Similarities and Contrasts Between Coalbed Methane and Shale Gas: Gas holding Mechanisms and Relationship to Resource/Reserve Estimates

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UGAS, Jakarta, Indonesia
19 – 20th November, 2013

Cipher Report #13-051

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OUTLINE OF PRESENTATION

- Scope/purpose of talk
- Definitions
- Why are these resources important?
- Character of a good play
- Pores and why they are important
- Gas holding & saturation mechanisms
- Resources & reserves: how to calculate
- Learnings and Transferables

Scope/Purpose of Talk

- Identify the importance of both CBM and Shale Gas in the world's energy mix
- What makes a good play in either of the two types of deposits
- Note importance of PORES
- Reserve/resource estimates

- Things that WON'T be covered are:
  - All the issues – can't be done here - e.g. drilling techniques, production profiles, water disposal issues etc
  - Pass on a cook book recipe to develop either CBM or Shale Gas

Why are both CBM & Shale Gas termed 'unconventional resources'?

Shale Gas

- Tight (low perm)
- Source & Reservoir
- Gas held within pores of both organic & clastic grains

Coalbed Methane

- Tight (low perm – mostly!)
- Source & Reservoir
- Gas held within pores of organic grains

Definitions

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Coalbed Methane:

Naturally occurring methane that forms from the organic materials from the coal and is stored within the coal. Thus the coal is both the source and reservoir. The gas can be formed biogenically or thermogenically. The gas is stored primarily through adsorption on to the coal surface within micropores. CBM is always thought of as an 'unconventional petroleum system.

Shale Gas:

Also naturally occurring methane (commonly with some proportion of C_4H_{10}, C_2H_6, and C_3H_6) that is present in organic-rich shale and associated lithologies. The gas is thought to be primarily sourced in situ from organics but stored in both organic and inorganic porosity systems. Shale gas can be part of a petroleum system with both unconventional and conventional gas accumulations.

5

Definitions – Coalbed Methane

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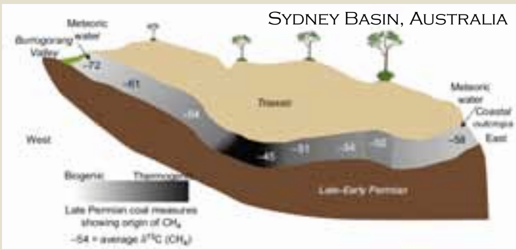
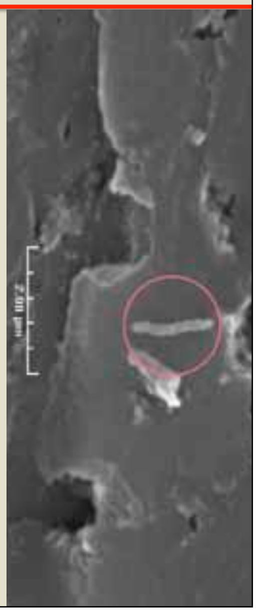
Biogenic



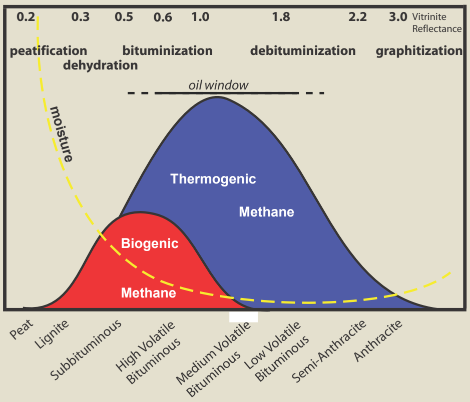


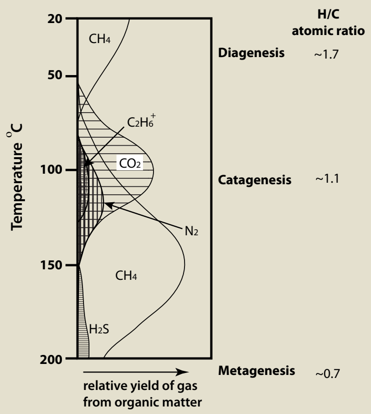
6

Modified from Flores et al. (2008); Faiz & Hendry (2006); Flores (2013)

Definitions – Coalbed Methane

Thermogenic

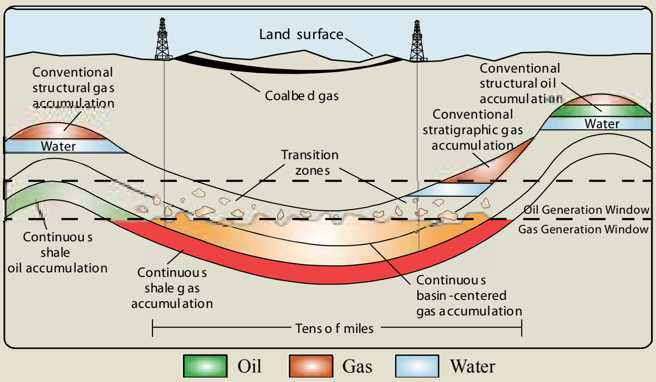




7

modified from Hunt (1979) and Moore (2012)

Definitions – Shale Gas



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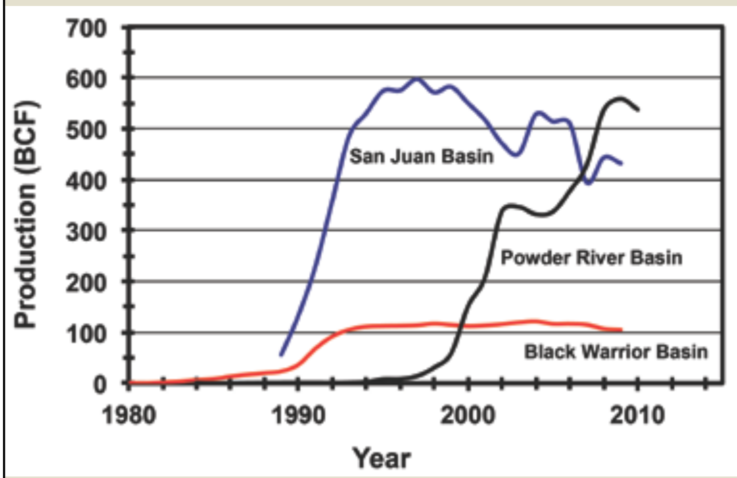
Modified from Charpentier & Ahlbrant (2003)

Why Are These Resources Important?
Coalbed Methane

Coalbed Methane Production in the USA

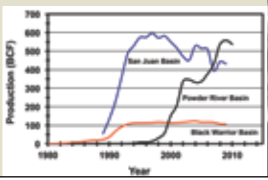


9

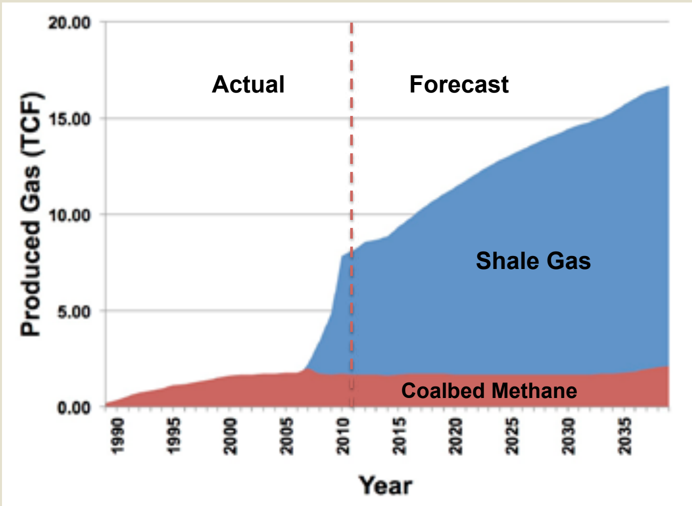
Modified from Moore (2012)

Why Are These Resources Important?
Coalbed Methane

- **Economic consequences**:
  - **Additional ‘dry’ gas supply**
  - **Relatively cheap discovered gas costs**
  - **Significant additional royalty tax for key US and Australian states**
- **Why did production come on line so fast?**
  - **Early tax incentives for exploration and development (Powder River Basin)**
  - **Government mandate on gas usage (Australia)**
  - **Clear regulatory regime, government leadership (USA & Australia)**



Why Are These Resources Important?
Shale Gas



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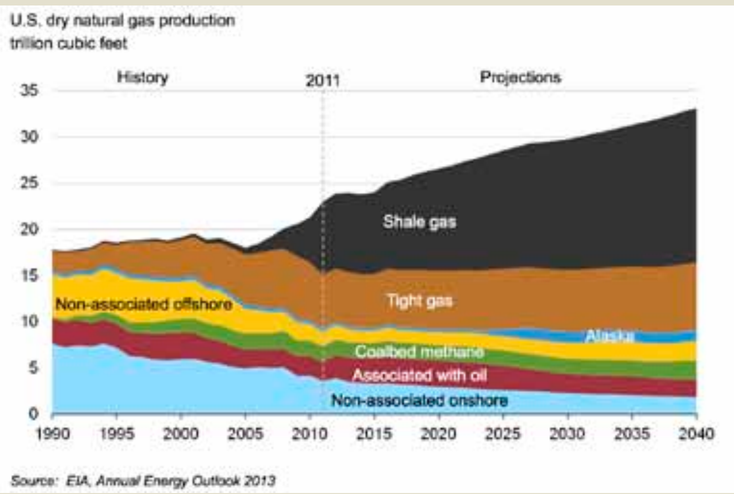
Modified from U.S. EIA (2011)

D. Duncan, USGS, 2010

Why Are These Resources Important?
Shale Gas



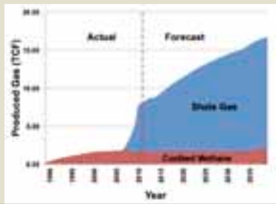
12

from Sieminski, 2013, U.S. EIA

D. Duncan, USGS, 2010

Why Are These Resources Important?
Shale Gas:

- **Economic consequences**:
  - **Decoupling of O&G market prices,**
  - **Electrical generation from coal fell,**
  - **Price of natural gas fell.**
- **Why did production come on line so fast?**
  - **Established regulatory framework & a physical infrastructure,**
  - **Private ownership,**
  - **Very competitive service industry,**
  - **Large domestic frack sand resource,**
  - **Few political obstacles.**



Character of a Good Play

Coalbed Methane:

- Reservoir depths <500 m, best <400 m
- Permeability >50 mD
- Gas saturations >60%
- Coal bed thickness >10 m for low rank coals, >2 m for higher rank coals
- Low ash (<10%, ideal)
- Non complex geology
- Area of recharge for biogenic enhancement
- Easy, inexpensive water disposal/treatment options
- Access to infrastructure/market

14

Character of a Good Play

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Shale Gas:

- High gas-in place content
- Permeability (> 100 nD)
- Organic richness (>2% TOC)
- Thermal maturity (>1.1 %$R_{o,}$ over mature oil-prone source rocks)
- Porosity (>4%)
- Water saturation (<45%)
- Oil saturation (<5%)
- Clay content and clay type (<50% clay)
- Quartz (>50%, recrystallized opaline best)
- Extensive thickness and areal extent
- Depth (>1,000 m)
- Non-complex geology

15

Importance of Pores: CBM

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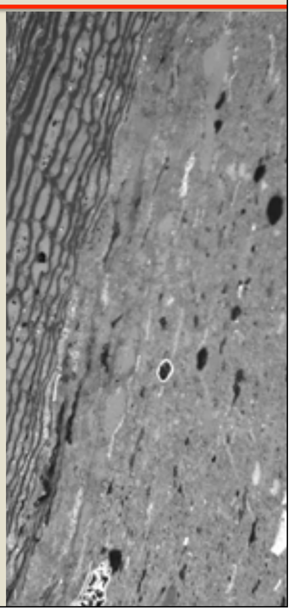
- It's the surface area of the pores which control gas holding capacity
- Thus, its better to have smaller, more abundant pores, than fewer larger ones
- Most gas is thought to be held in the microporosity (< 2 um) … or smaller…
- The greater number of pores also increases diffusion rate of methane through the matrix
- Porosity can be either 'open' or 'closed', with the latter perhaps not contributing to recoverable gas resources.



16

Importance of Pores: Shale Gas

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- It's the nanoporosity (1-500 nm) in bitumen or other organic material that controls most of the gas storage in producing shale formations.
  - Although some pores are in inorganic material (e.g. clay and pyrite)
- Nanoporosity results from exsolution of gaseous hydrocarbons during thermal cracking of oil.
- Porosity can be either 'open' or 'closed', with the latter perhaps not contributing to recoverable gas resources.
- Porosity and bulk gas volumes are often related to TOC content.

17

Controls on Gas Potential

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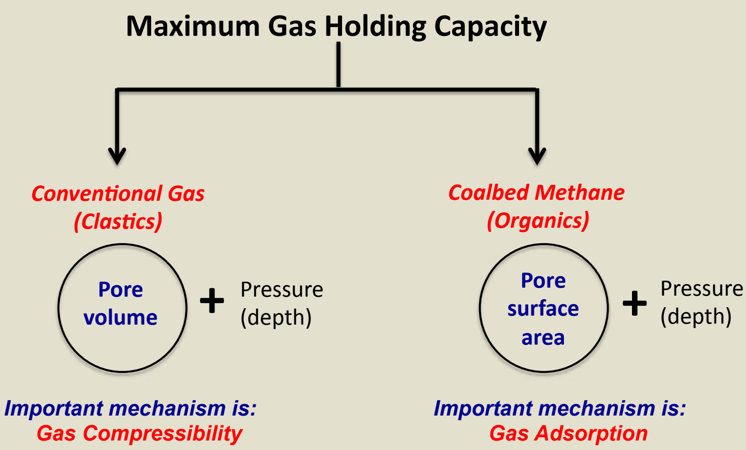
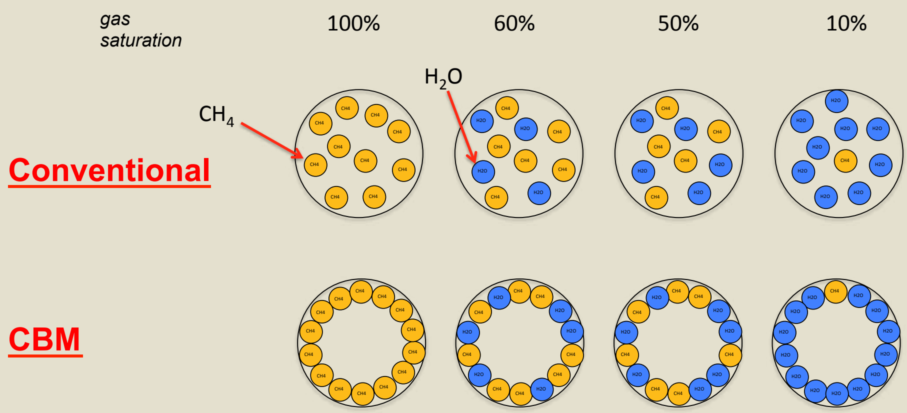


18

Gas Holding Mechanism & Gas Saturation



19

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Gas Holding Mechanism & Gas Content

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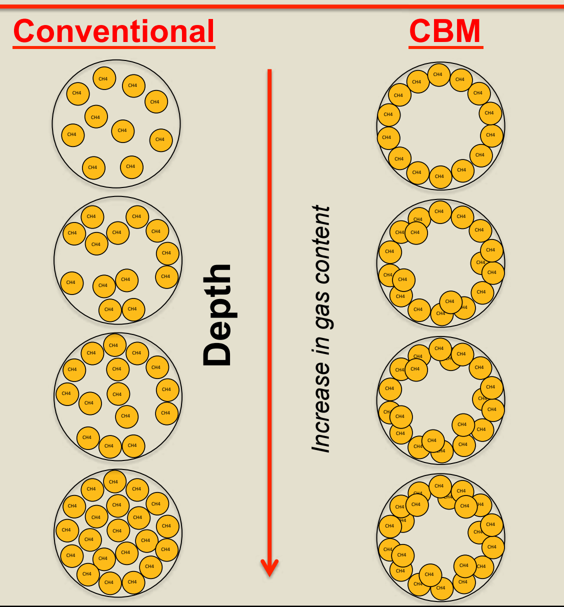
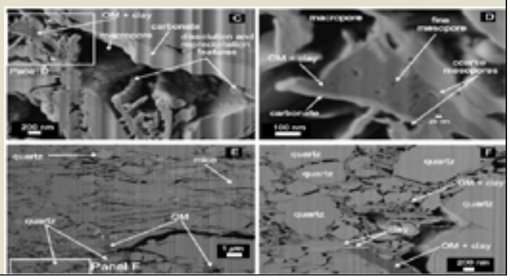


20

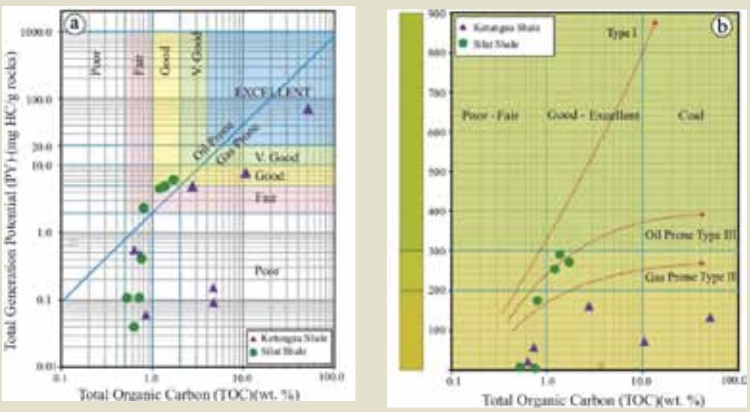
Gas Holding Mechanism in Shale

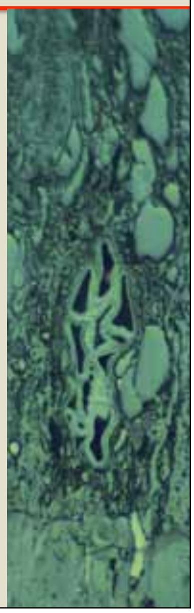
- Nevertheless, detailed understandings of hydrocarbon generation and retention processes within shale reservoirs are poorly understood.
- Methods of measuring pore volume and size, and sorptive capacity of shale using CBM and conventional reservoir analyses are of limited value in characterizing shale (Bustin et al., 2008) and must be used with care. Hybrid, multiple analyses are best.
- Generated gas can be stored as:
  - free gas in intergranular pores and natural fractures,
  - adsorbed on organic and inorganic surfaces,
  - dissolved in kerogen and bitumen.



from Curtis et al., 2012

Organics: A Moving Target!

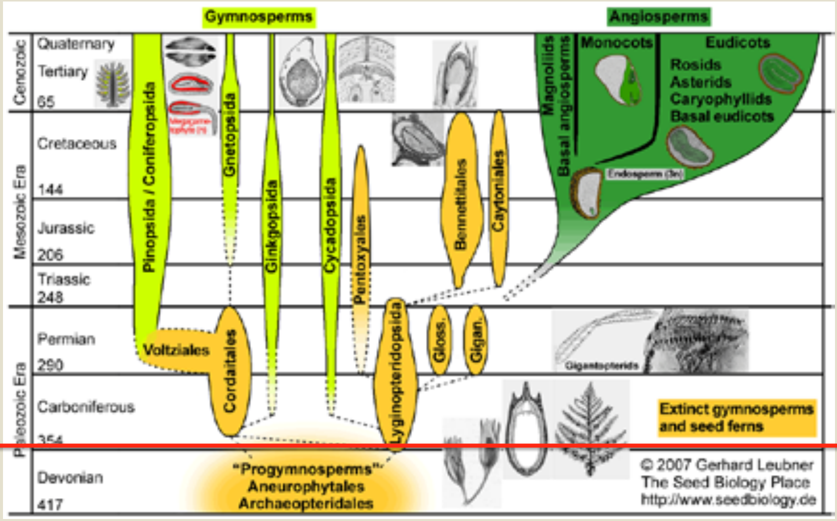




22

from Santy & Panggabean, 2013

Not All Organic Material Starts Out the Same: Coal



23

from http://www.seedbiology.de/evolution.asp

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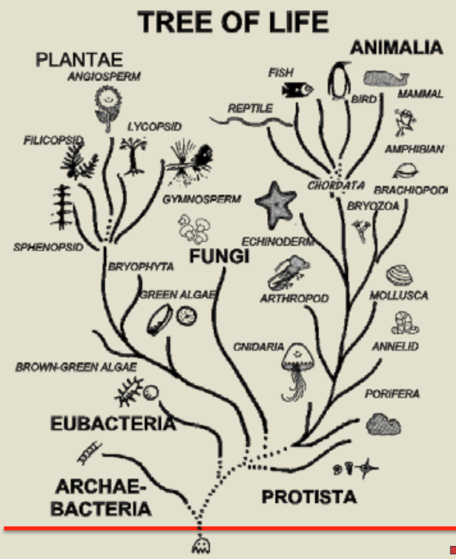
Not All Organic Material Starts Out the Same: Shale Gas



24

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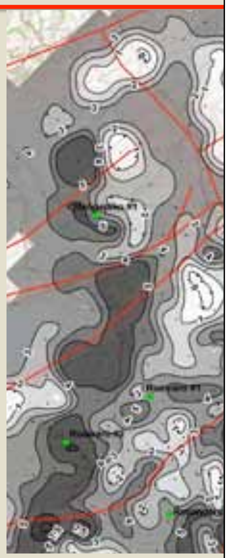
Implications for Resource/Reserve Certification



- Both CBM & Shale gas are characterised as a ‘continuous reservoir’; thus, greater lateral continuity is usually assumed for the reservoir (though for biogenic gas this might not be the case)
- Depth limited (permeability boundary): (1) CBM is usually limited to <1000 m, (2) for Shale gas there is usually a minimum of 1000 m or deeper
- It is clear in CBM that the gas is produced from the pores of the organics, but its not clear where and when the gas in Shale is produced: arguments for both production from organics first and from clastic sediments first. This makes estimation of OGIP and other Resources problematic
- Uncertainties in measurements of porosity and gas in place for shale requires that multiple analyses and logs be run to determine resources and/or reserves.
- ‘Deep pockets’ are needed to gather enough data for certification as the cost of discovery is very high (e.g. 2.4 – 7.6 million U.S. dollars per well in the Marcellus Shale)

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Learnings and Transferables

- Pores in both CBM & Shale gas play a defining role in both resource types
- Pore surface area is the key in CBM, whilst it may be that both pore volume (in the inorganics) and pore surface area (in the organics) both play a role in Shale Gas gas holding mechanisms.
- Shale gas reservoirs are usually a minimum of 1000 – 2000 m depth because of greater gas volumes
- CBM reservoirs work best at depths <1000 m (and really <500 m) because coal is compressible and thus loose permeability very quickly with depth
- In both CBM & Shale the origin and type of organic matter must be considered

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