Stimulating Methane Generation within Coal Seam Reservoirs

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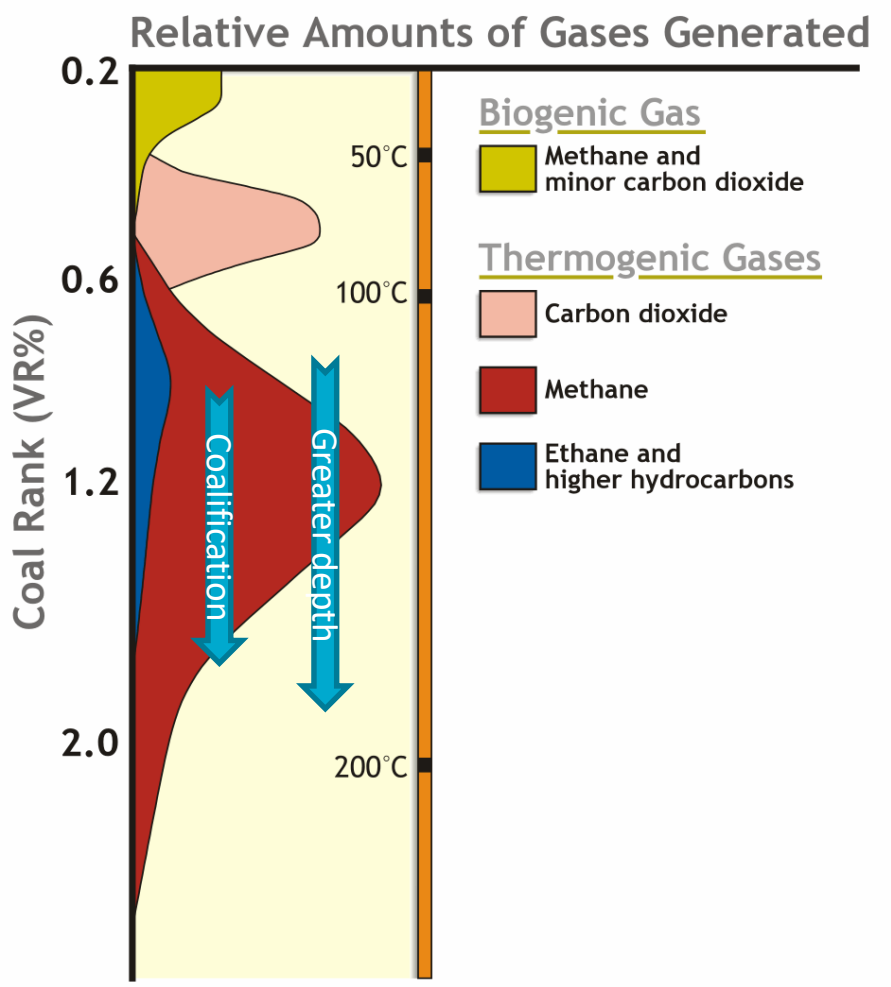
Objectives and Acknowledgments

- Microbially Enhanced Coal Seam Methane (MECSM) research project undertaken jointly with industry.
- Industry sponsorship and support from Santos Ltd., Asia Pacific LNG, AGL Energy and QGC.
- Objective is to improve methane recovery from CSG fields by enhancing biogenic gas process of indigenous microbial population.
- Phase 1 was a proof of concept that gas generation in coal could be stimulated.
- Phase 2 developed the reservoir application of gas generation.
- A field trial of MECSM is currently being planned by APLNG

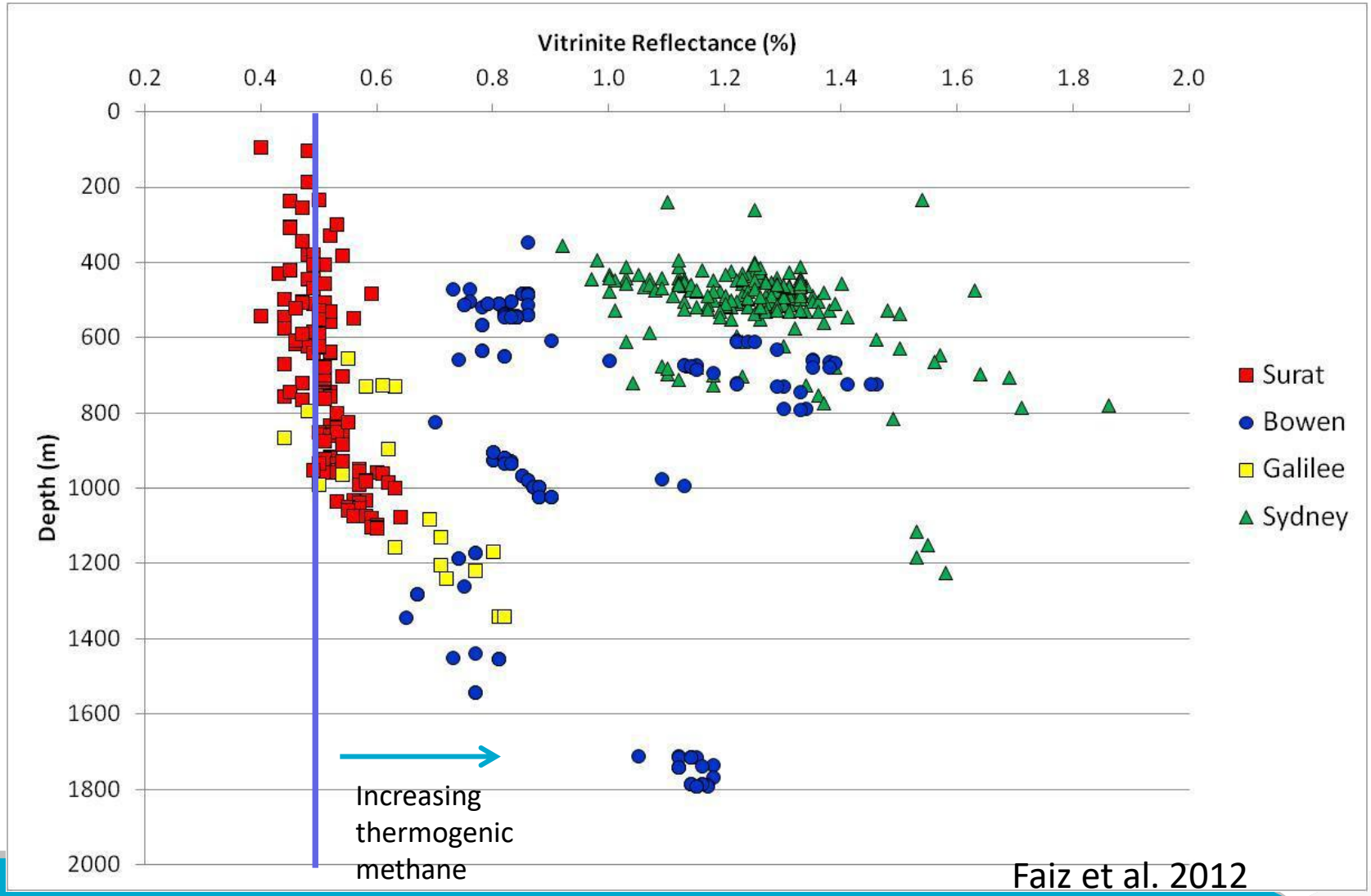
Origins of gas in coal

- Coal seam gas usually derived via two main processes.
- Thermogenic Gas
  - Produced during coalification due to heat and pressure over time.
- Biogenic Gas
  - Derived through microbial processes.
  - Primary – at an early stage of coalification.
  - Secondary – after coalification, following uplift of coal.



From Faiz et al., 2012

Coal rank for Australian basins

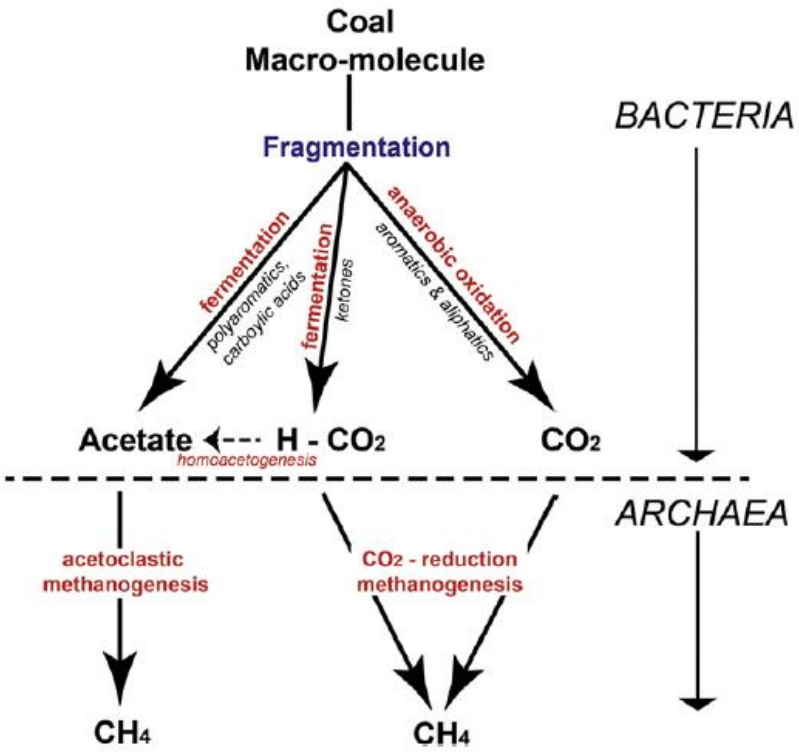


Faiz et al. 2012

Biogenic methanogenesis

- Anaerobic degradation of the coal to methane occurs through a microbial consortia.
- Similar process to bio-degradation of other organic materials.

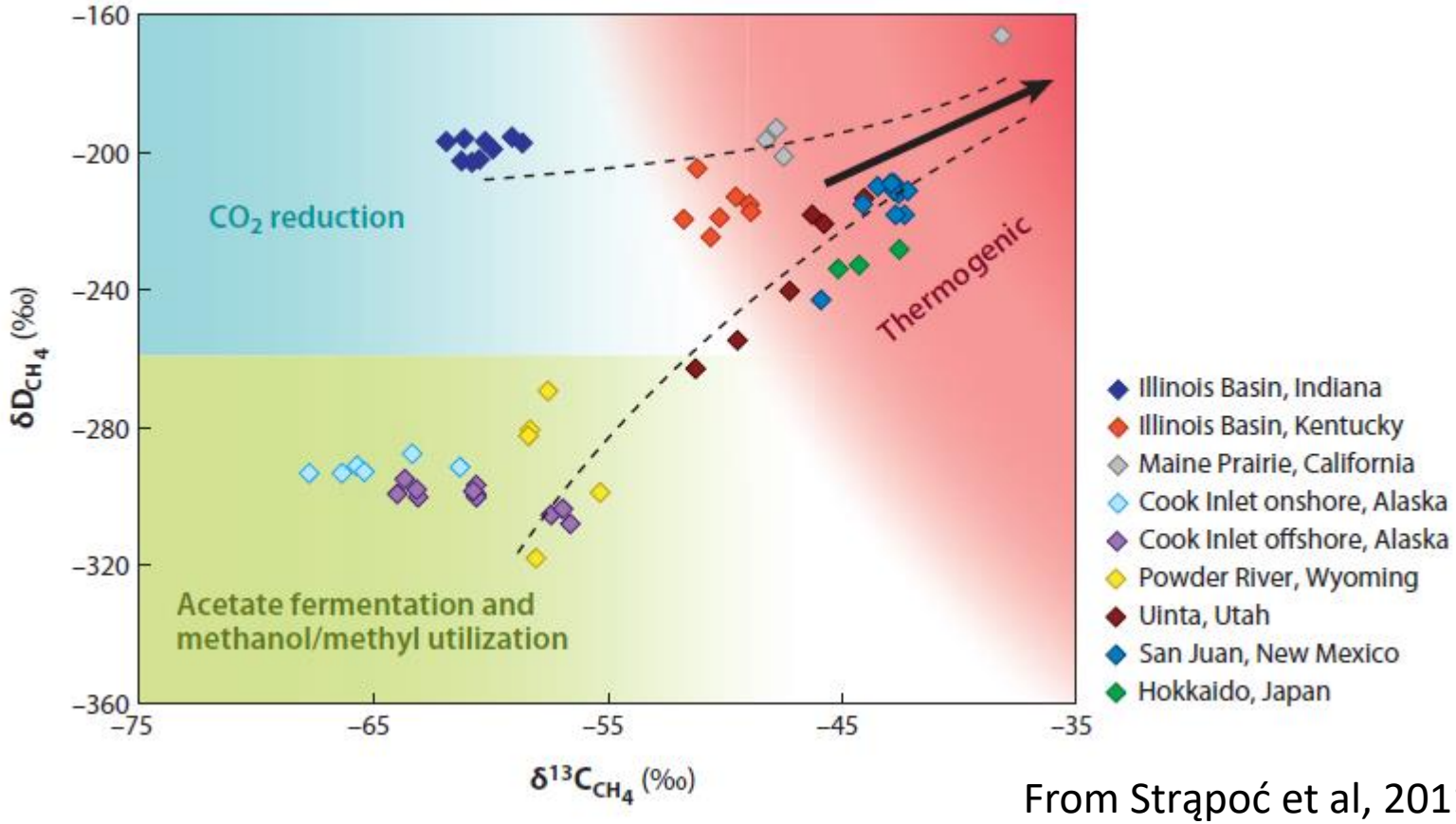
- Degradation of organic substrate into water soluble intermediates.
- Conversion of intermediates into substrates that can be utilised by methanogens.
- Methanogens (archaea) convert substrate to methane via acetoclastic or CO_2-reduction pathways.



From Moore, 2012

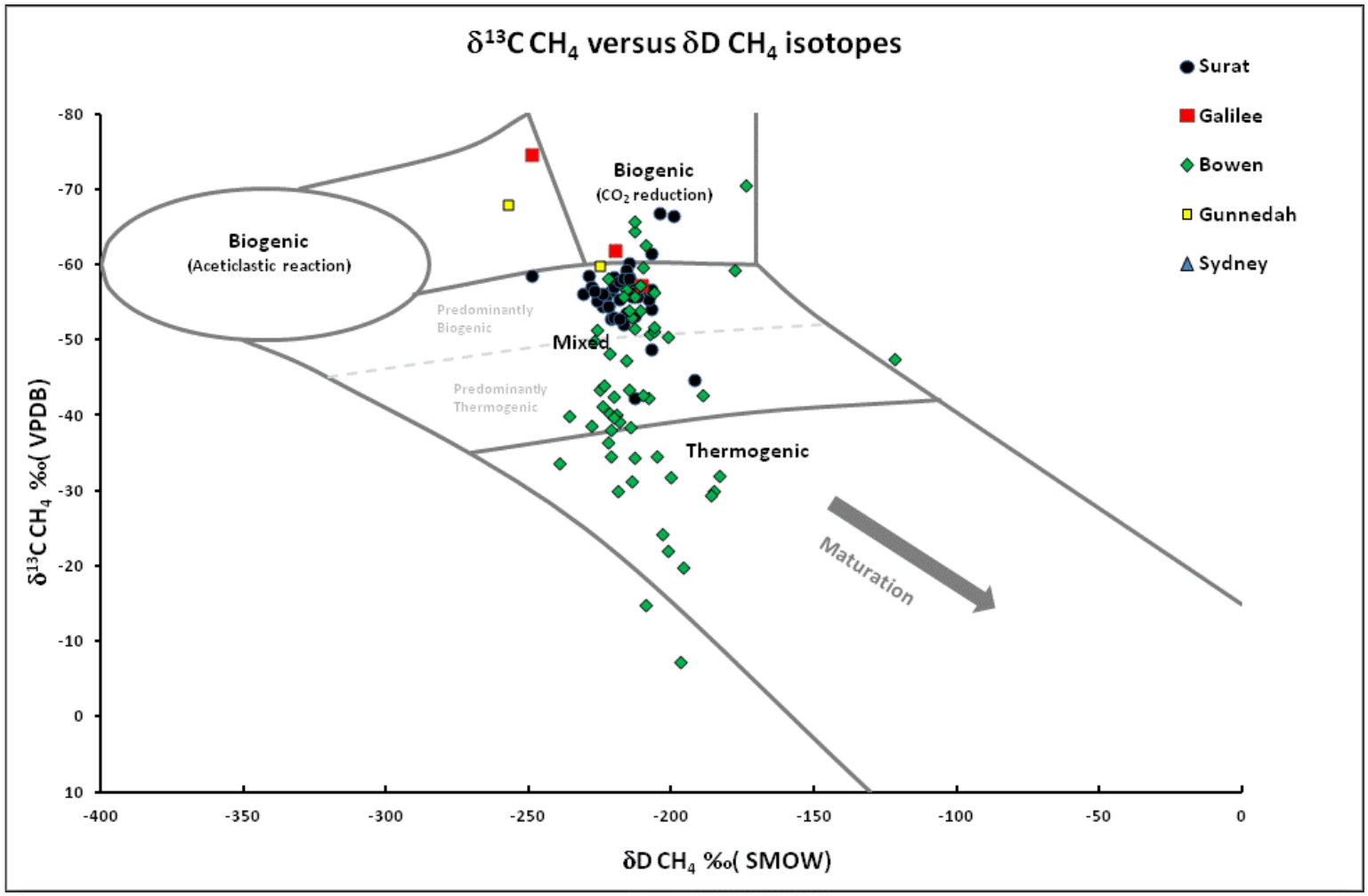
Origins of coal seam methane: US data

•Deuterium-hydrogen and carbon 13 isotope ratios indicate origin.



From Strąpoć et al, 2011

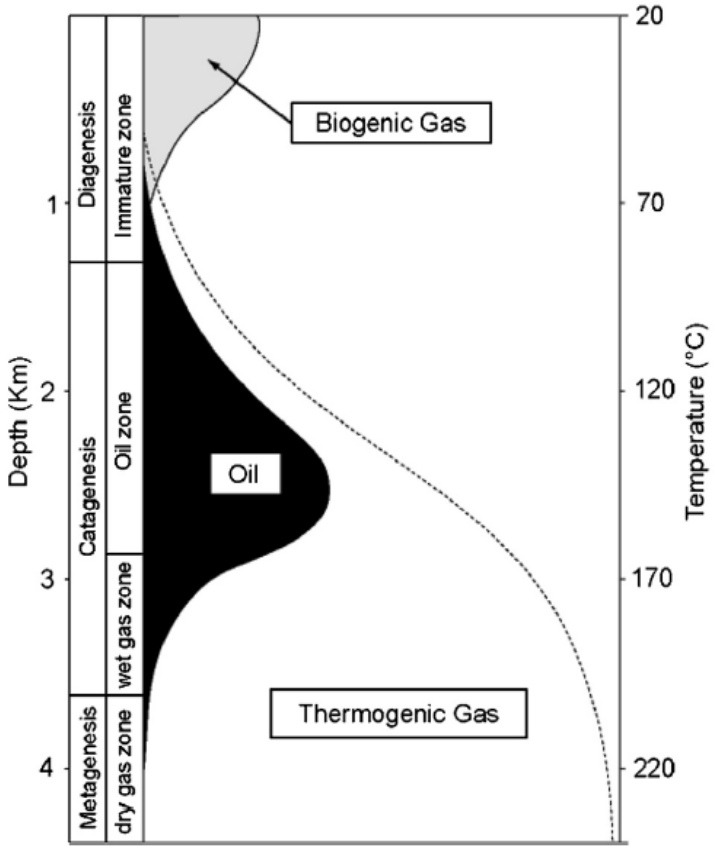
Origins of coal seam methane: Australian data



From Faiz et al. 2012

Temperature and biogenic methanogenesis

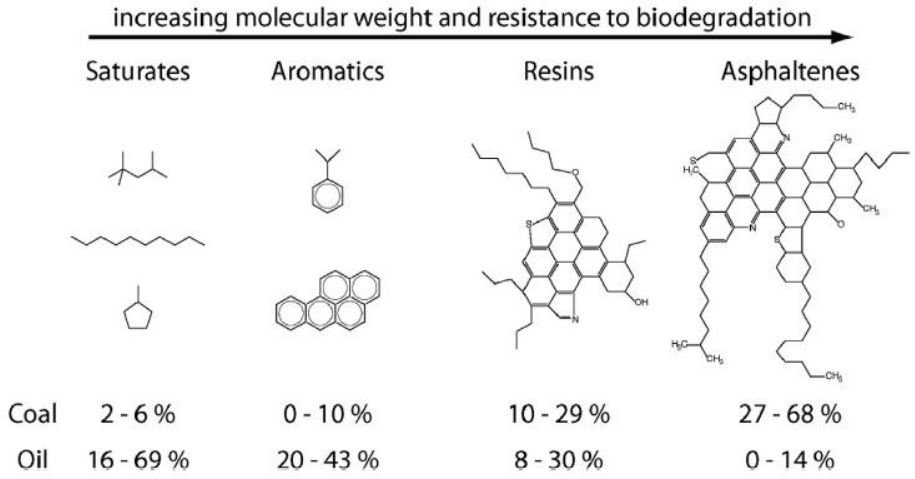
- Coal seams at present day temperatures below 80°C can contain methanogenic microbial community.
- Maximum activity occurs in the mesophilic – thermophilic range of 20°C to 65°C.
- Microbial activity in coal has upper limit of 110°C.
- Microbial activity occurs at the depths of interest for coal seam gas production.



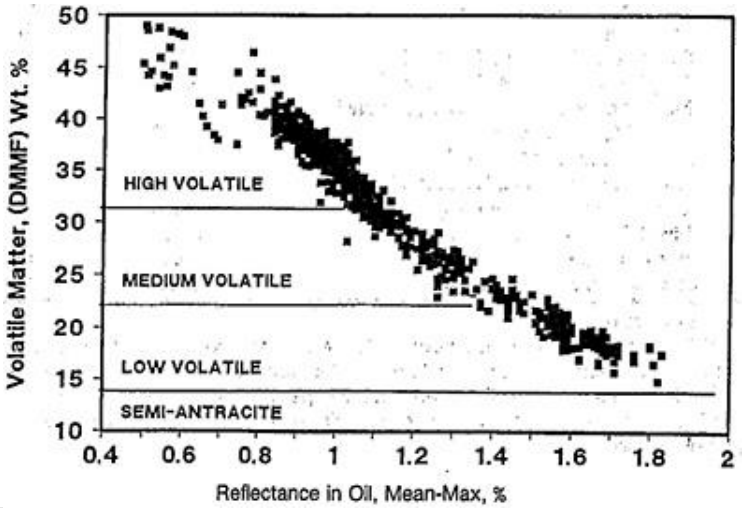
From Meslé et al, 2013

Coal organic matter and biogenic methanogenesis

- Only a portion of coal is bio-available.
- Proportion of the volatile fraction may be degraded.
- More complex organic matter fractions show increased resistance to biodegradation.



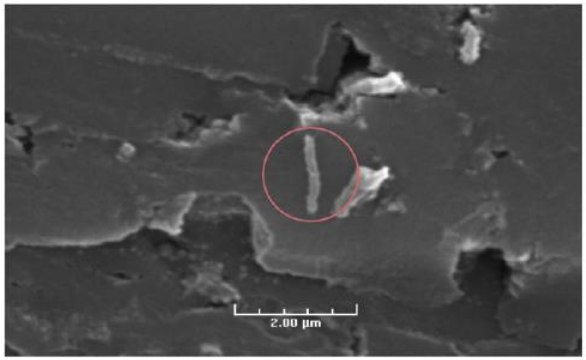
From Meslé et al, 2013

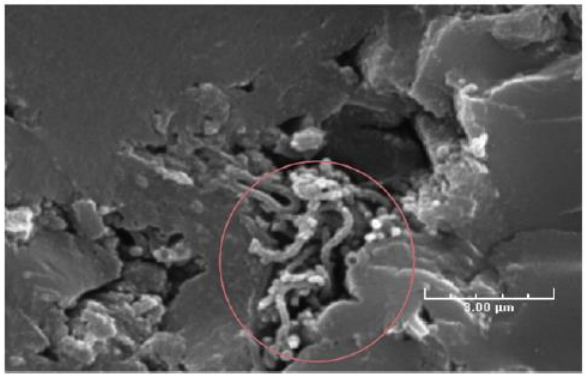


- Volatile matter may represent a significant fraction of coal depending on rank.
- Conversion by fermentative and acetogenic bacteria.

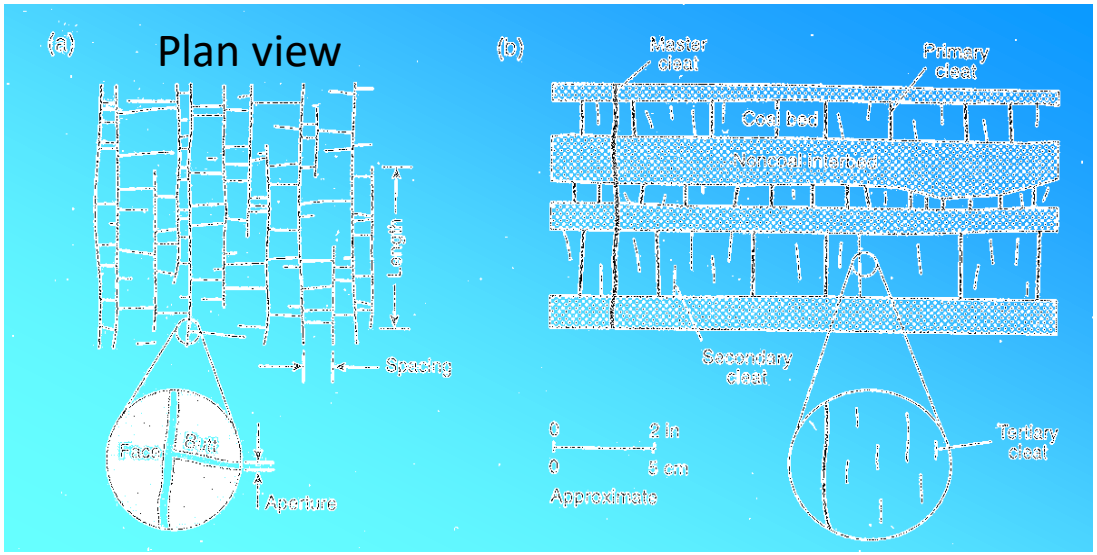
Coal structure and biogenic methanogenesis

- Fractured rock with dual porosity structure
- Bulk flow occurs in fracture system





From Moore, 2012



From Laubach et. al., 1998

•Much of internal coal surface area not accessible to microbial consortium.

•Substrate dissolved at coal-water interface and diffuses through aqueous phase to degrading microbes.

•Dissolved nutrients could diffuse into micro-porosity.

Nutrients and biogenic methanogenesis

- Microbial communities sustained by both coal seam organic matter and nutrients (nitrogen, phosphorous and potassium).

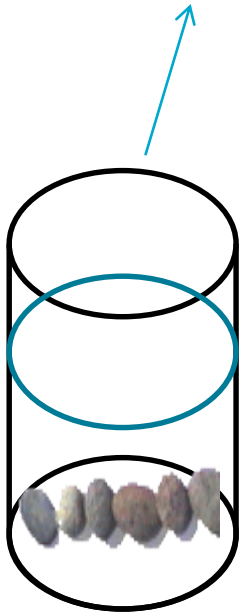
- Shallow coal seams
    - May receive sufficient nutrients via groundwater flow.

- Deeper coal seams
    - Groundwater low in nutrients
    - Under in situ conditions the nutrients required for microbial growth are derived from coal during degradation.

- Biostimulation - adding nutrients to coal seam reservoir formation water to stimulate in situ methanogenesis.

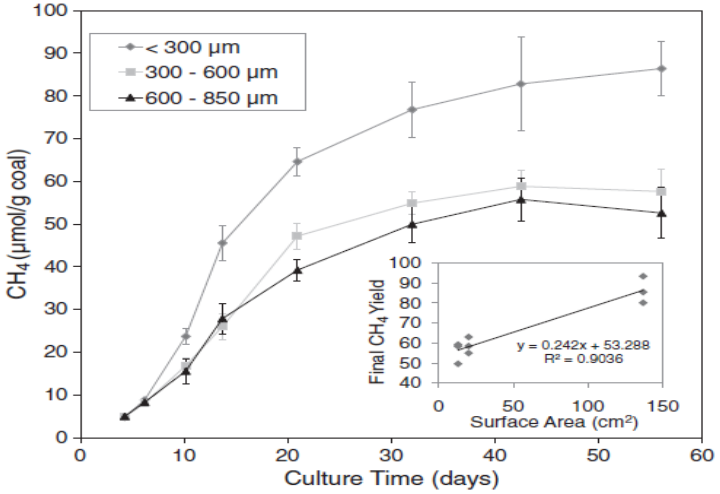
Biostimulation of coal methanogenesis

- Previous studies have demonstrated the effects of biostimulation under laboratory conditions.
- Nitrogen, phosphorous and potassium have been the main nutrients used to amend formation fluid.
- Conducted at atmospheric pressures and temperatures.
- Ratios of liquid to coal from 3:1 to 40:1.

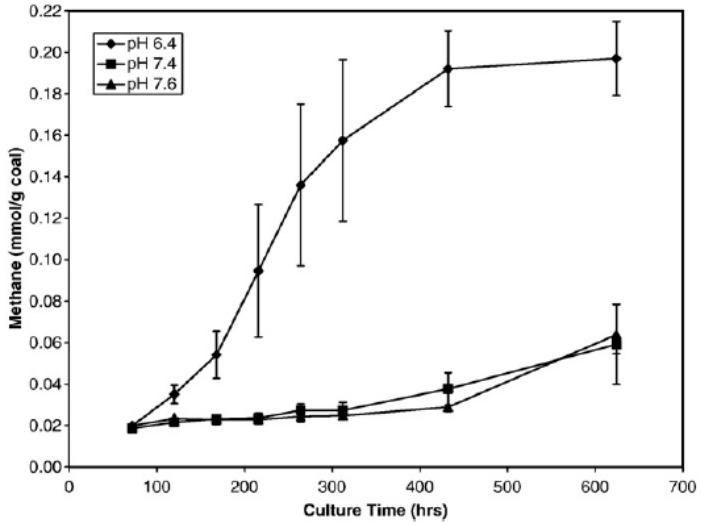


Previous studies: example results

- Significant variations in gas generated.
  - Function of coal properties
  - Endemic microbial community
  - Experimental conditions including particle size, pH, nutrient concentrations, temperature etc
- Plateau in gas generation observed.
  - Decline in production of organic compounds from coal substrates
  - Accumulation of toxic organics
  - Depletion of nutrients



Papendick et al. 2011



Green et al. 2008

Laboratory studies under reservoir conditions

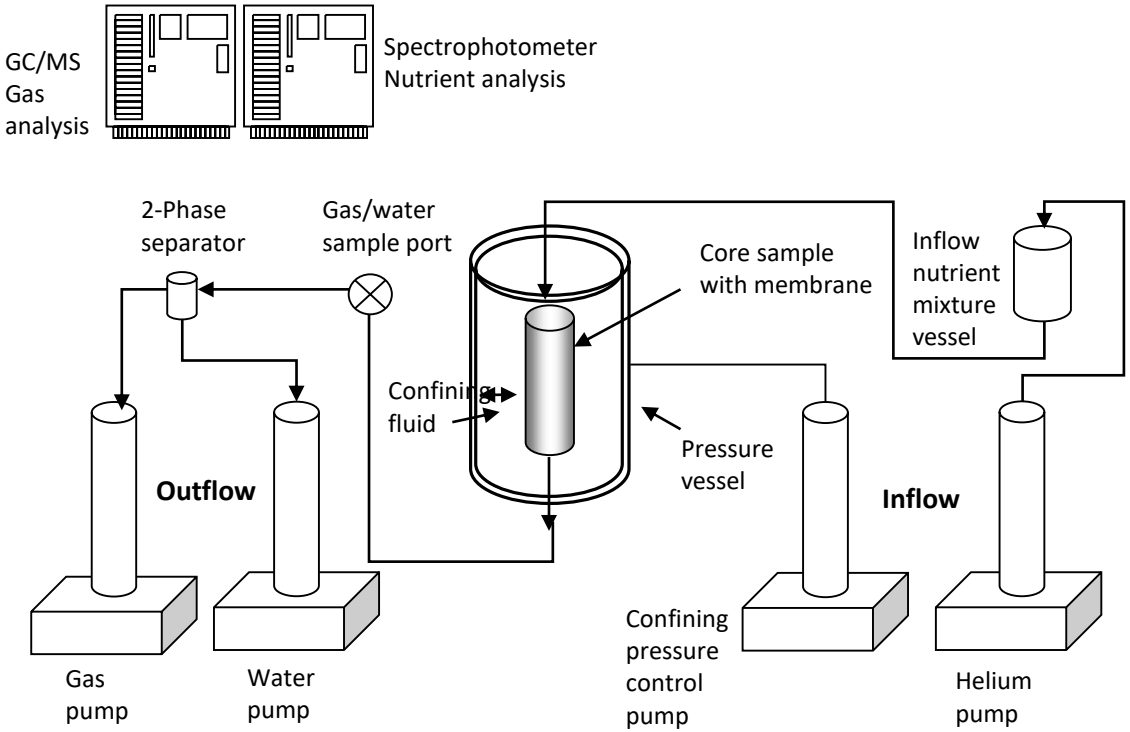
- Previous studies:
  - Utilised crushed coal at atmospheric pressure to characterise methane generation
  - Good gas generation rates observed

How do these laboratory results relate to what occurs in a coal seam reservoir?

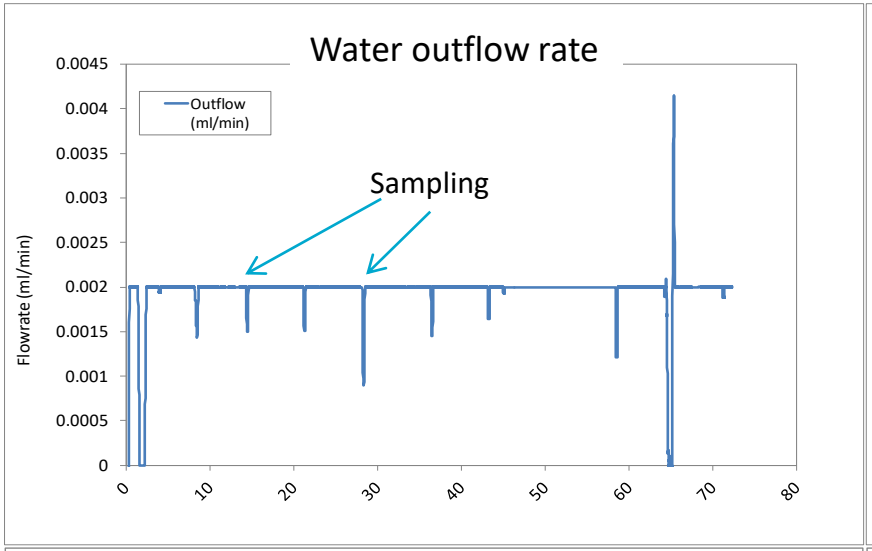
- This study:
  - Core flooding experiments replicating many key reservoir conditions.
  - Under anaerobic conditions
  - Using nutrient amended formation waters
  - With intact coal core
  - Conducted at reservoir pressure and temperature

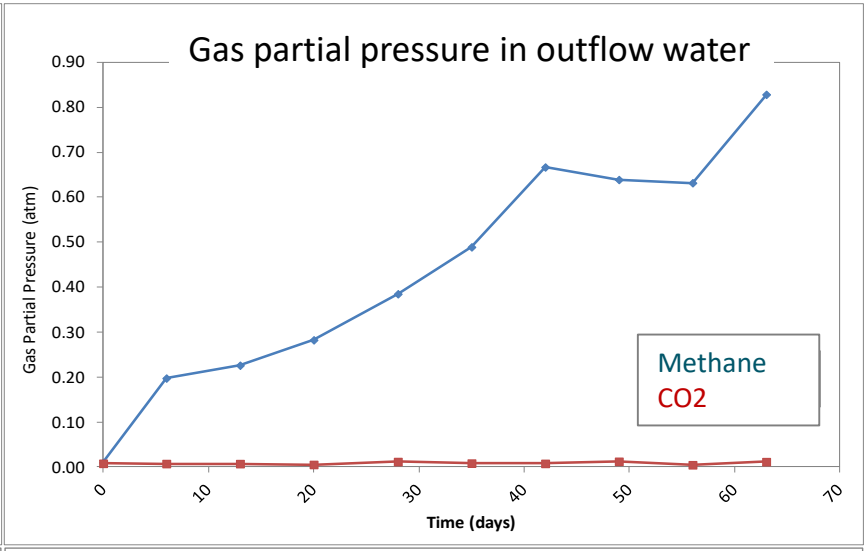
Core flooding rig

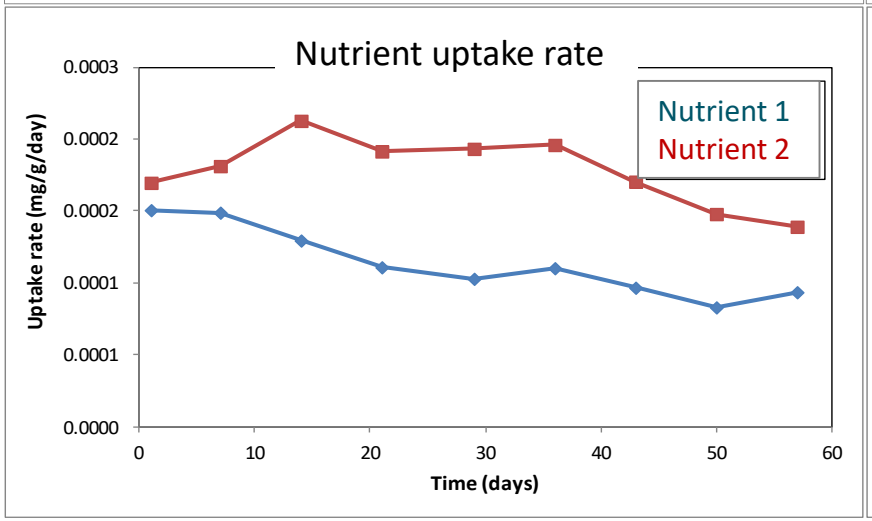
- Pressure vessel, fluids and pumps housed in temperature controlled cabinet
- Syringe pumps provide precise control and measurement of pressure and volume
- Phase separator on outflow to measure gas and water outflow rates.
- Nutrient and gas composition measurements using spectrophotometer and GCMS

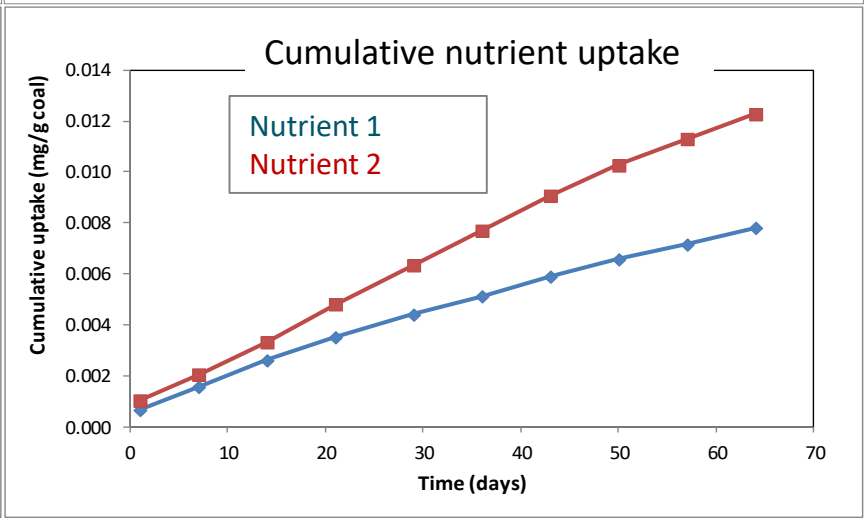


Example experimental observations









Some selected results

- Measured gas contents ranged up to 1.8 m^3/t over a 20 week period
- 5 coal samples collected from a range of Australian coal seam gas producing areas.
- 4 different formation waters, collected anaerobically from separate producing wells.

Core flood / sample number	Formation water	Residual CH_4 within the coal core (atm)	Gas generation results		Nutrient consumption	
			CH_4 m^3/t	CO_2 m^3/t	Nutrient 1 mg/g	Nutrient 2 mg/g
1	A	0	1.16	0.03	0.010	0.010
2	B	0	1.05	0.03	0.010	0.010
3	C	0.123	0.27	0.02	0.005	0.011
4	D	0	0.38	0.09	0.008	0.012
5	C	1.82	0.15	0.01	0.013	0.003

Conclusions

- Nutrient amendment of coal seam formation waters can lead to methane generation with intact coal at reservoir pressures and temperatures.

- Up to 1.8 m^3/tonne generated after a 20 week period.

- Indigenous microbial community in formation water could have an important influence on gas generation.