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

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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


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
"Unconventional" Natural Gas Reservoirs

Geologically complex and low permeability (<0.1 md normally) gas reservoirs that require special (non-standard) evaluation and technology.

Reservoir Spectrum

“Tight Sand” Fractured “Shale” Coal

Organic Content, wt. %

Gas Filled Porosity (Compression)

Water Filled Porosity

Gas Filled Micropores (Adsorption)

Organic Content

Non-Clay Matrix
Clay Solids
Clay Bound Water
Organic Matter
Adsorbed Gas
Free Shale Porosity
Free Matrix Porosity
Water + HC
Free Gas

Non-Shaley Solids
Shale Solids
Total Porosity

Shale

Effective Porosity + Free Shale Porosity

NSAI (2012)
Coal seam gas containment versus Pressure

adsorbed, free and total gas isotherms for methane in coal
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

Gas Saturation and pressure are important

Undersaturation
May or may not be a problem
depending on the amount and type of potential water production
Gas adsorbed in CSG

CSG/CBM Criteria

Gas Generation as a Function of Coal Rank

- Increasing coal rank
- Increasing gas volume

- Lipid
- Sub-bituminous
- Bituminous
- Lignite
- Anthracite
- Graphite
- Thermally-derived

- Methane
- Biogenic methane
- Nitrogen

- Carbon dioxide

- Water

- Methane

- Stable production stage
- Decline stage
- Dewatering production stage

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

- Gas generation in coal. As temperature and pressure increase, coal rank changes along with its ability to generate and store methane. Through time, devolatilization occurs, causing shrinkage of the coal rank and creation of endogenetic cleats.
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%

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

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

Associated Gases in Coal and Reserves Designations

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

Coal has a higher affinity for carbon dioxide than methane or nitrogen.
Reserves and Resources as classified by PRMS (not to scale)
West of the Leichhardt Fault has very poor reservoir characteristics.
Deeper Basin area
To the north...
West of Leichhardt 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
Changes in gas characteristics with depth – Surat Basin

Reserve estimation and the influence of coal seams on coal seam gas productivity
<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum distance from subcrop (km)</th>
<th>Maximum depth (m)</th>
<th>Estimate of general permeability (mD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surat Basin</td>
<td>20-30</td>
<td>7-800</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Undulla Nose</td>
<td>30-40</td>
<td>800</td>
<td>100s</td>
</tr>
<tr>
<td>Bowen Basin</td>
<td>10-15</td>
<td>5-600</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Fairview</td>
<td>10-15</td>
<td>1000 (steep dips)</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Sydney Basin</td>
<td>10-15</td>
<td>3-800 (variable)</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Newcastle Coalfield</td>
<td>5-10</td>
<td>4-500</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Gunnedah Basin</td>
<td>15-20</td>
<td>6-800</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Ordos Basin, China</td>
<td>5-10</td>
<td>6-700</td>
<td>&lt;5</td>
</tr>
<tr>
<td>San Yuan Basin, USA</td>
<td>50</td>
<td>1500</td>
<td>100s</td>
</tr>
<tr>
<td>General</td>
<td>10-15</td>
<td>6-800</td>
<td>Driven by permeability</td>
</tr>
</tbody>
</table>

Table 1. Influence of biogenic recharge - depth and distance from subcrop.
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
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”.

Desorbed gas samples selected by the client were used for isotopic analyses. The results of the analysis for $\delta^{13}$CH$_4$ suggest a mixed biogenic and thermogenic origin for the gas in the coals which is common for sub-bituminous to bituminous ranked coals.
WELL NAME: Ludwig-1

SAMPLING DETAILS

- SAMPLE NO: 5
- SEAM NAME: Upper Juandah
- DEPTH FROM (m): 1002.4
- DEPTH TO (m): 1002.9
- THICKNESS (m): 0.5
- COAL LENGTH (m): 1.85
- COAL WEIGHT (kg): 63
- CORE DIAM (mm): 58
- SAMPLE TYPE: Core

SAMPLE DETAILS

- CAN NUMBER: 1
- CAN NO: 1
- CAN WEIGHT (kg): 3.377
- CAN VOLUME (cc): 2200
- CAN WEIGHT (kg): 511312008
- CAN VOLUME (cc): 641
- CAN VOLUME (cc): 159
- CAN VOLUME (cc): 0

CORE DETAILS

- CORE PENETRATED: 5.3.08
- CORE AT SURFACE: 5.3.08
- Core: 5.3.08
- TIME ZERO: 5.3.08

COAL ANALYSIS DATA

- ASS %: 20.5
- VOLATILE MAT %: 41.1
- FIXED CARBON %: 34.4
- INHERENT MOISTURE %: 40
- CH4 (%): 75.8
- CO2 (%): 4.4
- H2 (%): 5.3
- N2 (%): 5.3
- C2H6 (%): 0.09
- C2H4 (%): 0.02
- CO (%): 0.54
- CO2 (%): 0.66
- O2 (%): 0.4
- O2 (%): 6.4
- H2 (%): 5.3

DESORPTION TIME

- DESORBED GAS: 287.4 (sec)
- RESIDUAL GAS (sec/g): 0.16
- TOTAL RAW GAS (sec/g): 1.91
- DAF LOST GAS (sec/g): 0.21
- DAF DESORBED GAS (sec/g): 2.16
- DAF Q1+Q2 (sec/g): 2.31
- DAF RESIDUAL GAS Q3 (sec/g): 0.09
- DAF TOTAL GAS Q1+Q2+Q3 (sec/g): 2.40

RESIDUAL GAS Q3 (sec/g): 0.09

GAS ANALYSIS (Air-Free)

- Early: 95.64
- Late: 96.16
- Early: 75.8
- Late: 4.4
- Early: 4.4
- Late: 5.3
- Early: 5.3
- Late: 5.3
- Early: 0.09
- Late: 0.02
- Early: 0.54
- Late: 0.66

LOST GAS PLOT

- Lost Gas (sec) = 287.4

DESORBED GAS PLOT

- Desorbed Gas (sec/g) = 1.59
Tectonic environment at time of cleat formation: Maximum and minimum horizontal stress magnitudes near equal and azimuths interchange.

David Titheridge
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.
Conventional Production

U.S. field production of crude oil, 1860-2013

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 unrecognised

Where is it going:
Further than you think
The cost curve is the key

Many basins exhibit the requirements for unconventional gas development
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.
Changing economics drives innovation, increased recoveries and substitution.

Areas are equal

Enormous volume of unconventional HCs now recognised

Global Oil and Gas Discovery and Production

What's actually occurring

Changing economics drives innovation, increased recoveries and substitution

Multi Peak Production Curve

Actual Discoveries
Including uneconomic and unrecognised especially Unconventional HC’s

Recognised Discoveries

Actual Utilisation

The world is about here

srk consulting
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.26 (Data: production, EIA; discovery, Klett (2003))

“Black Gold” or “Devils Excrement”
Acknowledgements

AGL Limited

SRK Consulting Australia

SRK Recent Unconventional Project experience in Shale Gas, Coal Seam Gas and Tight Gas
Australia >15 projects
China 3 projects
USA 1 project
Canada 1 project
Botswana 1 project
South Africa 1 project

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