CBM Reservoir

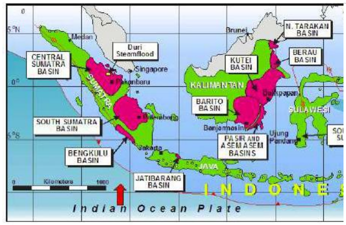
Adsorption (Gas content)

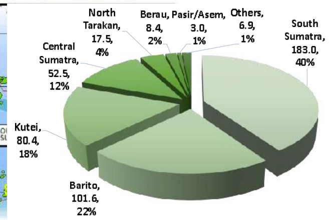
Ferian Anggara

Outline

- Overview
- Adsorption (Gas content)
- Porosity
- Permeability (Cleat system)
- Gas Flow
- Reserve Analysis
- Dynamic reservoir
- Enhanced recovery

Coal and CBM resources in Indonesia





Stevens and Hadiyanto, 2004

Coal bed methane (CBM):

337-453 Trillion cubic feet

Coal resources and reserves

Quality		Resources Million tons)		Reserve (Million tons)			
Class	Calorific Value (cal/gram)	Total	%	Probable	Proven	Total	%
Low	< 5,100	21,227.63	20.18%	7,603.88	1,105.40	8,709.28	41.21%
Medium	5,100 - 6,100	69,726.02	66.29%	7,063.52	2,904.41	9,967.93	47.17%
High	6,100 - 7,100	13,220.61	12.57%	861.73	1,410.44	2,272.17	10.75%
Very High	> 7,100	1,013.19	0.96%	73.29	109.18	182.47	0.87%
Total		105,187.44	100.00%	15,602.41	5,529.43	21,131.85	100.00%

LRC (Low, Medium, High) — HRC → Very High

Geological agency, 2010

Taylor et al., 1998:

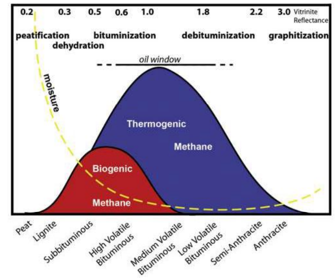
LRC: Low rank coal → < 7000 cal/gram

HRC: High rank coal → > 7000 cal/gram

What is Coal Gas?

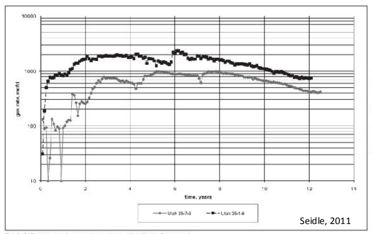
- This gas was considered one of the many hazards of coal mining
- Recently: unconventional resources
- Gas is generated during maturation of organic matter into coal and by microbes residing in a coal
- Coal deposits of all geologic ages have generated gas

Schematic showing biogenic and thermogenic gas generation



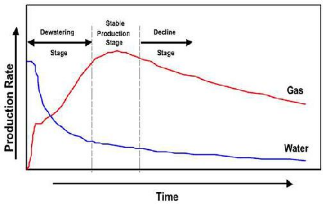
Moore, 2012

Typical of CBM Production Curve



Seidle, 2011

Fig. 1–2. Examples of slow negative decline—Uinta Basin, Ferron coal



Conventional Gas Vs. CBM

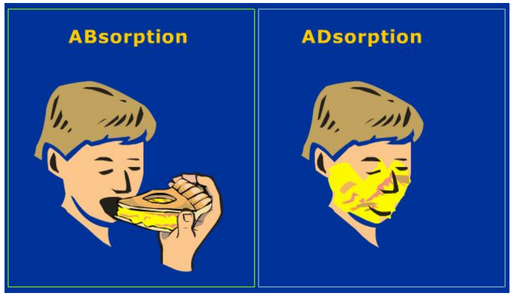
Conventional Gas	Coalbed
Darcy flow of gas to wellbore.	Diffusion through micropores by Fick's Law. Darcy flow through fractures.
Gas storage in macropores; real gas law.	Gas storage by adsorption on micropore surfaces.
Production schedule according to set decline curves.	Initial negative decline.
Gas content from logs.	Gas content from cores. Cannot get gas content from logs.
Gas to water ratio decreases with time.	Gas to water ratio increases with time in latter stages.
Inorganic reservoir rock.	Organic reservoir rock.
Hydraulic fracturing may be needed to enhance flow.	Hydraulic fracturing required in most of the basins except the eastern part of the Powder River basin where the permeability is very high. Permeability dependent on fractures.
Macropore size:[3] 1μ to 1 mm	Micropore size:[3] <5A° to 50A°
Reservoir and source rock independent	Reservoir and source rock same.
Permeability not stress dependent.	Permeability highly stress dependent.
Well interference detrimental to production.	Well interference helps production. Must drill multiple wells to develop.

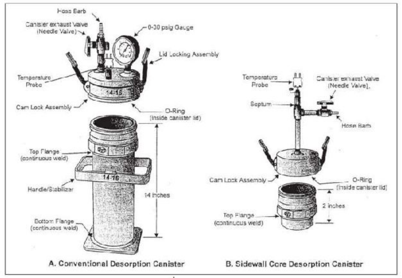
Levine, 1990

Outline

- Overview
- Adsorption (Gas content)
- Porosity
- Permeability (Cleat system)
- Gas Flow
- Reserve Analysis
- Dynamic reservoir
- Enhanced recovery

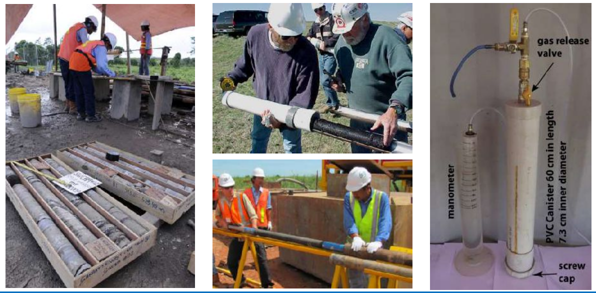
ADsorption vs ABsorption





Seidle, 2011

Sampling



Moore, 2012
Chiper coal, 2015

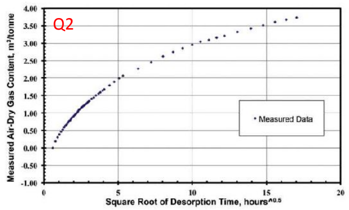
Gas desorption measurements

1. Lost gas (Q1)
   is the calculated amount of gas that has potentially been lost from the time the core leaves the reservoir at depth to when it is placed within a canister at the surface
2. Measured gas (Q2)
   the gas which is directly desorbed from the canister and measured using a manometer
3. Residual gas (Q3)
   - After a sample is either 'fully' desorbed or when the operator decides that enough has been measured to achieve the desired goals of the sampling, the coal is removed from the canister
   - Crushing coal to approximately 250 μm size particles, which has gas tight seals and a gas lead from which the gas evolved can be removed for measurement.

Total gas volume = Q1 + Q2 + Q3

Moore, 2012

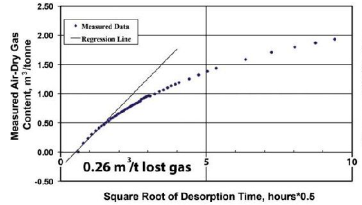
Q2& Q3 calculation



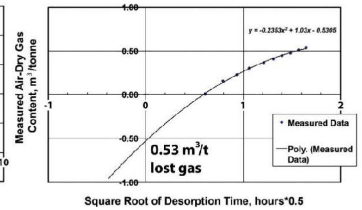
Moore, 2012

Q1 calculation

Linear regression



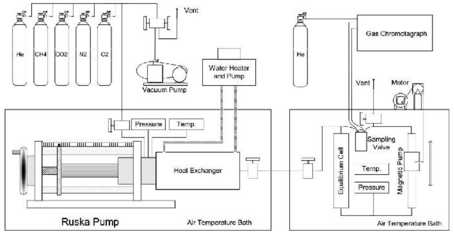
2nd order polynomial regression



Moore, 2012

Adsorption test

PVT Apparatus, Kyushu University-Japan



Gasem et al., 2009

Adsorption test

Client	Micah Global CBM
Sample Location	Brandon Basin Tonto Mine

Gas	Methane
Sample No	Rollo-20-7A
Formation	Jasper Fm
Depth (m)	**410**
Easting	N/A
Northing	N/A
Density (t/m³)	1.33

Adsorption Equation

$$V = \frac{a \cdot P}{P + b}$$

where
V - Gas content (m³/t)
P - Pressure (kPa)
a - Langmuir Volume (m³/t)
b - Langmuir Pressure (kPa)

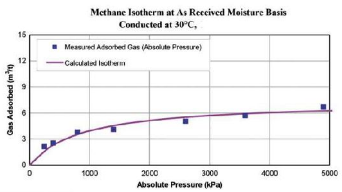
Proximate Analysis (%)	
Inherent Moisture	3.3
Ash	1.1
Volatile	32.8

Test Summary

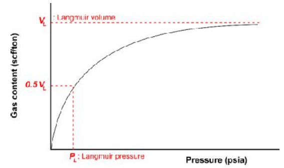
Absolute Pressure (kPa)	Gas Adsorbed (m³/t) Measured	Gas Adsorbed (m³/t) Calculated
101		0.77
251	2.09	1.65
401	2.50	2.32
801	3.78	3.53
1401	4.07	4.54
2601	5.01	5.51
3601	5.67	5.92
4901	6.67	6.25

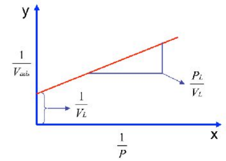
Isotherm Parameters

Parameter	At Gauge Pressure	At Absolute Pressure
a - Langmuir Volume (m³/t)	**6.59**	**7.36**
b - Langmuir Pressure (kPa)	**971.72**	**870.40**
Calculated gas content at 1 atm =	**0.77**	m³/t



Langmuir parameters





$$Vads = V_L \frac{p}{P_L + p} \qquad \frac{1}{V_{ads}} = \frac{P_L}{V_L}\left(\frac{1}{p}\right) + \frac{1}{V_L}$$

Gas saturation

1. **Desorption Isotherms**
   - "slow", "fast" or "in between"
   - reservoir temperature
2. **Adsorption Isotherms**
   - reservoir temperature
   - fresh samples!

%g = 1-((a-d)/a)*100

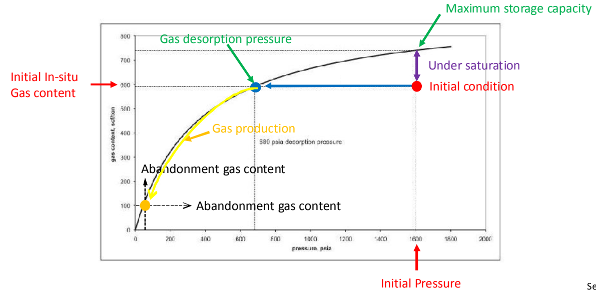
where,
%g, is gas saturation
a, is maximum gas holding capacity [adsorption]
d, is total measured gas [desorption]

Moore, 2010

- But different types of coal can hold more or less gas (i.e. different coals have different holding capacities)

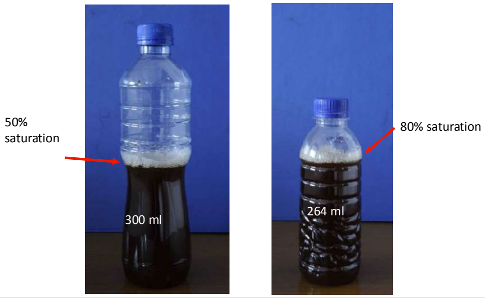
Moore, 2010

Gas saturation and desorption pressure



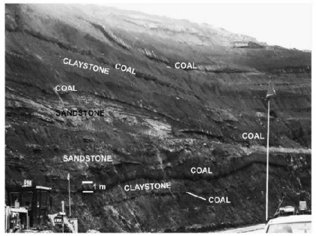
Seidle, 2011

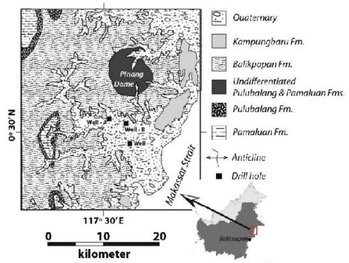
Which deposit would you pick?



Moore, 2010

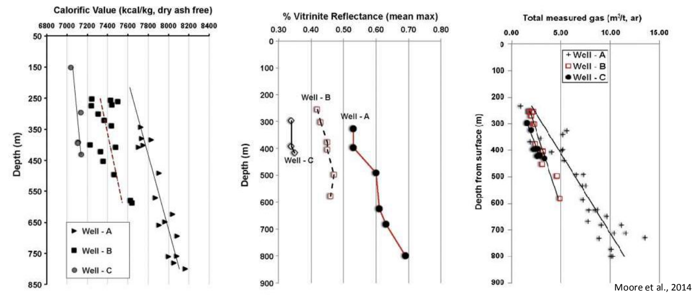
Coal properties & Gas content





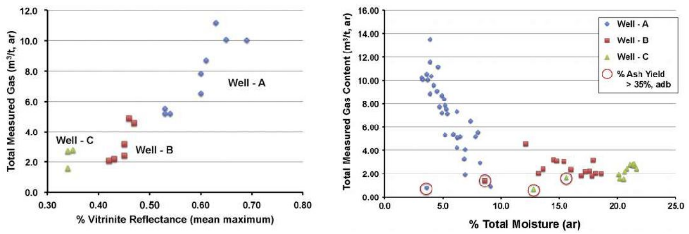
Moore et al., 2014

Coal properties & Gas content



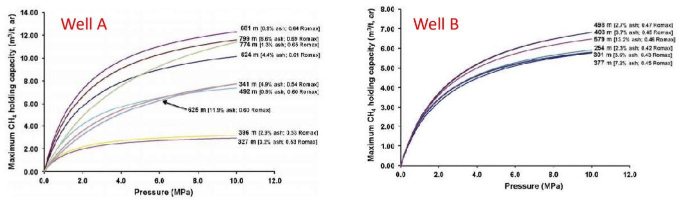
Moore et al., 2014

Coal properties & Gas content



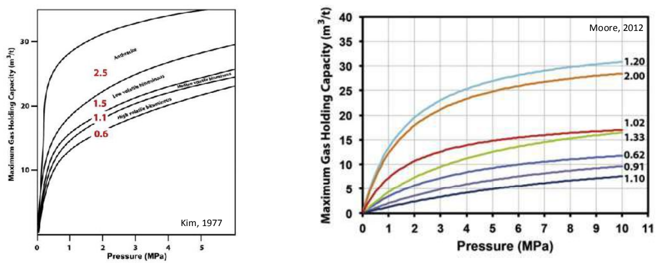
Moore et al., 2014

Adsorption isotherms



Moore et al., 2014

Adsorption isotherms related to rank



Rank–gas relationships shown are in general correct, they are far from universally observed

Gas in-place (GIP)

GIP= A x CT x d x GC

- A : area or distribution of coal being estimated
- CT: coal thickness
- d : density
- GC: gas content

Moore, 2010

End