Energy Program Review:
Origin and Controls on Microbial Gas Accumulations
(Task 7 Geochemistry of Solid Fuels Project)

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Presented by Task Leaders:
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Task Goal

• Understanding biogenic methanogenesis¹ in place in order to develop methodologies for enhancing microbial methane production from:
  – Coal
  – Coal waste
  – Shale
  – Depleted petroleum reservoirs

→ Necessary to understand microbial biodegradation pathways and physical and chemical conditions effecting microbial methane production from coal.

¹The formation of methane by methanogenic microbes.
Microbial Natural Gas Production from Coal

1. Enzymatic hydrolysis/solubilization of coal organics

2. Degradation of soluble coal organics
   (Orem and others, 2010)

3. Methanogenesis
   • Acetoclastic (acetate)
   • Hydrogenotrophic (H₂/CO₂)
   • Methylotrophic (Methanol, methylamines)

Jones and others, 2010.
Microbial Natural Gas Production from Coal

- Pathways of coal solubilization (1 & 2) are still poorly understood.

- Different methanogenic pathways (3) dominate in different environments (Schlegel and others, 2013; Jones and others, 2008).

Jones and others, 2010.
How can we enhance natural gas production in coal?

- Stimulate microbial populations
  - Increase biomass in coal deposits
  - Enhance degradative capabilities

- Modify coal matrix
  - Physical modification
    → increase microbial access to coal by increasing surface area
  - Chemical changes
    → increase bioavailability of organic material in coal by chemical oxidation
Research Approach

Field Studies
• Obtain coal and formation water samples for physical, chemical, and microbial community characterization

Lab Experiments
• Biodegradation pathways
• Rates of gas production
• Improving gas yields

Applications
• Methods for enhancing in place methanogenesis
• Field test
Field Site

• BLM managed land

• Coal beds include:
  – Knobloch
  – Calvert
  – Nance
  – **Flowers-Goodale (FG)**
  – Witham
  – Terret

• Coal beds extend into Wyoming
  – Similar in physical, chemical, and hydrologic properties
Why Tongue River Coal?

• High potential for microbial methanogenesis
  – Low salinity (no competition with microbial sulfate reduction)

• Remote location

• BLM land
  – Facilitates testing
  – Access is assured
## Summary of Research & Results to Date

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Field Site Results

• Recharge is correlated with biogenic methane. (Bates and others, 2011)

• Most productive coal bed methane wells are along the margins of the PRB.

• Cyanobacteria (algae) detected in the basin and highest abundance at the outer margins. (Barnhart, E., 2013, USGS, personal commun.)
Field Site Results

• *In situ* microbes
  – Methanogens detected but in low abundance
  – *Actinobacteria* preferentially associated with coal seams
    • Implicated in coal degradation (Ballav and others, 2012)
    • Future work is needed to assess the role of these organisms in coal degradation
Lab Results:
Biostimulation of methane production from coal

- Batch systems with native PRB microbes
- Increased methane with algal extract

Barnhart, E., 2013, unpubl. data.
Field Studies
• Obtain coal and formation water samples for physical, chemical, and microbial community characterization

Lab Experiments
• Biodegradation pathways
• Rates of gas production
• Improving gas yields

Applications
• Methods for enhancing in place methanogenesis
• Field test

• Patent
• FY13/14 research plans
Patent

- **Process for Enhancing Microbial Natural Gas Production from Coal Using Coal Oxidation and Stimulation with Algal Residues**

- Joint Submission:
  - USGS (W. Orem, E. Jones, E. Barnhart, A. Clark, L. Ruppert)
  - Montana State University (M. Fields, E. Barnhart, A. Cunningham, R. Gerlach, L. Spangler)

- Provisional Patent Application No.: 61/612,718 filed in 2012
Patent Strategy
Enhancing Microbial Natural Gas Production from Coal
Patent Strategy
Enhancing Microbial Natural Gas Production from Coal

Phase 1:
Natural Gas Collection
Patent Strategy
Enhancing Microbial Natural Gas Production from Coal

Phase 2:
Algal Cultivation
Patent Strategy
Enhancing Microbial Natural Gas Production from Coal

Phase 3: Produce New Microbial Natural Gas
Patent Strategy
Enhancing Microbial Natural Gas Production from Coal

Phase 3: Produce New Microbial Natural Gas
Benefits of Enhancement Strategy
Patent Application No.: 61/612,718

• Beneficial use of coal bed produced water

• Algae
  – Biofuel production increases profitability
  – Growth removes atmospheric CO₂

• Stimulation of microbial methane
  – Reuse of coal bed methane infrastructure
  – Multiple stimulation cycles possible

• Transferable technology
  – Other fossil energy substrates (e.g., depleted petroleum reservoirs)
  – Wastes (e.g. coal slurry, rock piles)
FY13/14 Research Plans

Field studies and lab experiments

• Objectives:
  – Examine pathways of coal degradation by native Flowers Goodale microbes.
  – To refine the technology for enhancing natural gas production from coal via algal extract stimulation.
  – Perform hydrologic testing at the field site to determine the efficacy of performing a future field test.
Collaborators

- **Montana State University, Center for Biofilm Engineering**
  Dr. M. Fields, Dr. A. Cunningham, E. Barnhart (PhD student)

- **University of Arizona**
  Dr. J. McIntosh, Dr. D. Vinson (Post-Doc), D. Ritter (PhD student), S. Osborn (PhD 2010), B. Bates (MS 2010), C. Pantano (MS 2012)

- **Arizona State University**
  Dr. M. Ziv-El, Dr. H. Cadillo-Quiroz

- **National Institute for Biotechnology and Genetic Engineering, Pakistan**
  Dr. R. Haider

- **Bureau of Land Management**

- **ArcTech, Inc., Chantilly, VA**

- **University of Queensland, Australia**
  Dr. P. Jagals

- **University of Alberta, Canada**
  Dr. S. Mitra, A. Stephen (PhD student)

- **Colorado School of Mines**
  Lisa Gallagher, Ph.D. student
References

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