Williston Basin Petroleum Conference May 7-9, Minot, ND

ALBERTA RESEARCH COUNCIL

Role of Biogenic Gas Generation for Sustainable CBM Production

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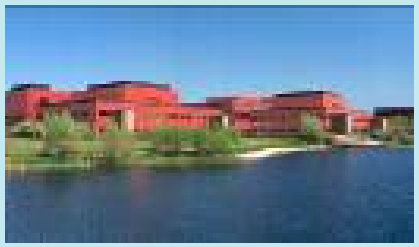
ARC Background

ARC Then

- Established in 1921
- Canada's first provincial research organization
- For 85 years, ARC has contributed to the growth and development of Alberta



ARC Now

- 500 highly qualified people
- $82 M annual operating budget
- Not-for-profit corporation wholly owned by the province of Alberta, governed by a board of Directors
- Technology Development Centres:
  - Engineered Products/Services
  - Energy
  - Integrated Resource Management
  - Life Sciences

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Acknowledgements

- Alberta Science and Research Authority
- Alberta Energy Research Institute
- Natural Resources Canada
- Environment Canada
- Alberta Environment

Talk Outline

- Introduction
- Objectives/Goals
- Results
- Future work
- Field application

CBM Production in Alberta (2005 data, CSUG)

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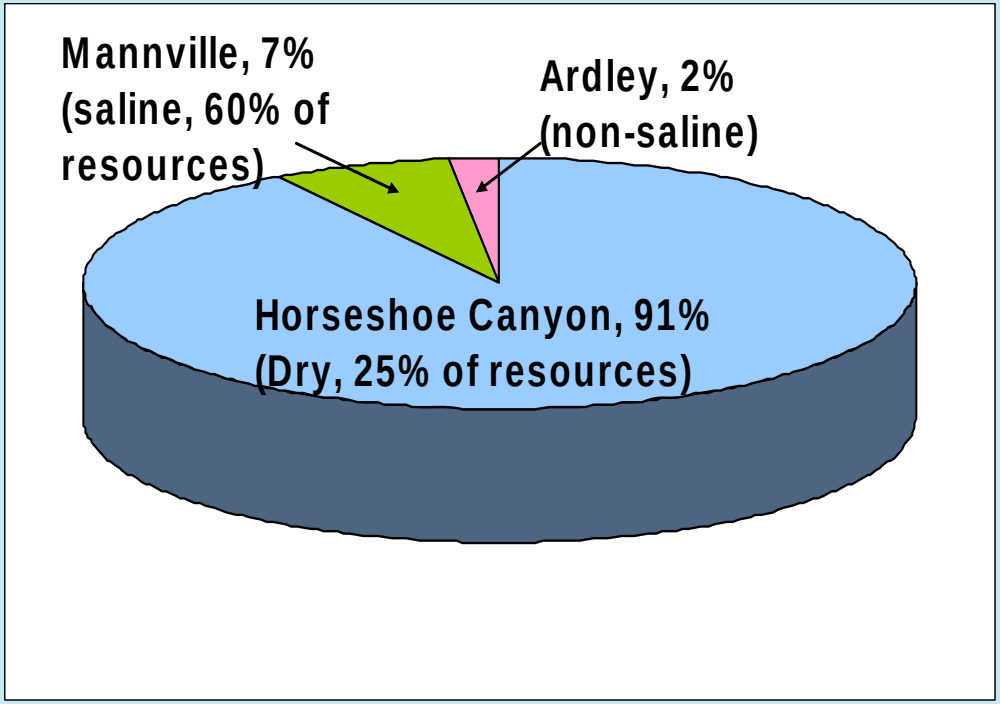
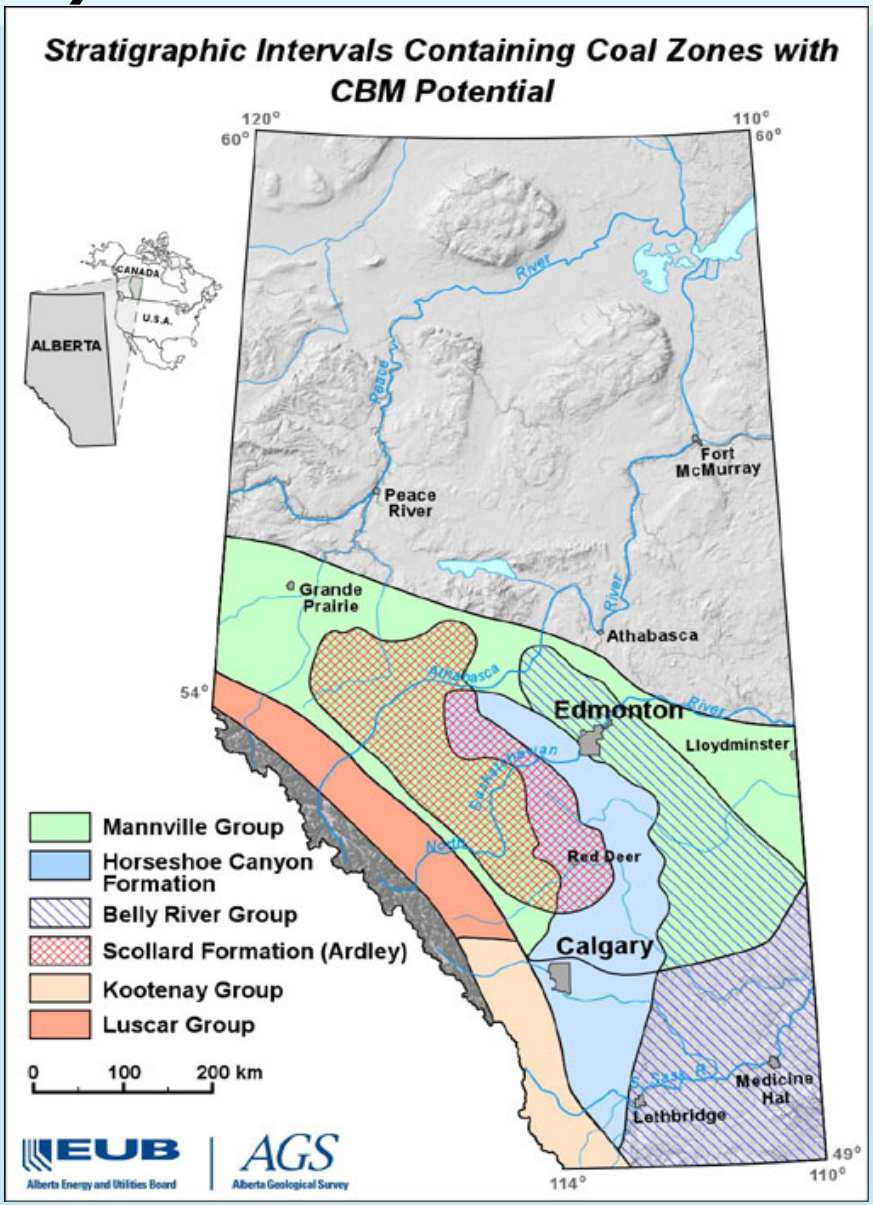
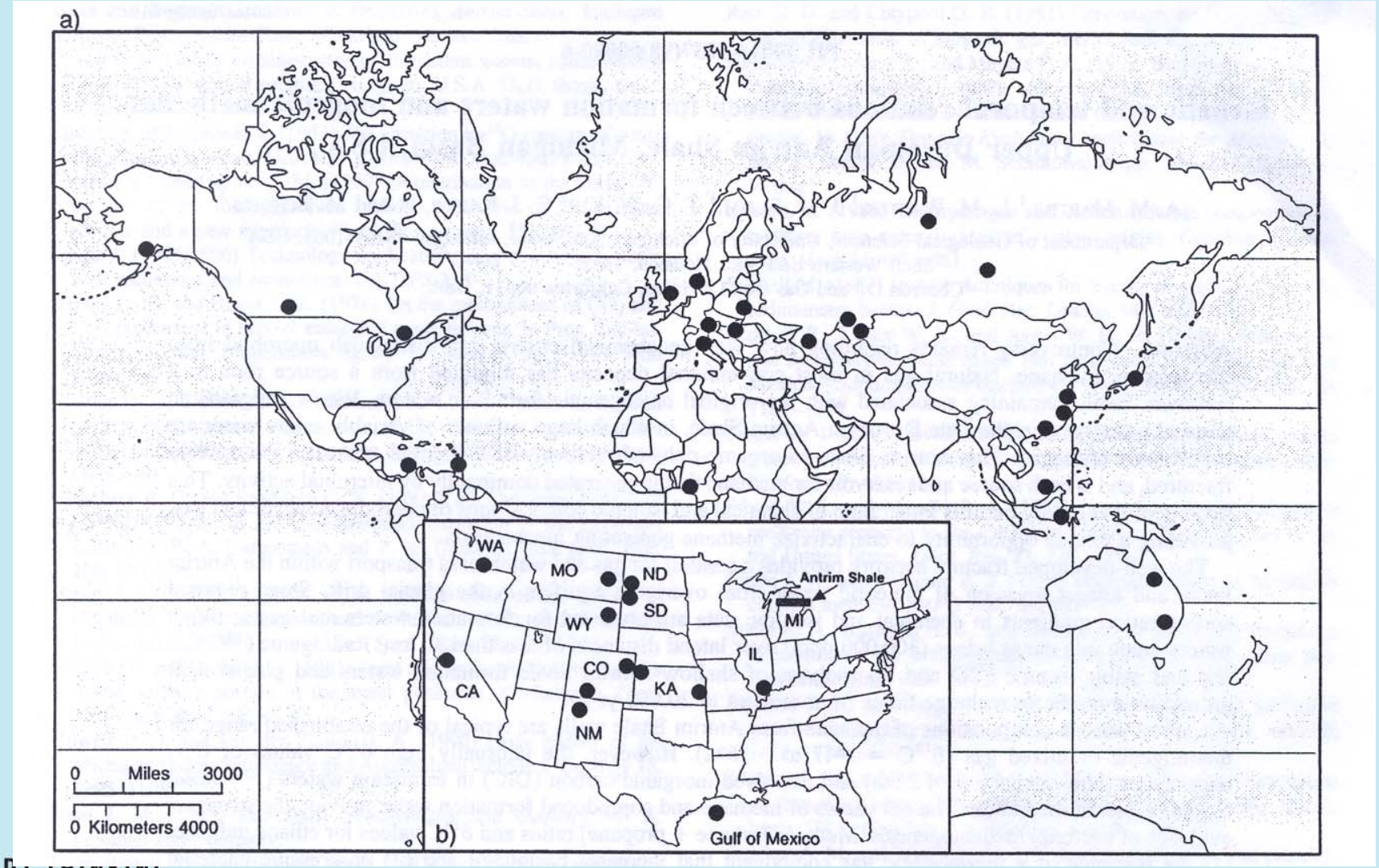
- Current estimates of 700 Tcf gas.
- 1 billion+ $ invested in 3000+ wells in Alberta.
- Current production of 350+ MMcf/D.
- Major CBM plays in Alberta (by % existing wells):





Biogenic methane production is detected in a variety of geological deposits throughout the world.



From: Martini et al., 1998

Outcomes of biogenic methane production that may benefit CBM companies

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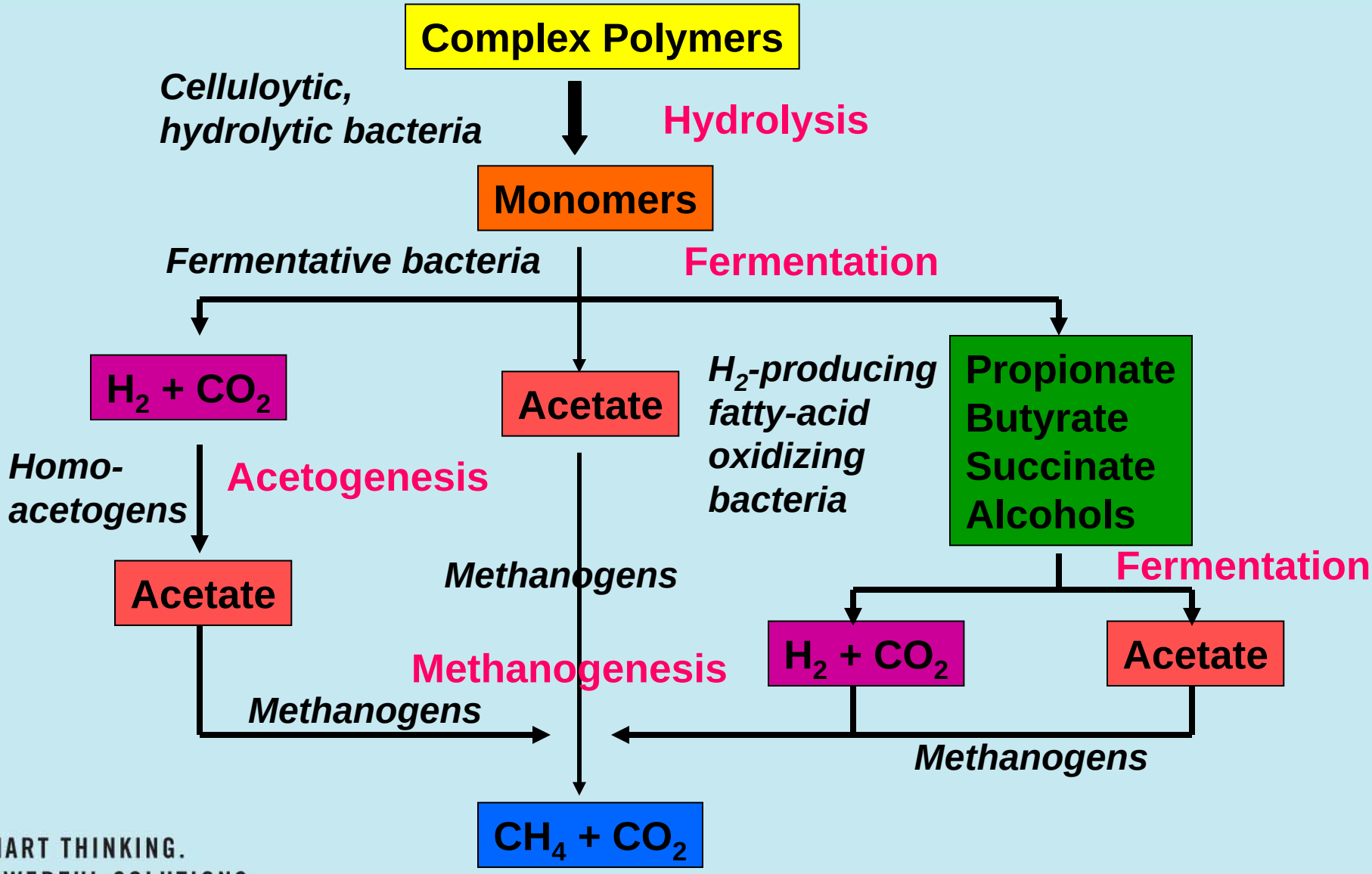
- **Mechanism for the regeneration of methane in the later life of a CBM reservoir when pressure is lower.**
- **Technology to allow ongoing methane generation in coal seams, especially in those with low gas content coals.**
- **Mechanisms to increase productivity potential of a CBM reservoir by enhancing seam permeability.**

"If only one-hundredth of one percent of US coal reserves were converted into methane through microbial processes, coal gas reserves would increase by 23 Tcf, or approximately 10% of current reserves" (A.R. Scott, AAPG conference, 2001)

Anaerobic degradation with methane production



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Major methanogenesis reaction pathways

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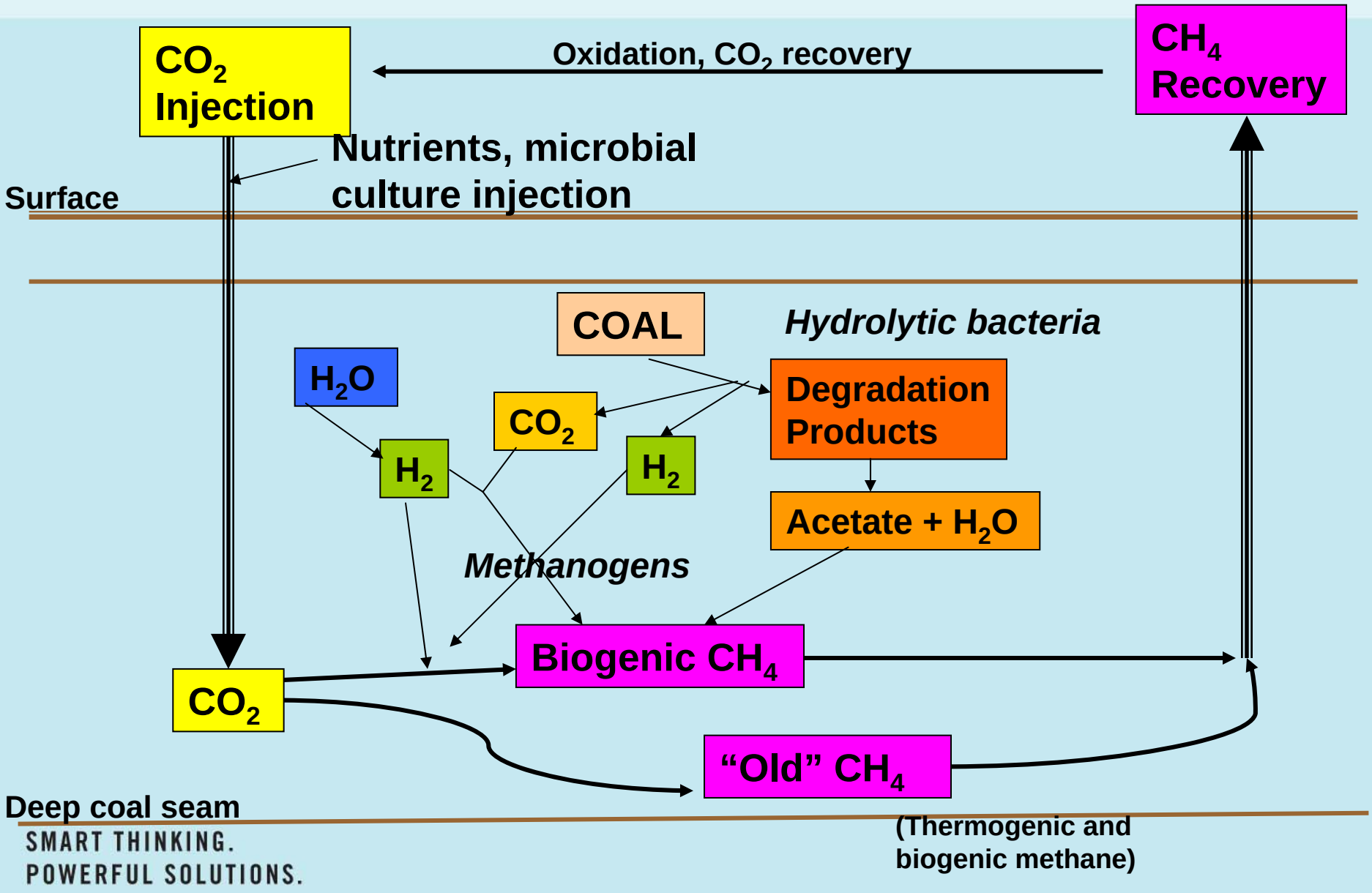
CARBONATE REDUCTION: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

ACETATE FERMENTATION: $CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$

Microbial enhanced CBM can be coupled to CO_2 storage to create a closed-loop fuel cycle.



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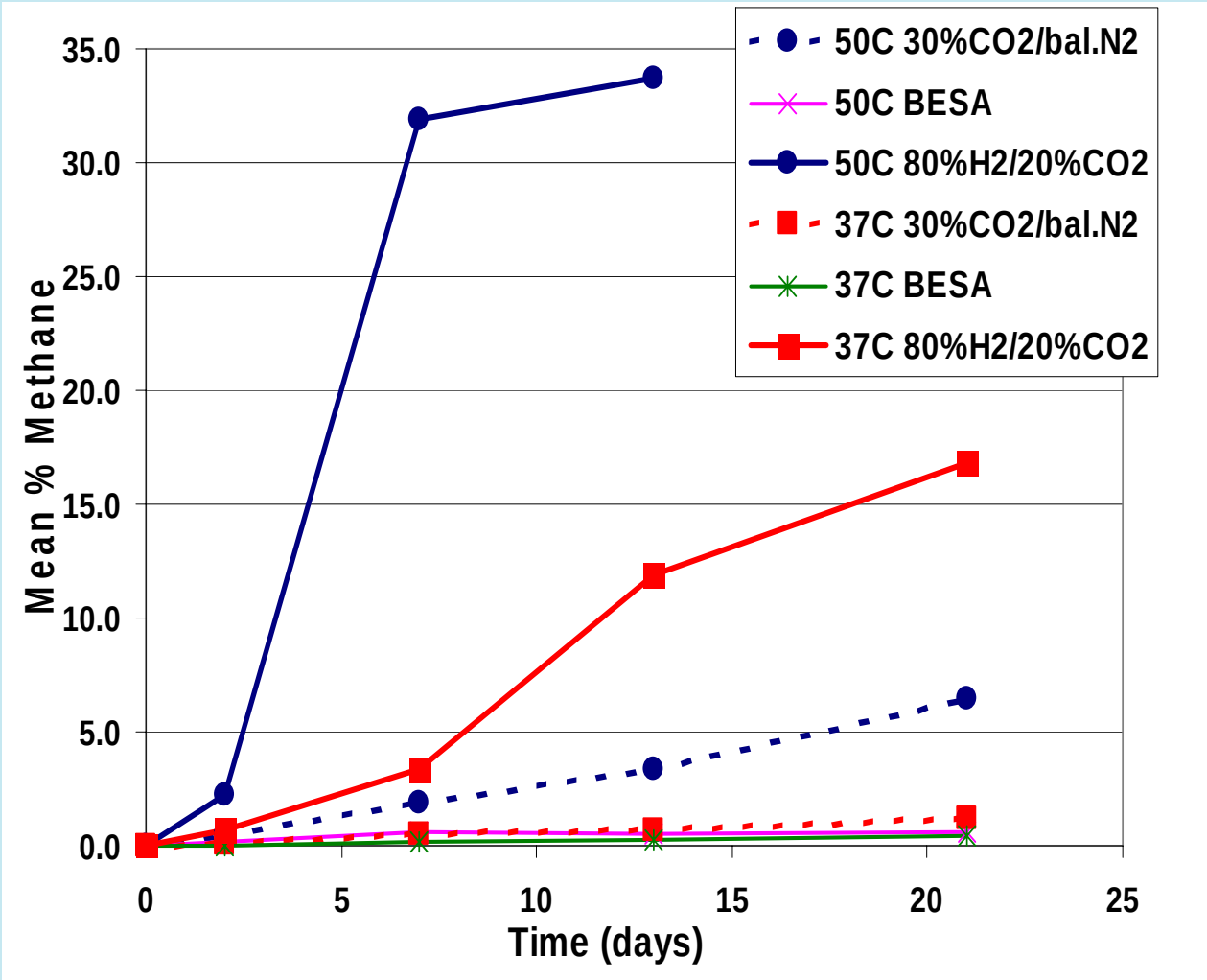
Objectives and Goals

- **Proof of concept: investigate and understand rates of biogenic methane production under different conditions. Determine mechanisms for optimizing rates and economics of process.**
- **Microcosm studies (atmospheric pressures).**
- **Mesocosm studies (elevated pressures, batch mode).**
- **Mesocosm studies (elevated pressures, dynamic).★**
- **Field demonstrations.**

Results

A thermophilic, methanogenic consortium was isolated from bituminous coal cuttings



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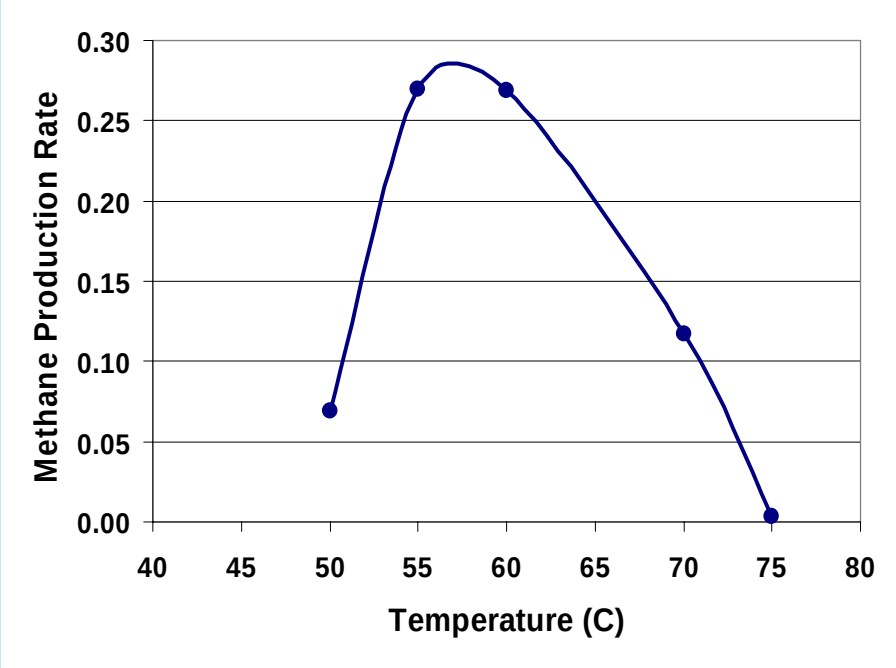
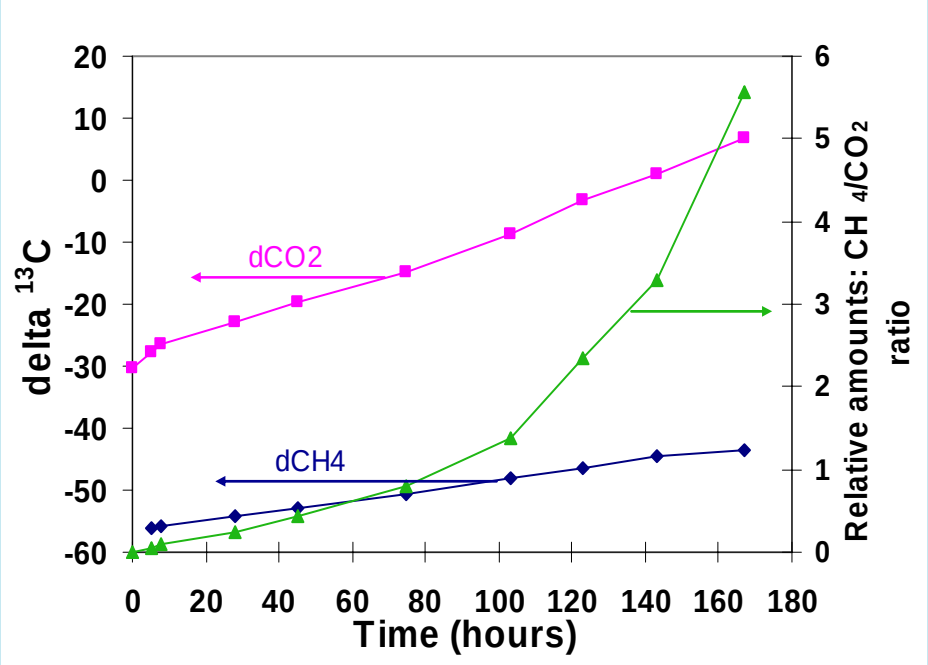
Some characteristics of thermophilic methanogenic culture





- **Optimum growth temperature of 60ºC.**
- **Stable isotope analysis indicates methanogenesis by carbonate reduction pathway.**

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Growth of thermophilic, methanogenic culture at elevated pressures

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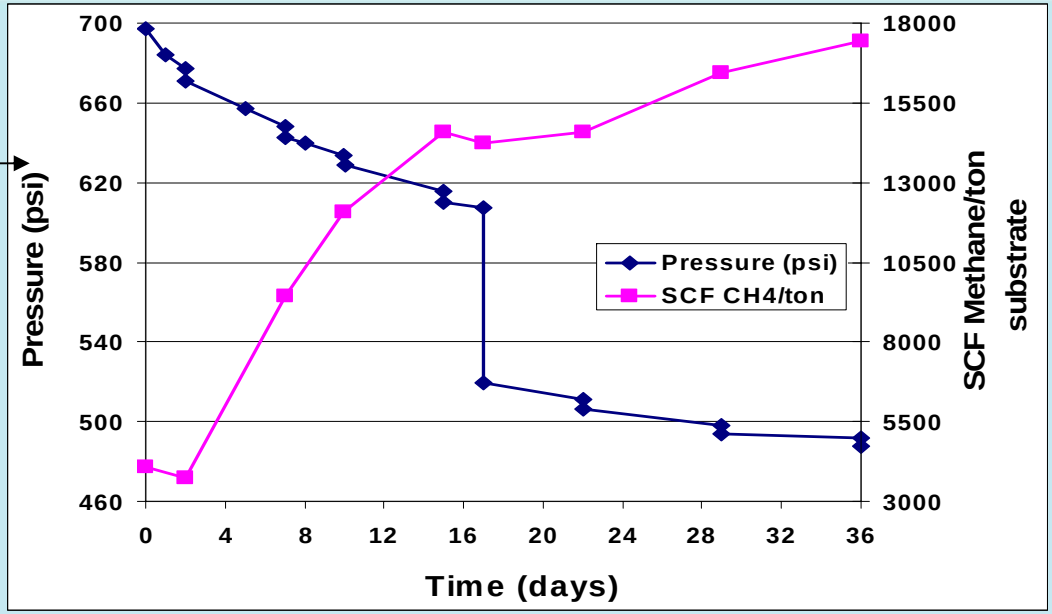
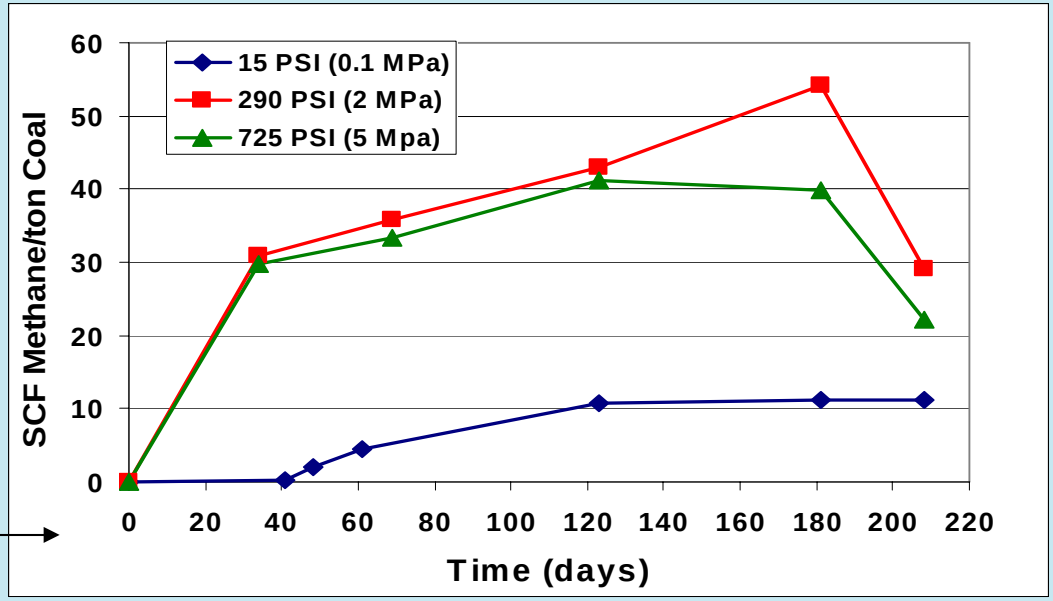
80% H_2, 20% CO_2 headspace, no coal present



20% H_2, 80% N_2 headspace, crushed coal



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Mesophilic methanogenic cultures enriched from coal cuttings

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- Cultures enriched from 12 CBM desorption canisters that had unexpected gas production.
- Incubated at 30ºC.
- Methanogenic activity observed when cultures grown in a dilute nutrient broth.

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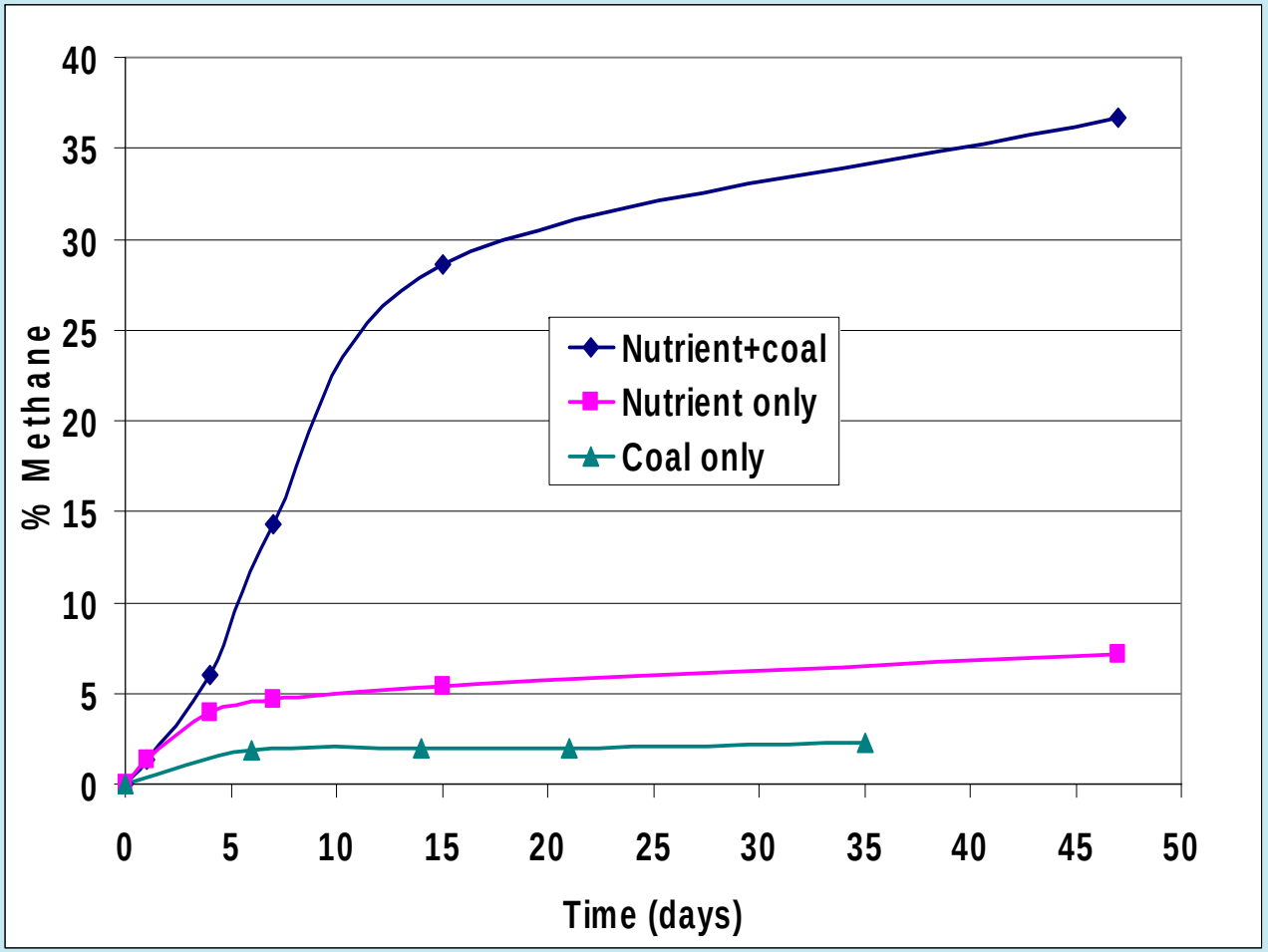
Effect of nutrient addition on methanogenesis

- Addition of a nutrient (a complex nitrogen source) significantly enhanced methane production over cultures with the nutrient or coal only.
- Nutrient may stimulate growth and activity of hydrolytic bacteria (they provide the substrates for methanogenesis).



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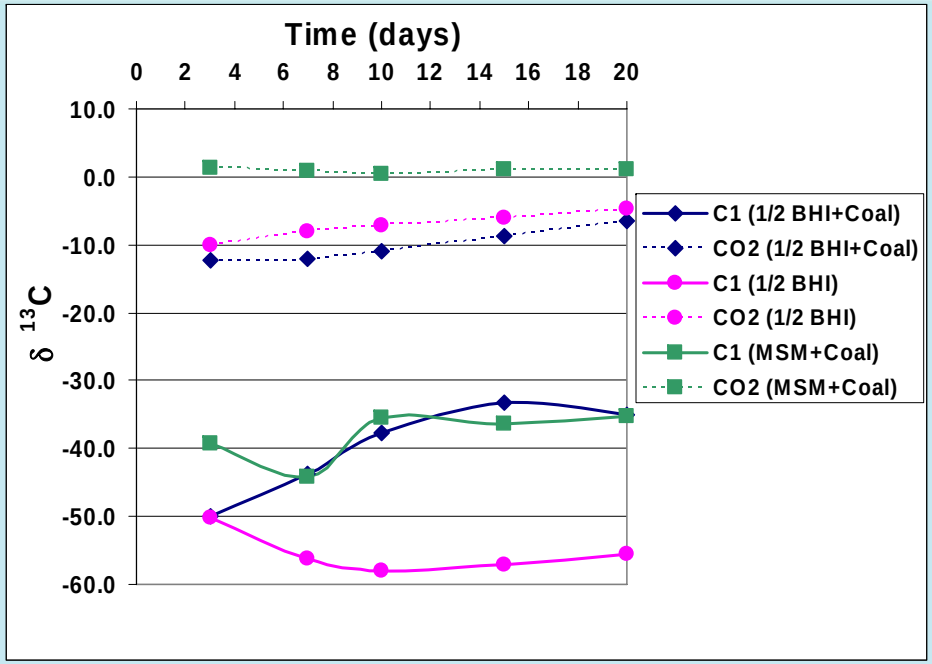
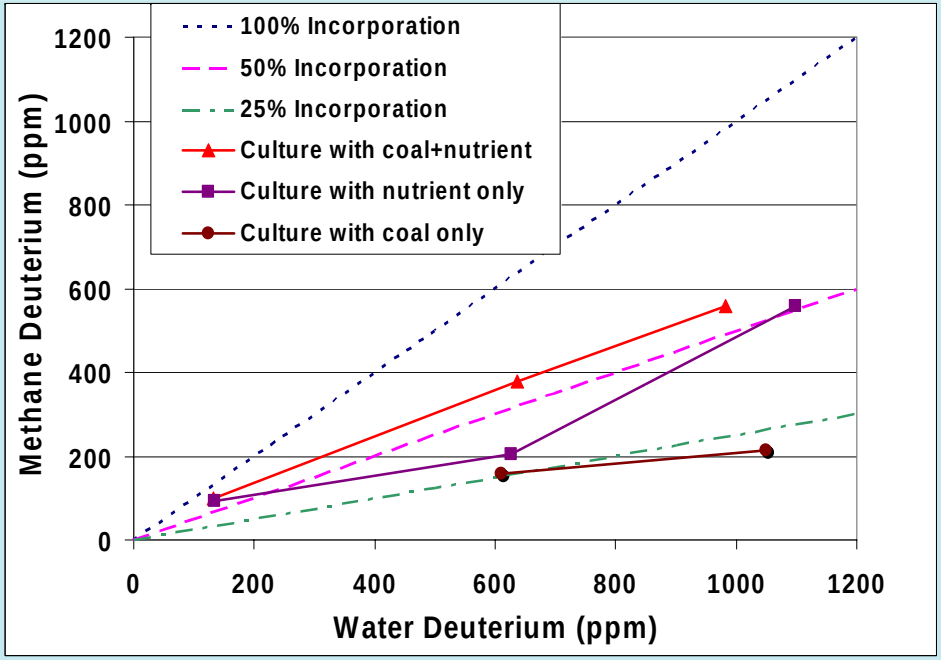
Stable isotope analysis of methanogenesis from coal





- Stable isotope analysis of $^{13}C_{CH4}$ and $^{13}C_{CO2}$: different values depending on culture conditions.
- Deuterium incorporation into methane: approximately half of culture water hydrogen incorporated into CH_4 when nutrient present.
- Work will lead to understanding of microbial processes, develop signatures of microbial activity for monitoring purposes.

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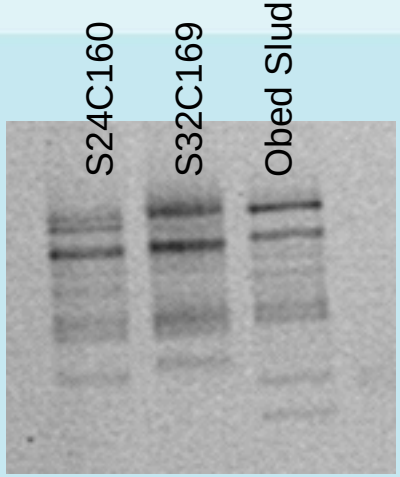
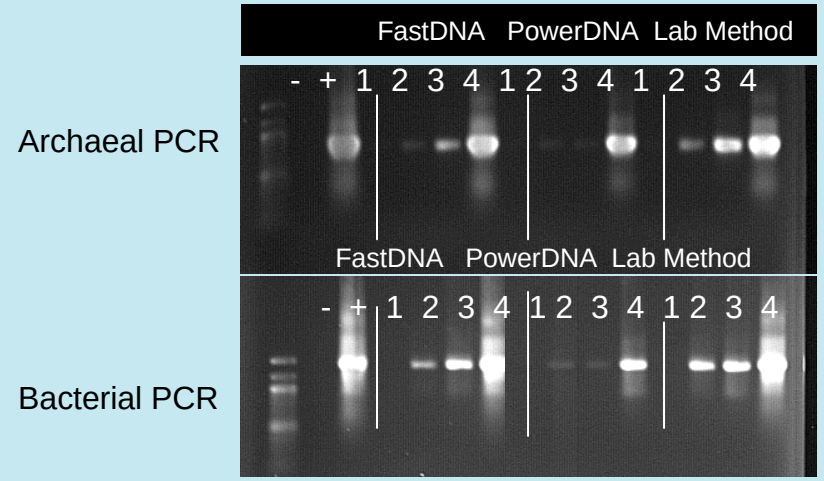
Identification of microbial species

- **Identify the methanogens and bacteria from coal enrichment cultures as well as from fresh coal and groundwater samples by DNA extraction and sequencing of genes.**
- **Identification of microbes will guide the informed manipulation of in situ conditions to enhance coal bed methanogenesis.**
- **Major Archaeal species found: *Methanosarcina* spp. and *Methanothermobacter* spp.**
- **Major bacterial species found: *Sedimentibacter* spp, clostridia.**





1. Negative extraction
2. Coal + phosphate buffer
3. Coal + *M. sarcina* culture
4. Coal + PCR product

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Summary of mesophilic methanogenic cultures

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- **Addition of nutrients had a significant effect on enhancing methanogenesis.**
- **Cultures able to grow at elevated pressures in presence of coal cores.**

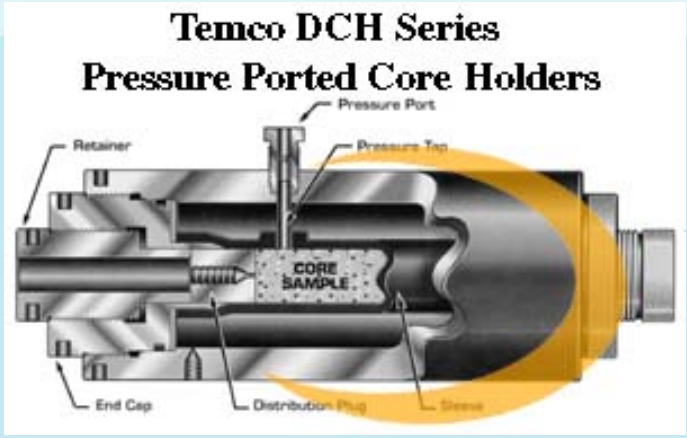
Extrapolation of selected results:

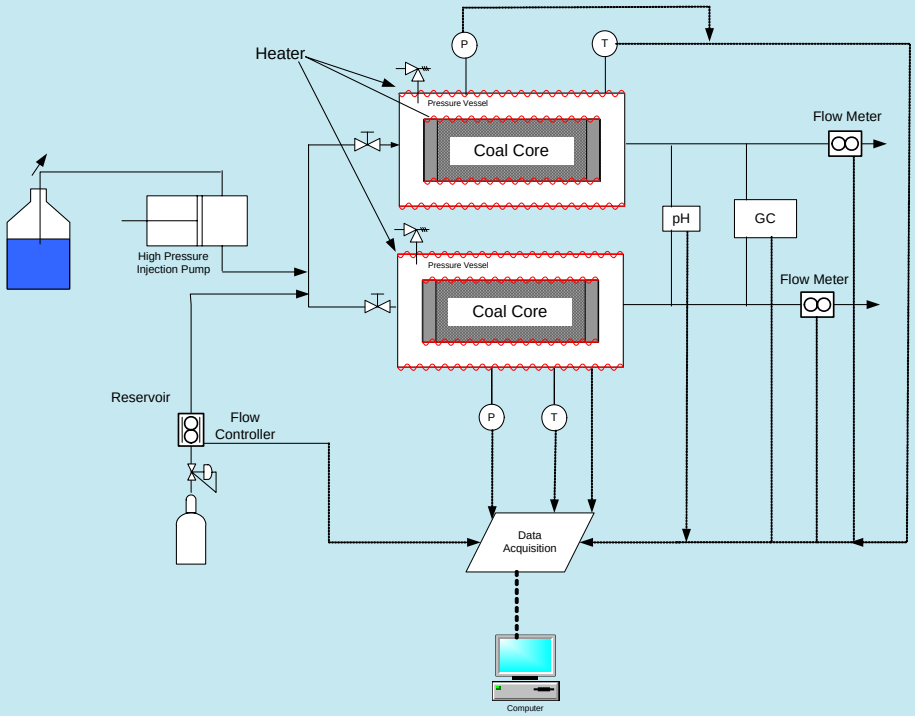
Culture	Scf CH_4	Scf CH_4/ day	Scf CH_4/tonne coal	Scf CH_4/tonne/ day	MMScf CH_4/ reservoir	MMScf CH_4/ reservoir/ day
Inoculated crushed coal at atmospheric pressure, 30ºC						
Coal (74 d)	$3.9e^{-6}$	$5.3e^{-8}$	7.2	0.097	3.6	0.048
Coal + nutrient (68 d)	$2.3e^{-5}$	$3.4e^{-7}$	218.9	3.2	108	1.6
Inoculated whole core at 100 psi, 30ºC						
Coal (83 d)	$9.2e^{-4}$	$1.1e^{-5}$	1.7	0.021	0.86	0.0104
Coal + nutrient (27 d)	$3.0e^{-3}$	$1.1e^{-4}$	5.6	0.21	2.7	0.102

Reservoir: 10 m thick, 10 acres, 493,714 tonnes (Scott, 1999)

Future work

- **Build flow-through columns.**
- **Determine and optimize methanogenesis rates under a dynamic system.**
- **Gear up for field demonstration**
  - **Site selection**
  - **Injection/fracturing methods**
  - **Monitoring methods**





Continuous Flow Methanogenesis System

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Field application

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1. With primary production:

- **New well.**
- **Inject nutrient solution with or after fracturing solution.**
- **Shut in well to allow microbial population to increase and become activated (??)**
- **Monitor activity, recover gas.**

2. After primary production:

- **Completed well or late stage.**
- **Shut in well to allow microbial population to increase and become activated?**

For both scenarios:

- **Periodically dose CBM play with nutrient solution to maintain high microbial activity.**
- **Stagger the stimulation of wells within a CBM play: when one well is shut in, another one is active.**