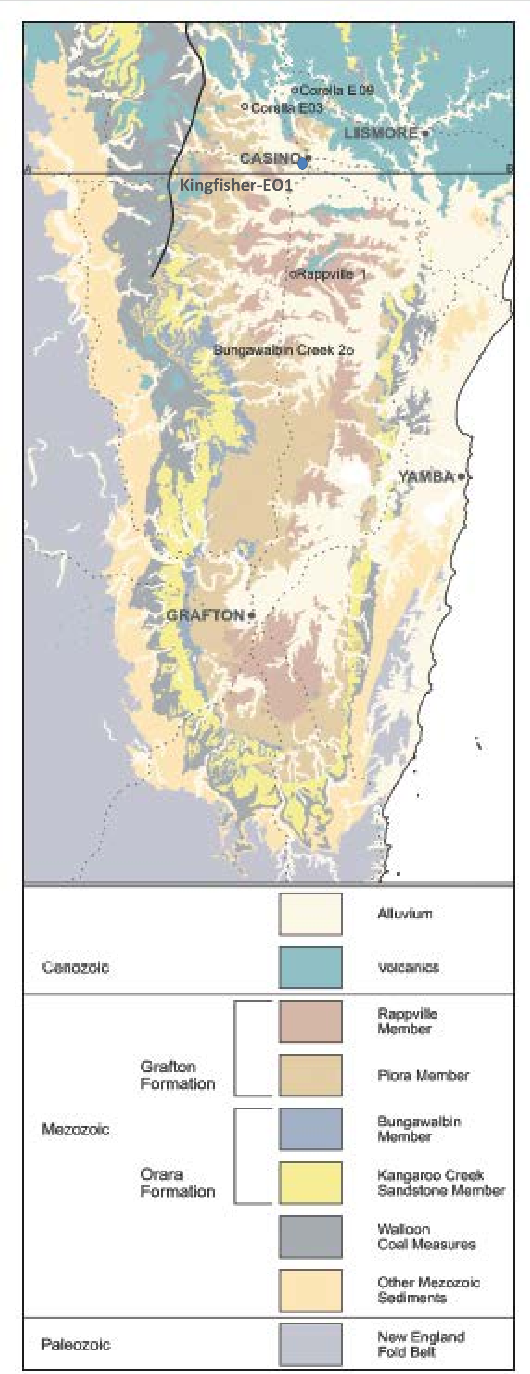
| DESORPTION TIME | Days |
|---|---|
| ON TEST | 75.8 |
| 63% Q2 | 6.4 |
| 63% Q1+Q2 | 5.3 |

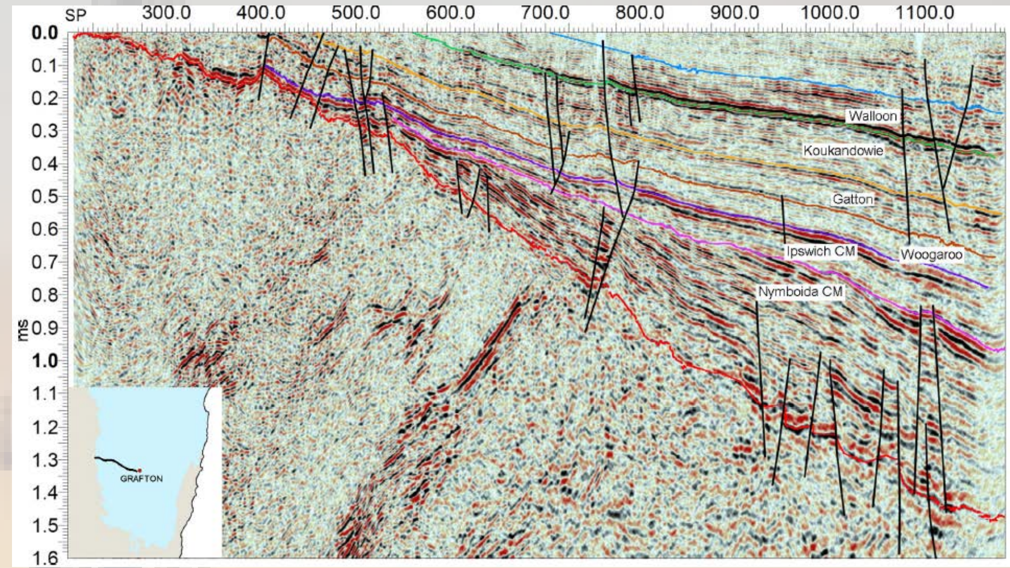
| GAS ANALYSIS (Air-Free) | Early | Late |
|---|---|---|
| CH4 (%) | 95.64 | 96.16 |
| C2H6 (%) | 0.02 | 0.02 |
| CO2 (%) | 0.34 | 0.66 |
| N2 (%) | 4.00 | 3.16 |



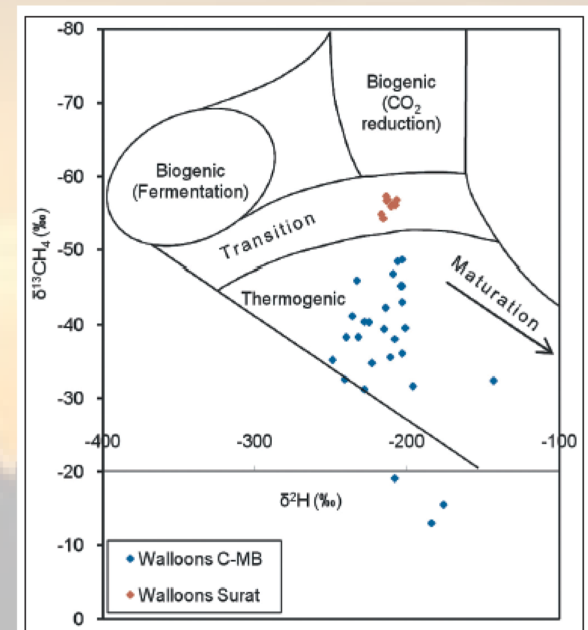



# Clarence Moreton Basin







**Tectonic environment at time of cleat formation:** Maximum and minimum horizontal stress magnitudes near equal and azimuths interchange .

David Titheridge

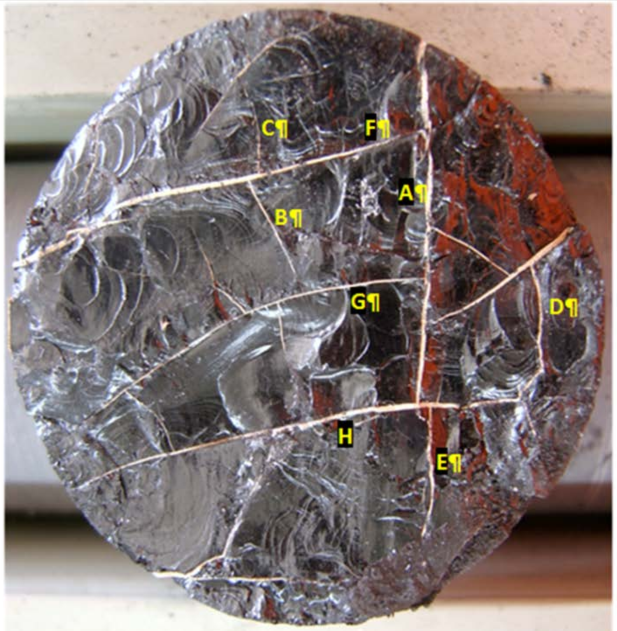



Figure 5. DH 54. Castor 2 Seam ~667m.

Orthogonal cleat system is present but face/butt relationships are not consistent.

"N-S" cleats are A, B, C, D, E. "E-W" cleats are F,G,H. F and G abut A, however A abuts H, and B abuts F etc.

Photo: SV408480

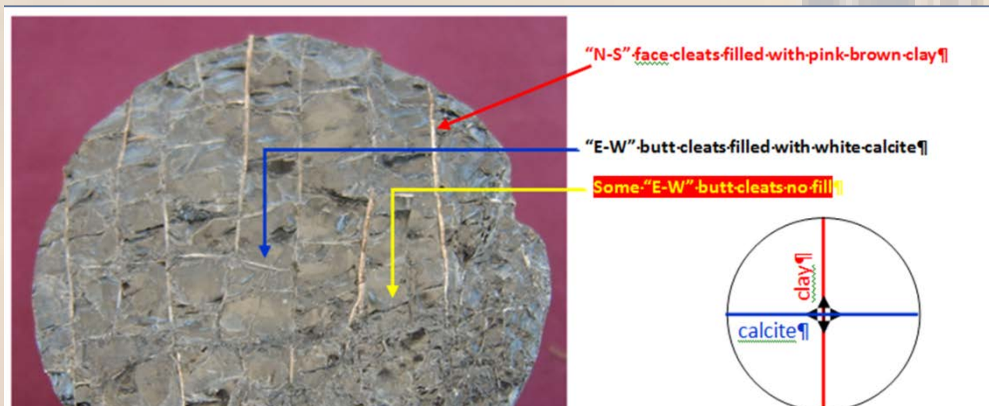
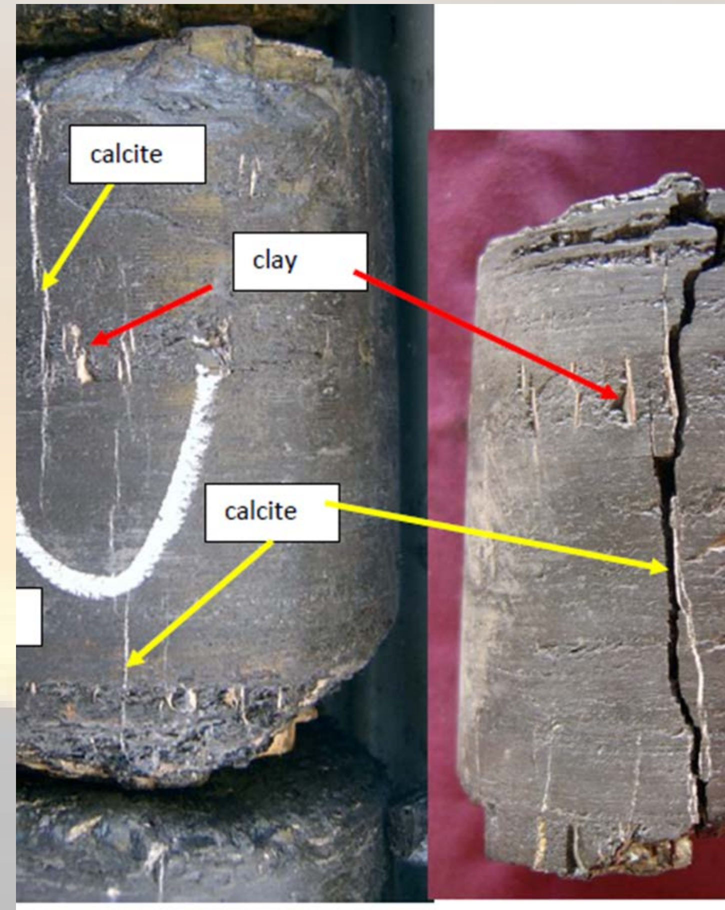
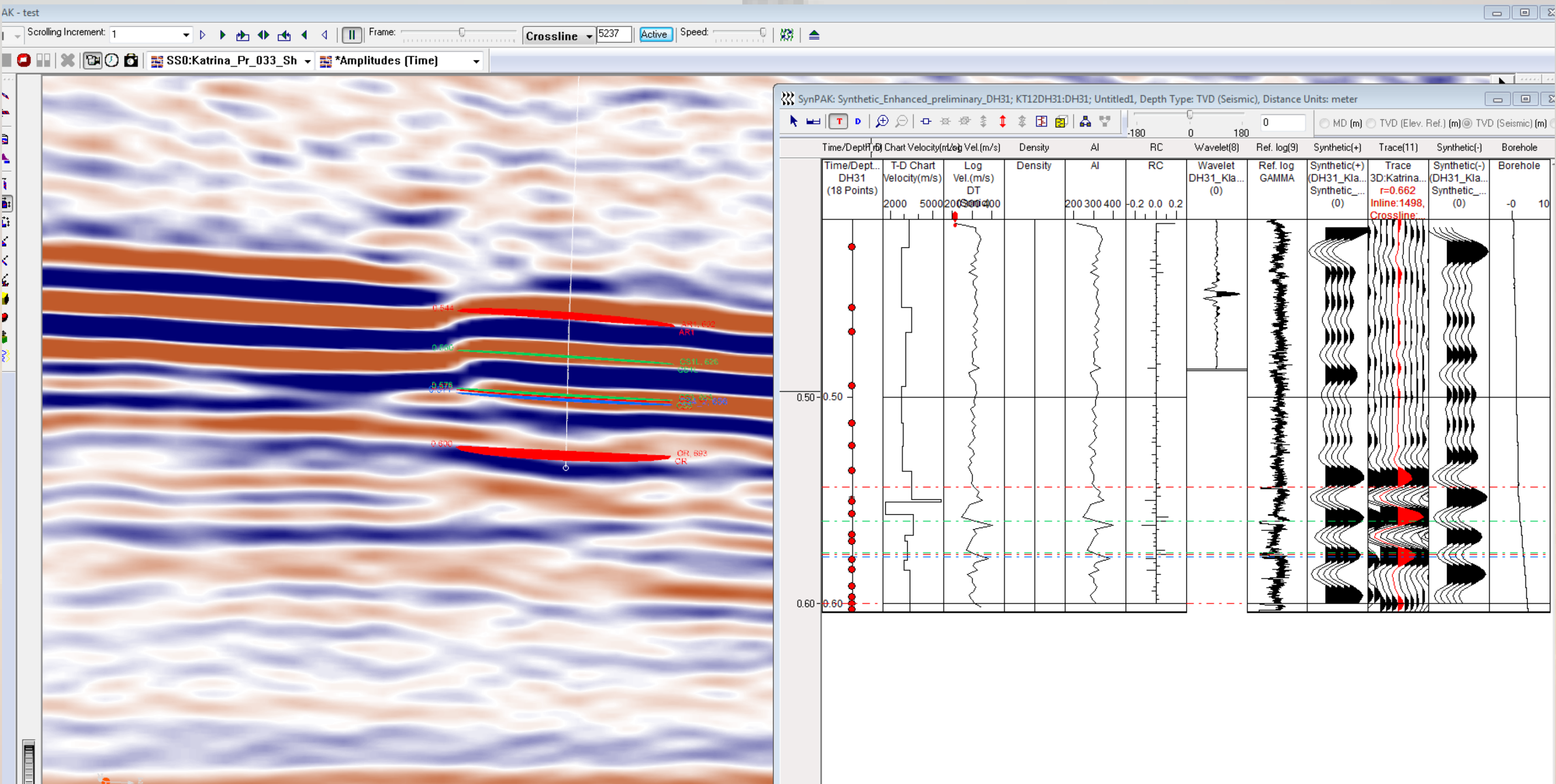


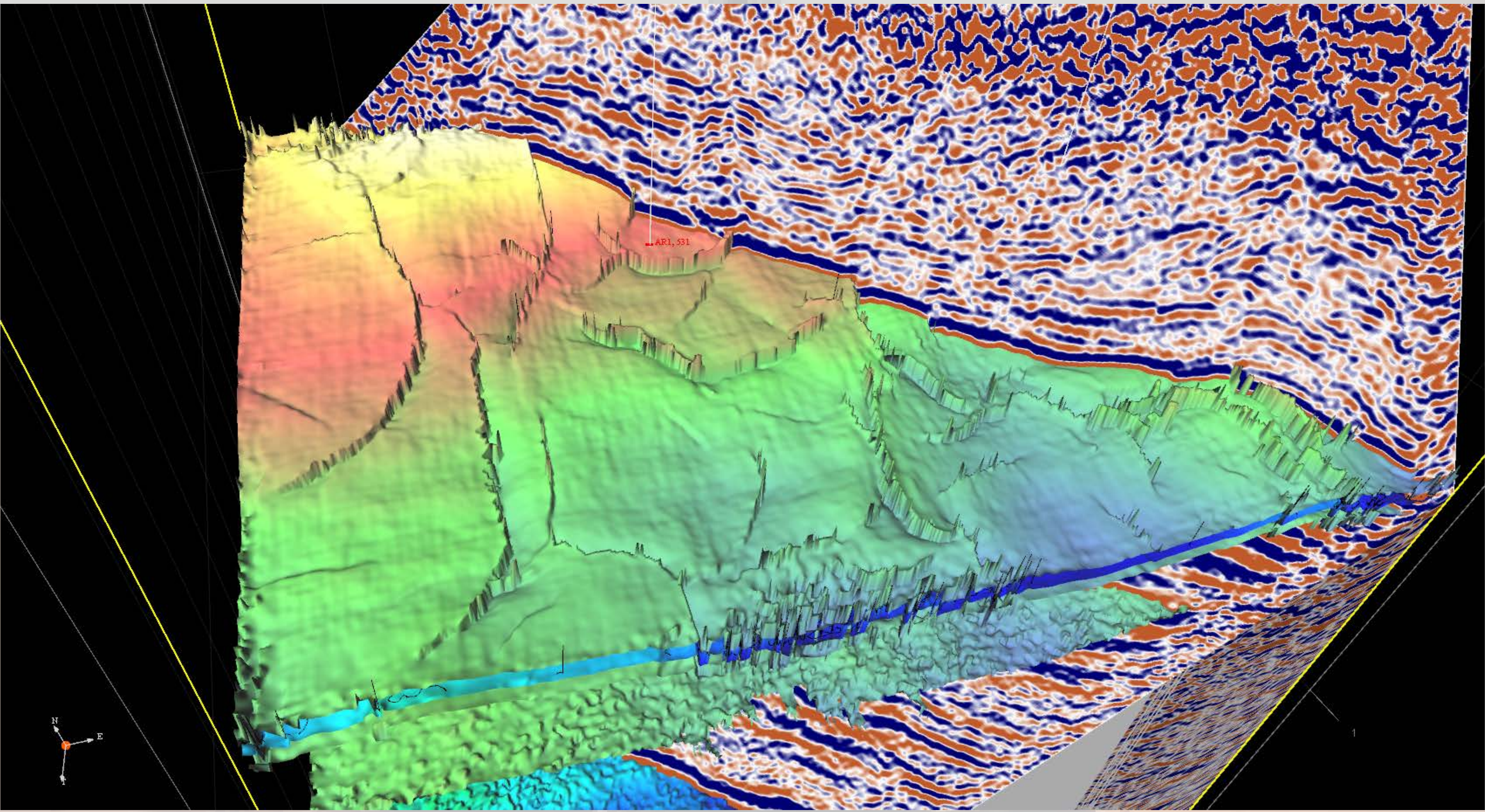

Figure 9. DH 60 Castor 4 Seam. Distinct orthogonal face and butt cleat. Face cleats clay filled, butt cleats filled with calcite or no fill. Photo: SV408268.



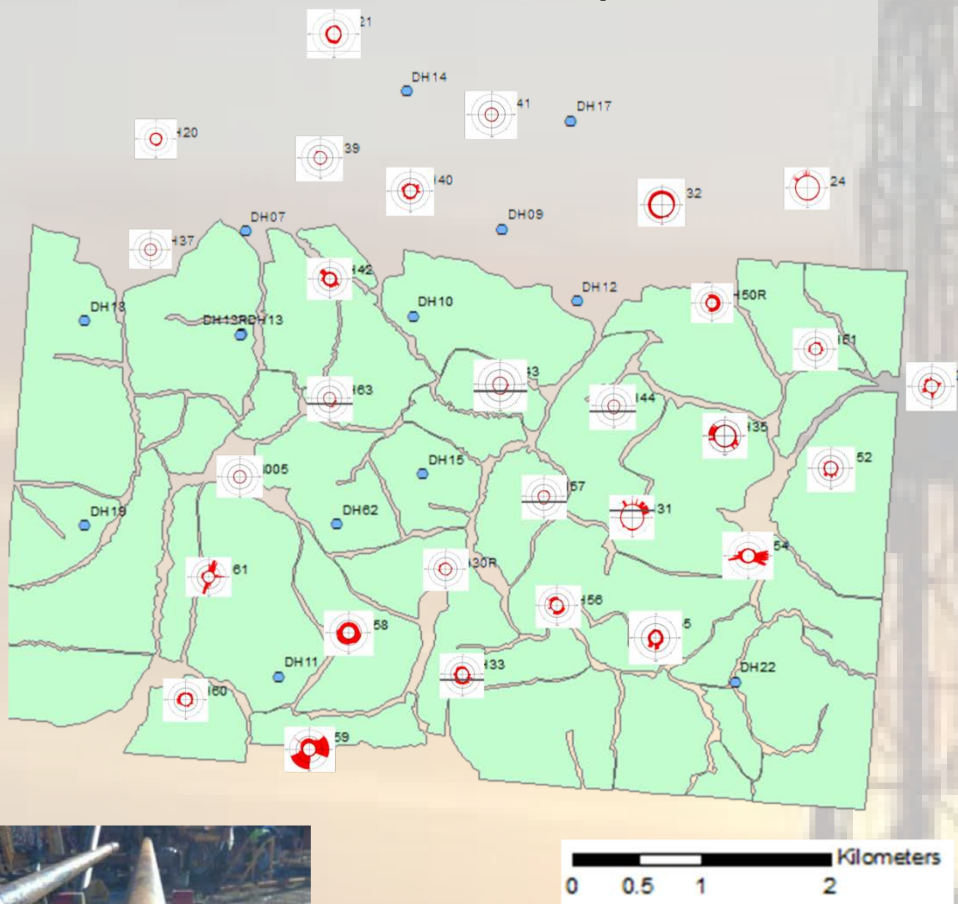
# Fault definition by synthetic generation and comparison



# Fault mapping from 3D seismic data in the southern Bowen Basin



# Well breakout plots across Bowen Basin 3D seismic area



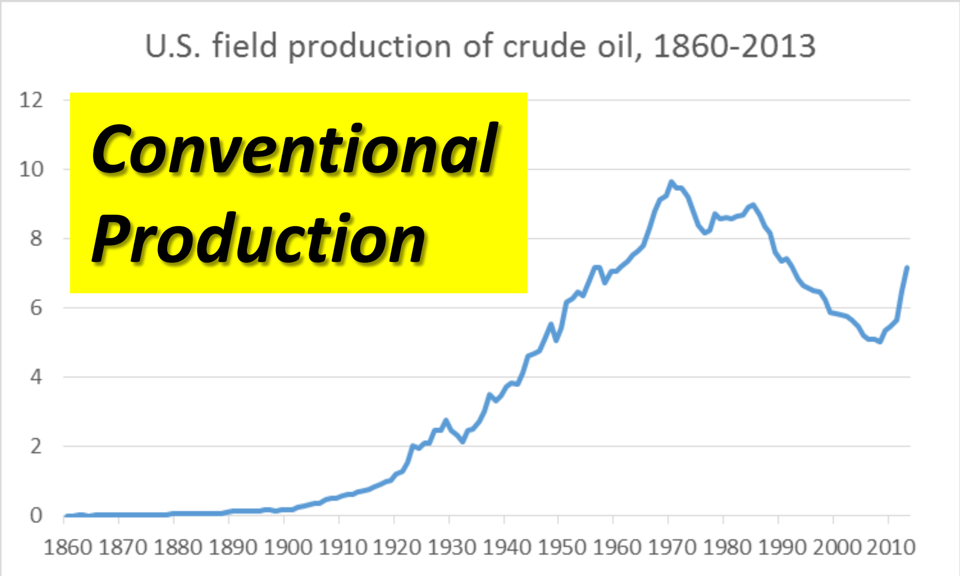

**Katrina**
**Evaluated safely under the Coal Legislation for $400k/drillhole**

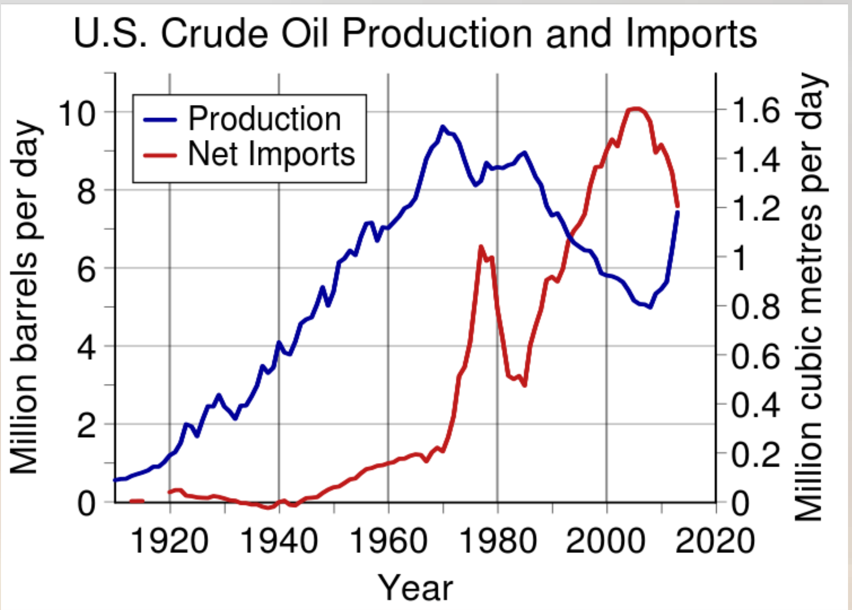
- These variations present a significant geological risk to exploration and field production estimates if not understood and quantified. There is a significant contrast between borehole spacing that is considered adequate for CSG reserve estimation and for coal reserve estimation:

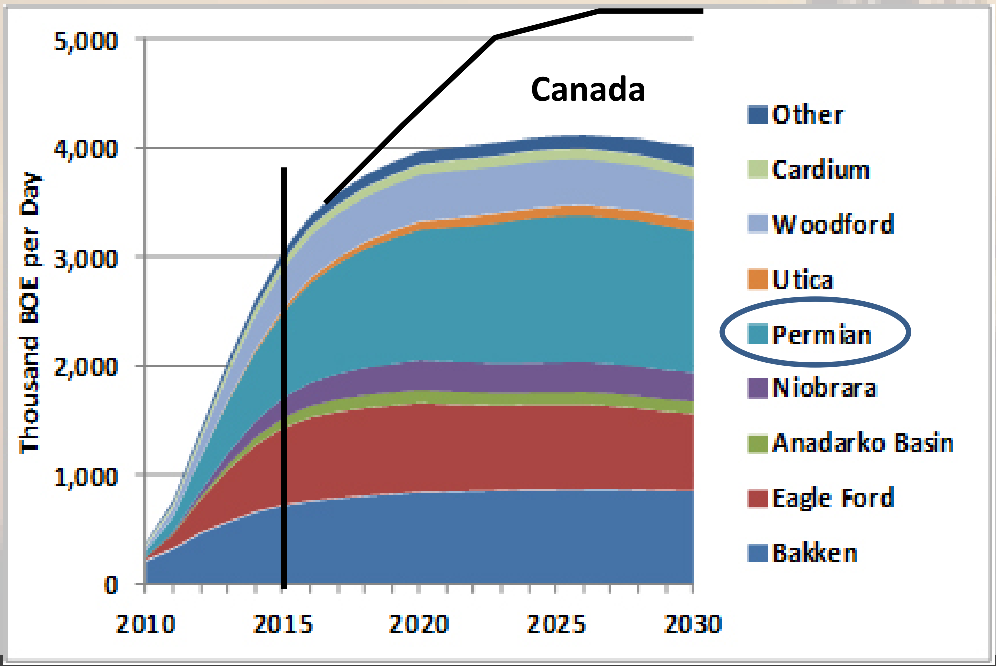
- Oil and Gas – Pilots up to 7 km apart, supportive boreholes at 1-2 km spacing.

- Coal – Points of Observation at 1km to 500m apart, supported by chip holes at half that distance to confirm seam continuity and correlations.

- This contrast in data density may be interpreted to suggest that CSG operators may often be blind to high frequency variations in gas saturation and therefore production.




**Peak**
**Unconventional Gas**
**in North America**
**maybe 2030**

# *Unconventional Gas and Oil Production*

## Where did it come from:

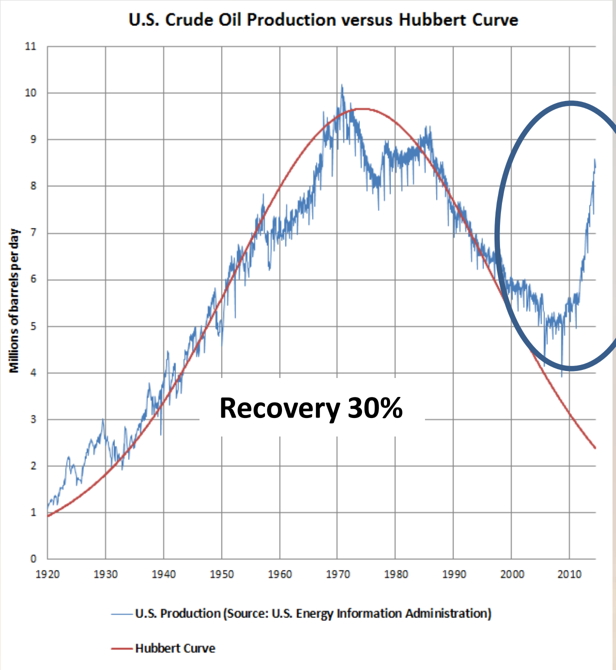
Its always been around but uneconomic or unrecogmised

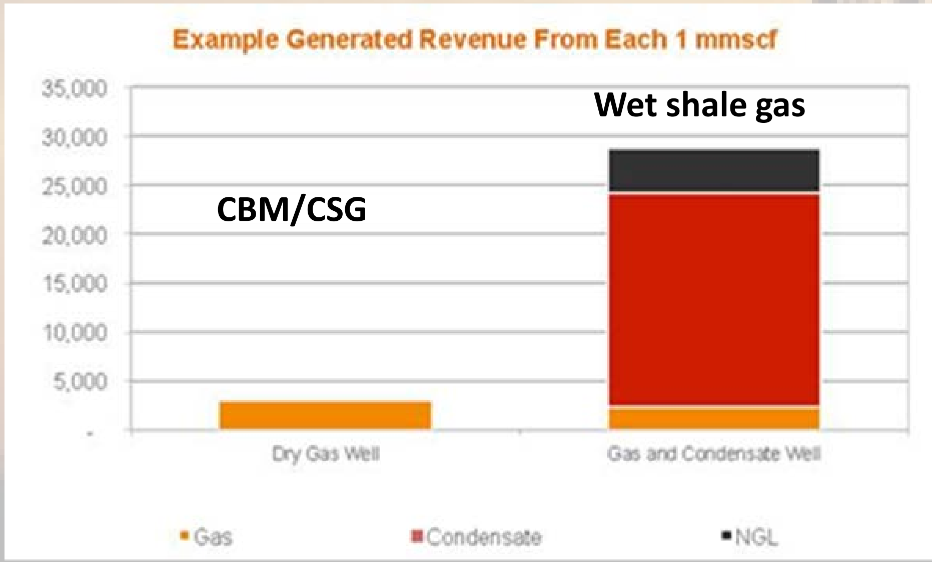
## Where is it going:

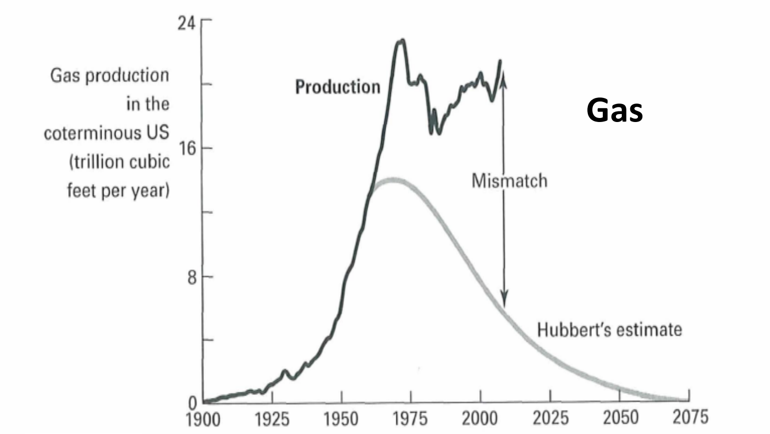
Further than you think

The cost curve is the key

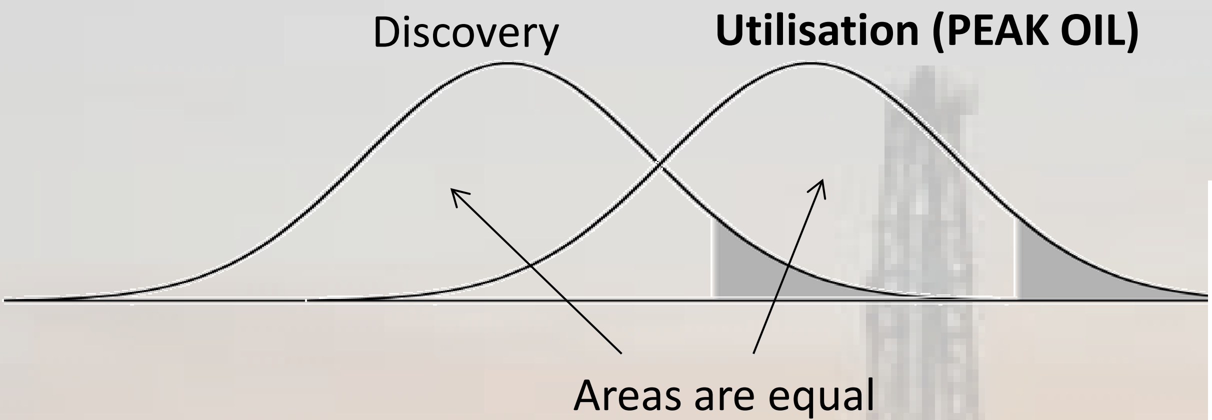
## Many basins exhibit the requirements for unconventional gas development



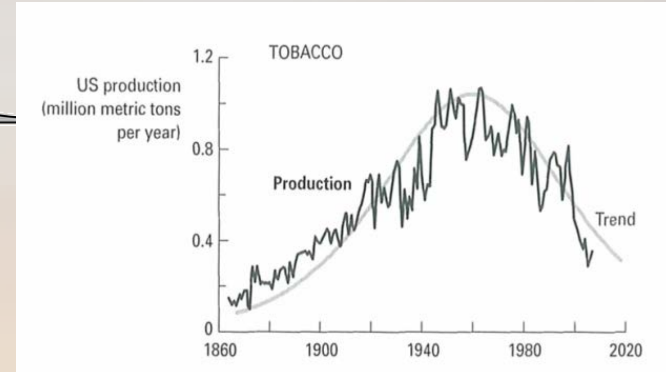




Comparison of 1956 Hubbert's prediction of US natural gas production with actual natural gas production data showing a significant mismatch. Hubbert's original curve in 1956 was drawn by hand (after Deming (2000)[18]). (Data: production from EIA and curve from Hubbert (1956)[19])

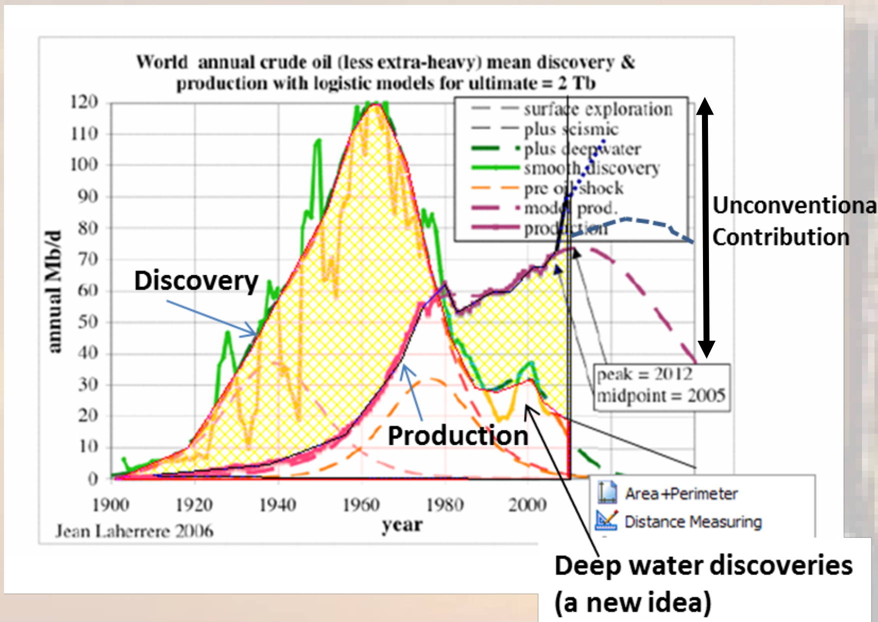


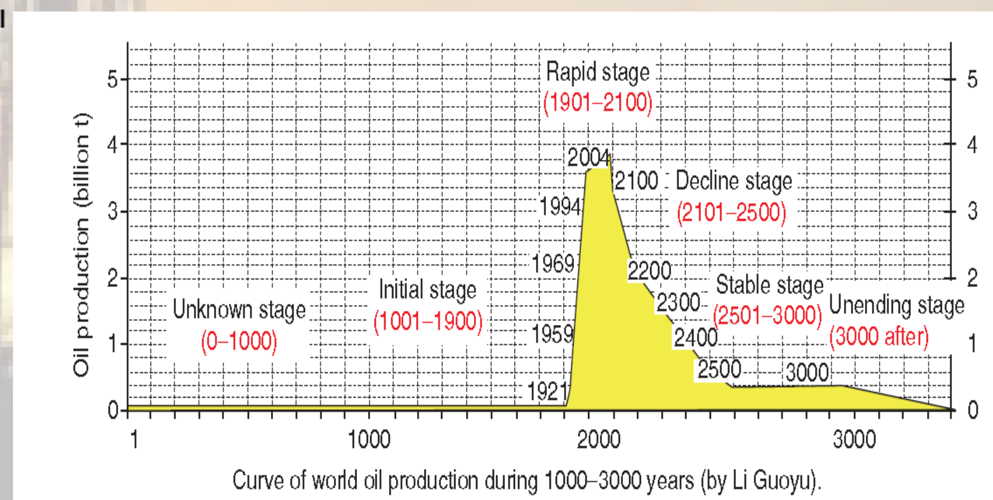

# Hubbert's Concept

Economic discoveries and economic utilisation



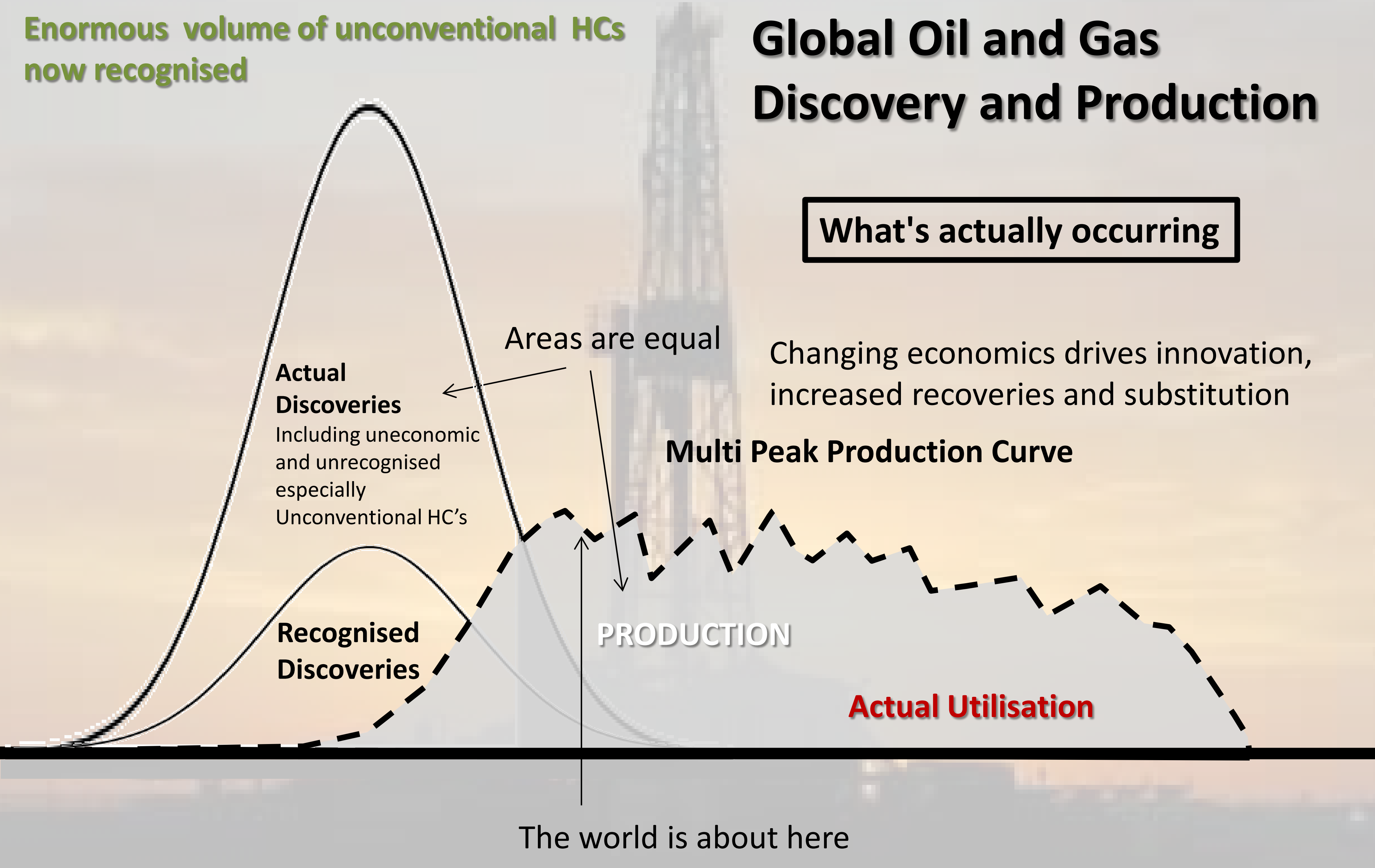

# Peak Oil
# - a misleading concept

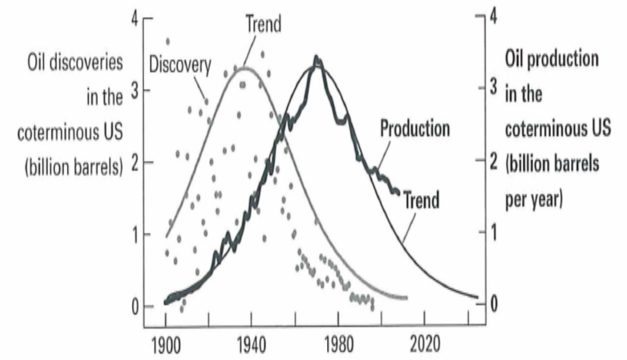


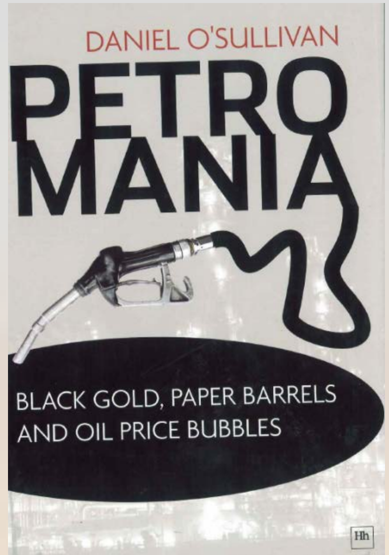

Graph of world oil production, with postulated production up to the third millenium.

# Global Oil and Gas Discovery and Production

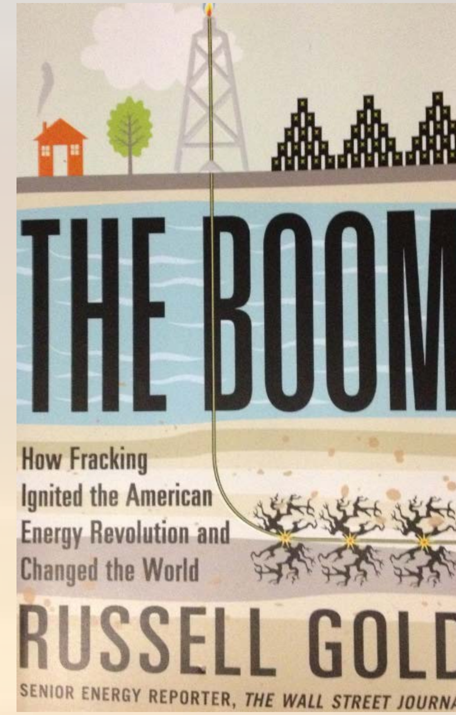


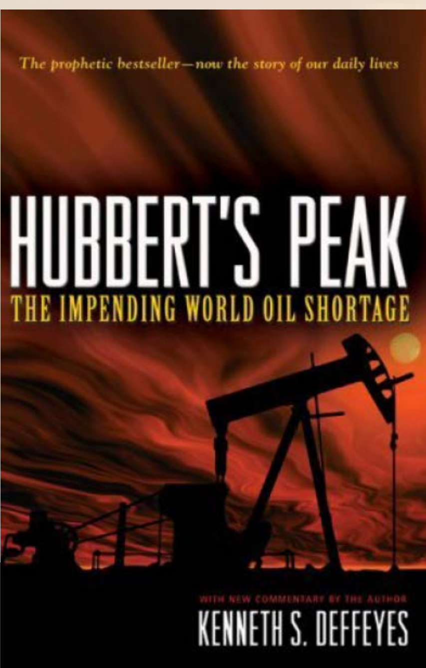


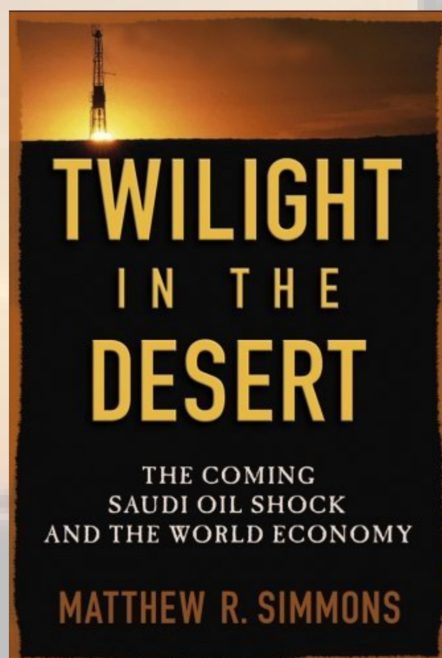

Peak in 1935 of oil discoveries in the US lower 48 states and corresponding peak in US lower 48 state oil production in 1970. Note: a similar analysis and figure is presented by Laherrère.[56] (Data: production, EIA; discovery, Klett (2003)[57])

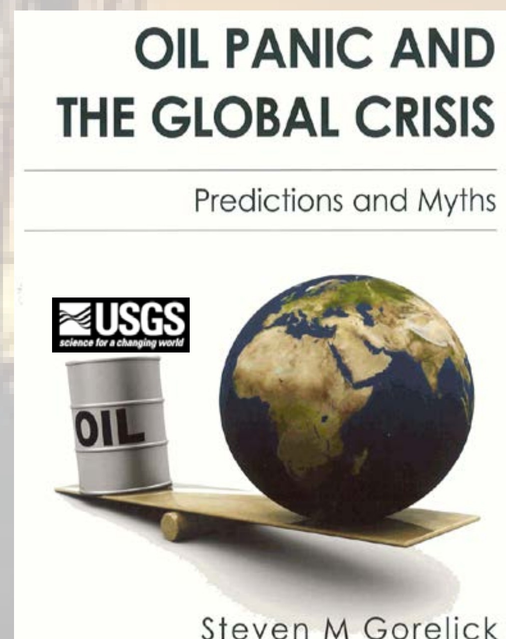



# "Black Gold" or
# "Devils Excrement"



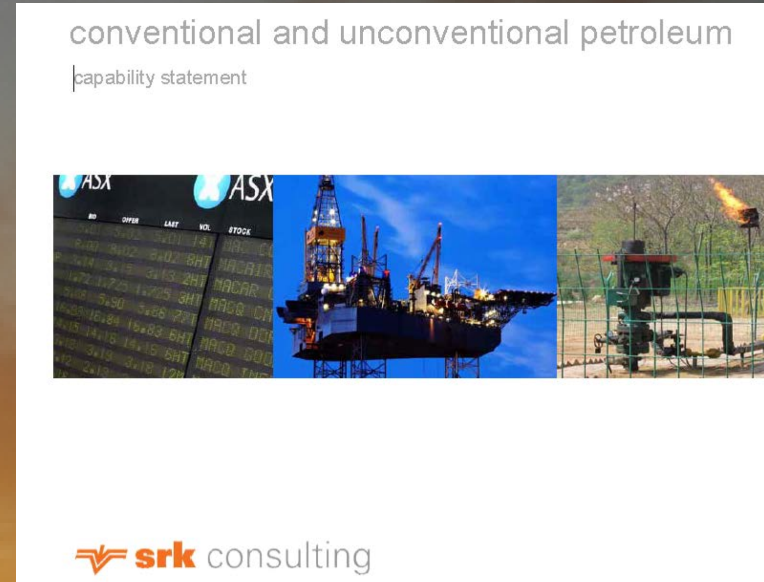



# Acknowledgements

**AGL Limited**

**SRK Consulting Australia**

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**China 3 projects**
**USA 1 project**
**Canada 1 project**
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**South Africa 1 project**

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