Microbial Activity in Australian CBM Reservoirs*

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Search and Discovery Article #80033 (2009)
Posted January 20, 2009

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, April 20-23, 2008

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Abstract

Coalbed Methane (CBM) in Australian basins consists of methane, carbon dioxide, ethane and higher hydrocarbons. Gas and coal geochemistry data indicate extensive microbial activity, especially in coal seams shallower than about 600 m. Microbial activity causing secondary biogenic gas generation possibly occurred subsequent to uplift of the eastern Australian basins during the Late Cretaceous and Tertiary. Stable isotope data indicate that CO₂ reduction is the main pathway of secondary biogenic methane generation in the eastern Australian coals.

The gas saturation levels of coal seams are highly variable depending on the thermal maturity, burial history, and groundwater flow. In coal seams that have been uplifted and where meteoric water recharge has occurred, secondary microbial activity has enhanced the methane saturation levels. Without such secondary gas replenishment, however, many of these coals remain significantly undersaturated. In the Sydney Basin, for example, the CBM production rates are up to an order of magnitude higher in areas where coal seams have been re-saturated with secondary biogenic gas compared to areas containing only thermogenic gas.

The types of microflora that are generating gas in Australia CBM reservoirs are unknown. The CSIRO is currently investigating the processes of biogenic gas generation in Australian coals including the ability of the indigenous microflora in a range of Australian coals to generate methane under laboratory conditions. Experiments will also be conducted to assess the viability of injecting suitable micro-organisms and/or nutrients into depleting and under-saturated coal seams to enhance methane production.
Microbial Activity in Australian CBM Reservoirs

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\textsuperscript{3}Energy Transformed Flagship
CBM is an important energy source for Australia

Biogenic CH$_4$ and CO$_2$ are significant components in Australian coal seam gas reservoirs

“Sweet-spots” for CBM production mainly related to zones of secondary biogenic gas generation

Microbiological studies indicate the presence of a great diversity of prokaryotes
Acknowledgements

AGL Energy
Australian Coal Seam Methane Ltd
BHP Billiton
Macquarie Energy
Maddingly Brown Coal Ltd
Origin Energy
Santos Ltd
Sydney Gas Ltd
Coal Deposits in Australia

Western Australia, Queensland, New South Wales

High rank Coal
Low rank Coal
CBM Methane Production

~80% of used in QLD comes from CBM
Background

Origin of gas in coal

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Burial History and Sources of Coal Seam Gas

Relative Amounts of Gases Generated

- **Biogenic gas**: Methane and minor carbon dioxide
- **Thermogenic gases**
  - Carbon dioxide
  - Methane
  - Ethane and higher hydrocarbons

Burial

High Rank Coal

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Burial History and Sources of Coal Seam Gas

Relative Amounts of Gases Generated

- **Biogenic gas**
  - Methane and minor carbon dioxide

- **Thermogenic gases**
  - Carbon dioxide
  - Methane
  - Ethane and higher hydrocarbons

**Biogenic Gas Generation**

- **Complex Organic Compounds in Plants**
- **Monomers and Oligomers**
- **Long Chain Fatty Acids**
  - \( H_2 + CO_2 \text{ or Formate} \)
  - \( CH_4, CO_2 \)

- **Acetate**

(1) fermentative anaerobes
(2) \( H_2 \) producing acetogens
(3) \( H_2 \) consuming methanogens
(4) acetotrophic methanogens
Burial History and Sources of Coal Seam Gas

Relative Amounts of Gases Generated

- Biogenic gas
  - Methane and minor carbon dioxide
- Thermogenic gases
  - Carbon dioxide
  - Methane
  - Ethane and higher hydrocarbons

Biogenic Gas Generation
Secondary Biogenic Gas
Burial

High Rank Coal

CSIRO
Burial History and Sources of Coal Seam Gas

Relative Amounts of Gases Generated

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Biogenic Gas Generation

- Complex Organic Molecules in Plants
- Monomers and Oligomers
- Long Chain Fatty Acids

Burial

- High Rank Coal

Coal Rank (VR%)
- 0.2
- 0.6
- 1.2
- 2.0
- 3.0

Coal Temperature
- 50°C
- 100°C
- 200°C

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(1) fermentative anaerobes
(2) H₂ producing acetogens
(3) H₂ consuming methanogens
(4) acetotrophic methanogens

CH₄, CO₂
Burial History and Sources of Coal Seam Gas

**Relative Amounts of Gases Generated**

- **Biogenic gas**
  - Methane and minor carbon dioxide
  - Monomers and Oligomers
  - Long Chain Fatty Acids

- **Thermogenic gases**
  - Carbon dioxide
  - Methane
  - Ethane and higher hydrocarbons

**Biogenic Gas Generation**

- Secondary Biogenic Gas
  - Monomers and Oligomers
  - Long Chain Fatty Acids

**High Rank Coal**

- Loss of some thermogenic gas

**Coal Rank (VR%)**

- 0.2
- 0.6
- 1.2
- 2.0
- 3.0

**Temperature**

- 50°C
- 100°C
- 200°C

**Uplift**

- (1) fermentative anaerobes
- (2) H₂ producing acetogens
- (3) H₂ consuming methanogens
- (4) acetotrophic methanogens
Australian coal seams comprise a mixed gas composition

other minor gases: $\text{N}_2$, $\text{C}_2+$, $\text{H}_2\text{S}$
Source of gas in coal seam gas reservoirs
Carbon and Deuterium Isotopes

Classification system from Whiticar et al., (1986)

Origin of CO$_2$ in Australian Coals - Based on $\delta^{13}$C Isotopes

Data from Smith et al (1985), Faiz et al (2003); Draper and Boreham (2006)
Carbon Isotopes for Methane - Sydney Basin

![Graph showing δ^13C CH₄‰ vs. depth (m)].

- Biogenic
- Thermogenic

High–Low Volatile Bituminous Coals
Higher Hydrocarbons and Depth - Sydney Basin

- **Av. Temp.**
  - VR ~0.9
  - 32°C
  - 45°C
  - VR ~1.7
  - 58°C

- **C_{2+}%**

- **Depth (m)**
  - dry gas
  - optimal temp for most mesophilic methanogens ~35°C
  - wet gas

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Cross-section of Average Carbon Isotopes for CH$_4$

-72
-61
-54
-45
-51
-54
-50
-58

Burrogorang Valley

Triassic

Late-Early Permian

Biotic
Thermogenic

Late Permian coal measures showing origin of CH$_4$

-54 = average $^{13}$C CH$_4$

Meteoric water

Coastal outcrops
“Sweet-spots” for methane production in many Australian basins are related to areas with secondary biogenic gas
Example:
Camden CBM Project, Sydney Basin

“High Production Fairway” is confined to areas of secondary biogenic gas generation

Modified from Faiz et al (APPEA, 2003)
Wet Gas and Total Gas Content - Sydney Basin

Data from ~500 and 650 m

Ethane %

Total Gas Content (m³/t)

Biogenic – high CH₄ content

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Microbiology of Australian CBM Reservoirs

• Preliminary studies to characterise microbial diversity in CBM reservoirs

  ➢ Coal and associated formation water samples analysed

  ➢ Anaerobic culturing

  ➢ DNA extracted, cloning and sequencing
Coal Seam Gas model for Sydney Basin

Faiz and Hendry (2006)
PCR Amplifications from Bacteria and Archaea

16S rDNA extracted, amplified, cloned and sequenced
Phylogenetic Tree - Bacterial Amplicons

Coal samples

- Phyllobacterium
- Rhizobium
- Agrobacterium

- Rhodobacter
- Bradyrhizobium
- Methylocapsa

- Acidiphilium
- Acidocella
- Cytophaga
- Bacteroides
-弧菌属

- Thiomonas
- Beta- proteobacterium
- Arcobacter
- Hydrogenophaga
- Azoarcus
- Thauera

- Pseudomonas
- Gamma proteobacterium
- Pseudomonas
- Eschericha
- Thauera

- Aeromonas
- Eschericha
- Shewanella
- Methylo bacter

- Nitrincola
- Nitrilcola
- Marinobacter
- Marinobacter

Water samples

- Bacteroidetes
- Epsilon proteobacteria
- Beta proteobacteria

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Li et al. 2008

500bp
Phylogenetic Tree – Archaeal Amplicons
Region - A

Thermococcus
- Thermococcus litoralis AY099180

Sulfophobococcus
- S. zilligii X98064
- Ignisphaera sp. DQ060322

Archaeoglobus
- Archaeoglobus fulgidus DQ374392
- Haloferax lucentensis AB081732

Li et al., 2008
Summary

- Significant geochemical evidence exists for biogenic gas generation in Australian coals.
- Secondary biogenic gas is important for achieving high methane saturation levels in most Australian coals.
- Many “sweet spots” for CBM production related zones with secondary biogenic gas.
- Further microbiological studies are being conducted to determine the potential in-situ bio-gasification of deep coal seams.
References


Thank you

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