Enhanced mine gas drainage

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Nature of gas storage in coal

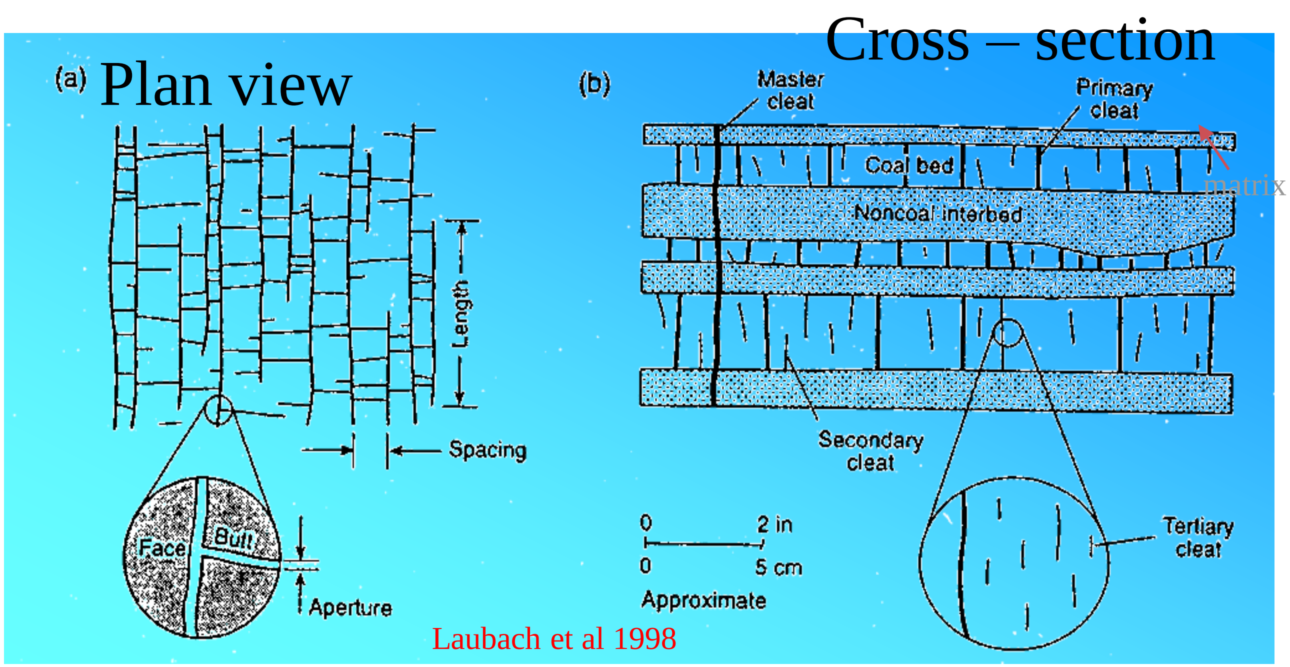
- Coal physical structure
  - Has a dual porosity
    - Macropores – the cleat system
    - Micropores – the coal matrix
  - Most of the porosity and surface area is in the matrix (eg 85%)

Total porosity is low

Majority of gas is adsorbed to solid structure

Most surface area is within the matrix

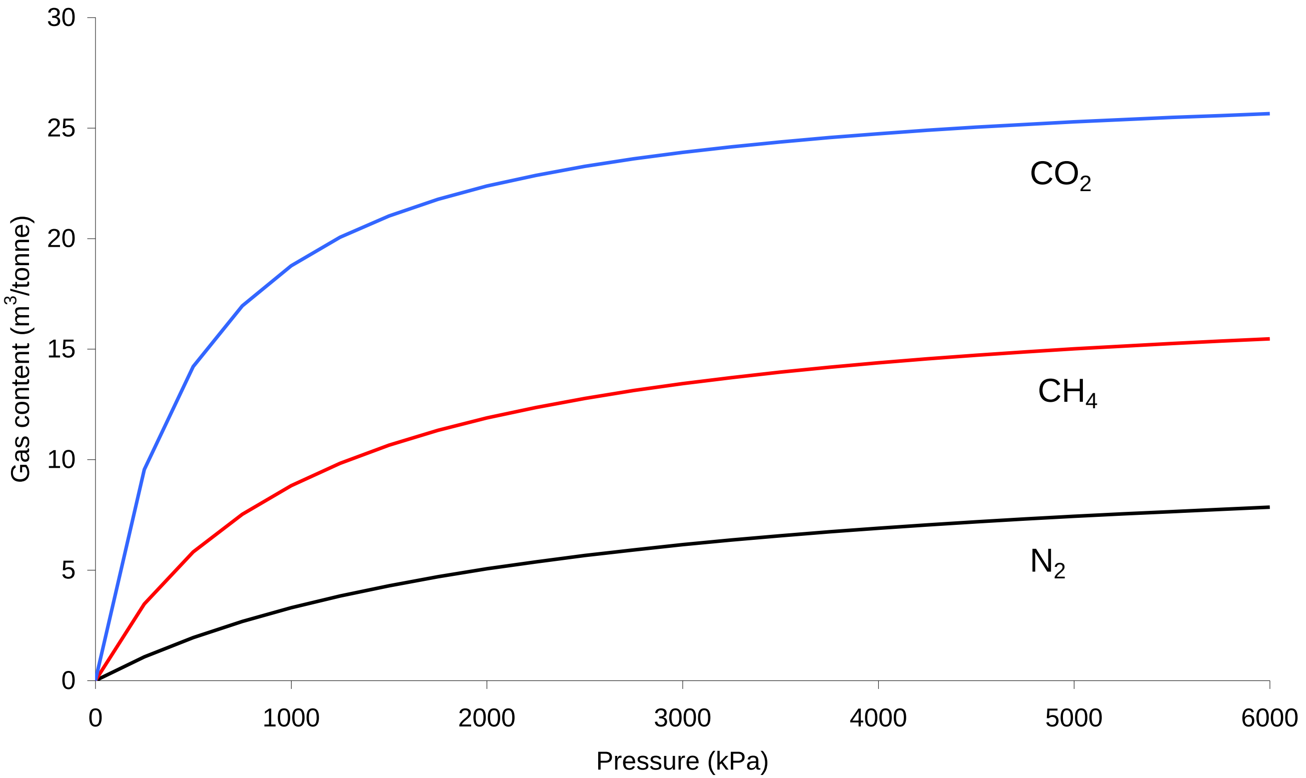
- Cleat systems
  - Two main sets - orthogonal
    - Face cleats
    - Butt cleats
  - perpendicular to bedding plane



Laubach et al 1998

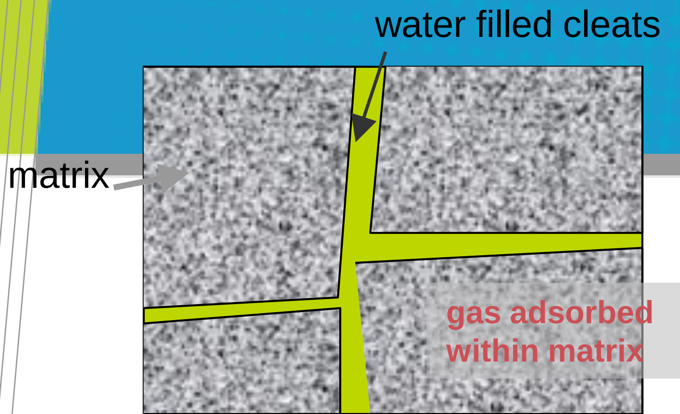
Gas adsorption in coal

- Quantity stored is a function of pressure, temperature
- Coal adsorbs more CO_2 than CH_4, capacity for nitrogen is low
  - typically 2 molecules of CO_2 for each CH_4 molecule
  - 4 CO2 or 2 CH4 for every N2

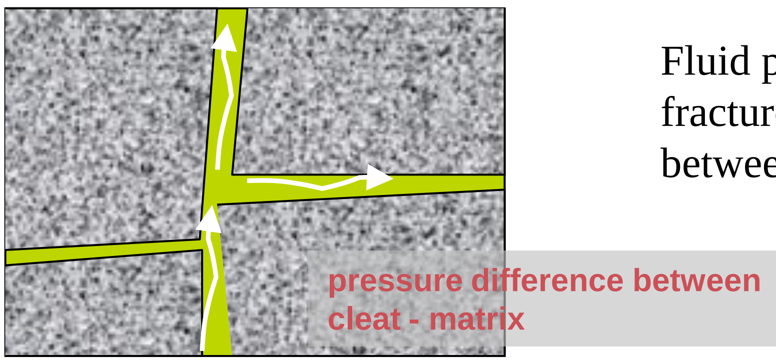


Bulli seam

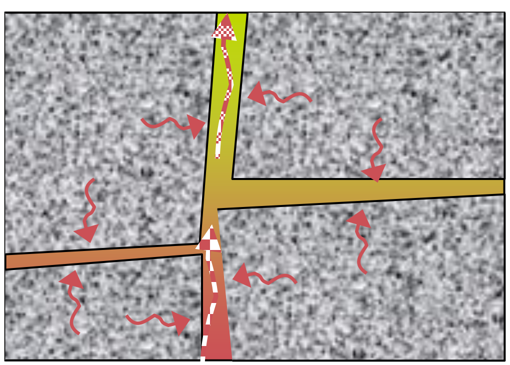
Primary coal seam gas recovery



Initial state – pressure maintains a certain mass of gas adsorbed

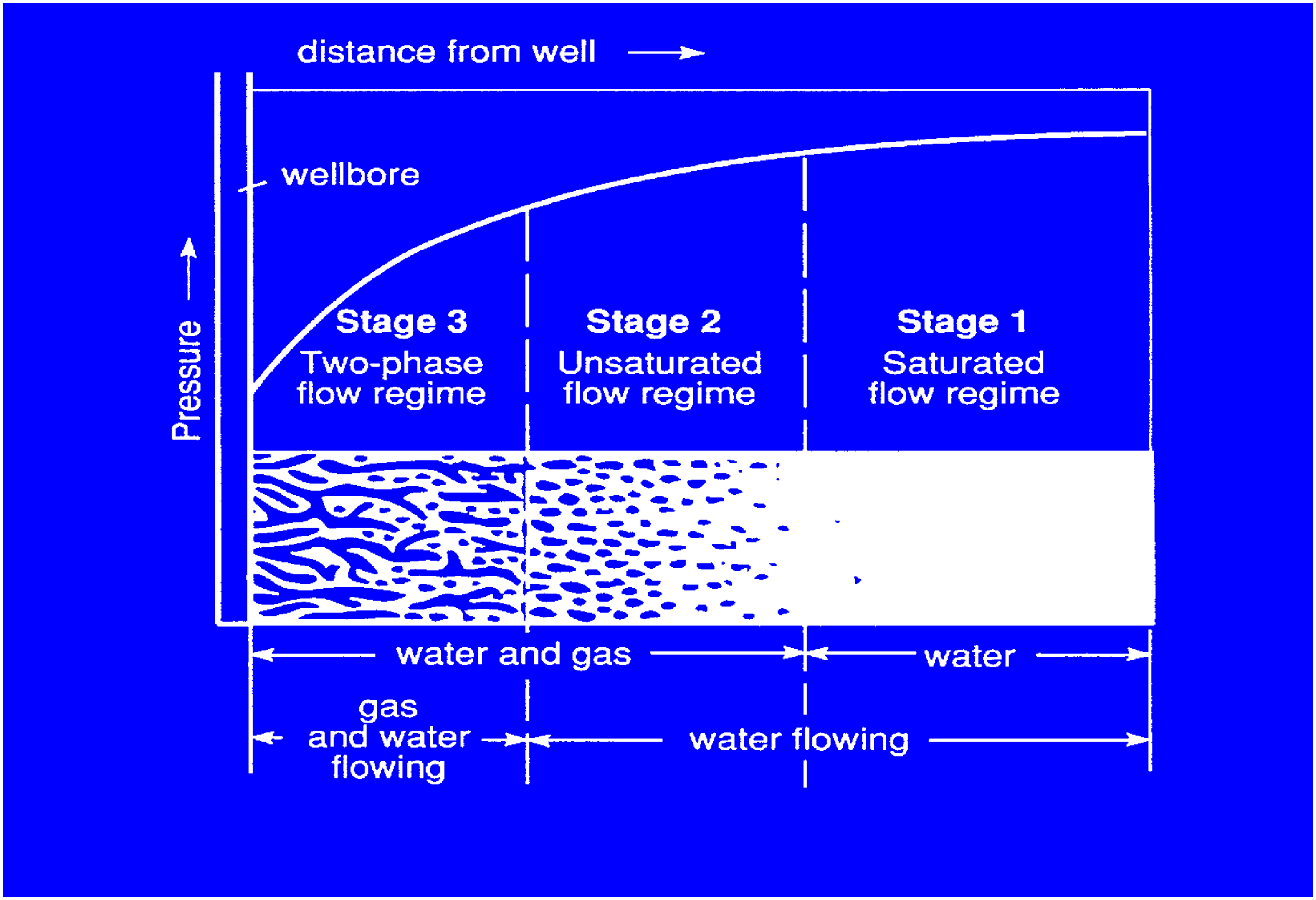


Fluid pressure lowered in cleat/ fracture system – pressure difference between cleat and matrix

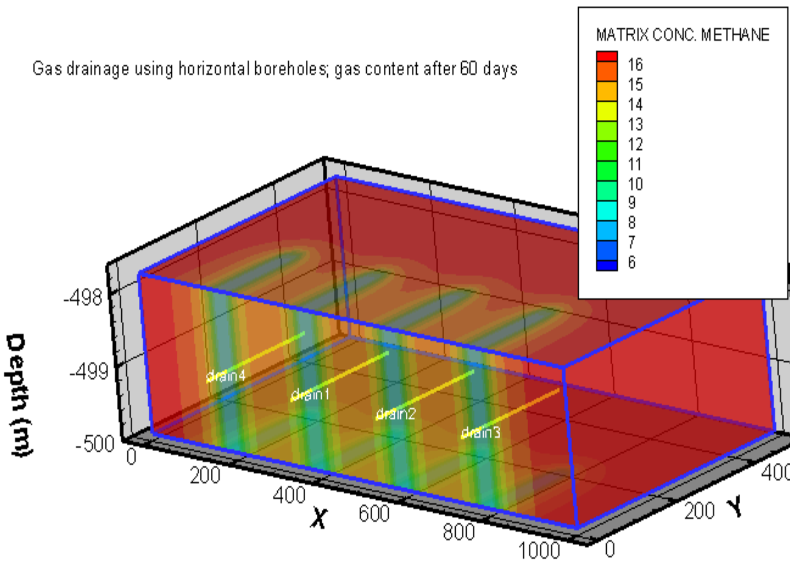


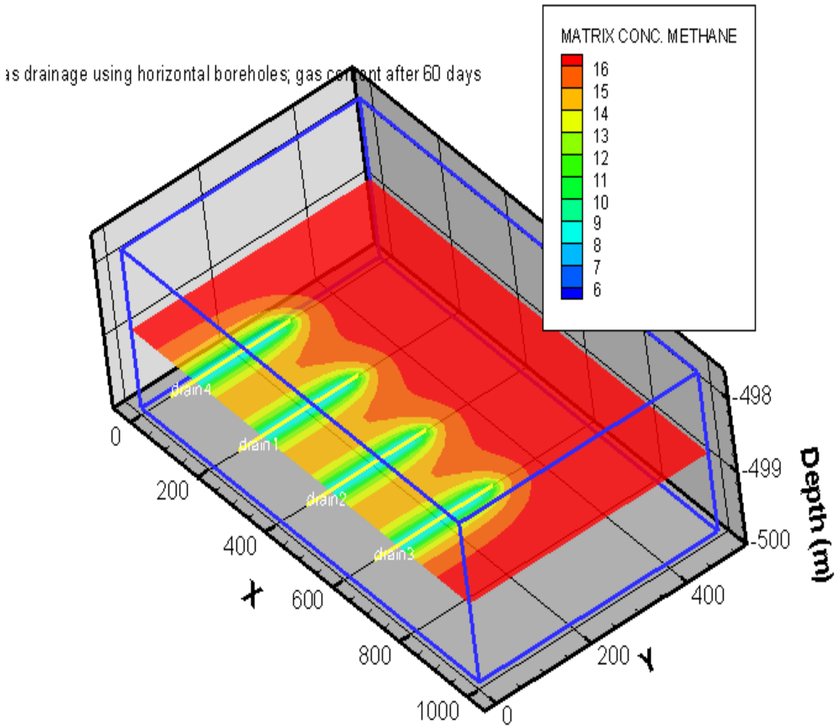
Pressure lowered, gas desorbs and diffuses through matrix to cleat – water and gas flow within cleats

Two-phase flow system around the well



Gas drainage effectiveness

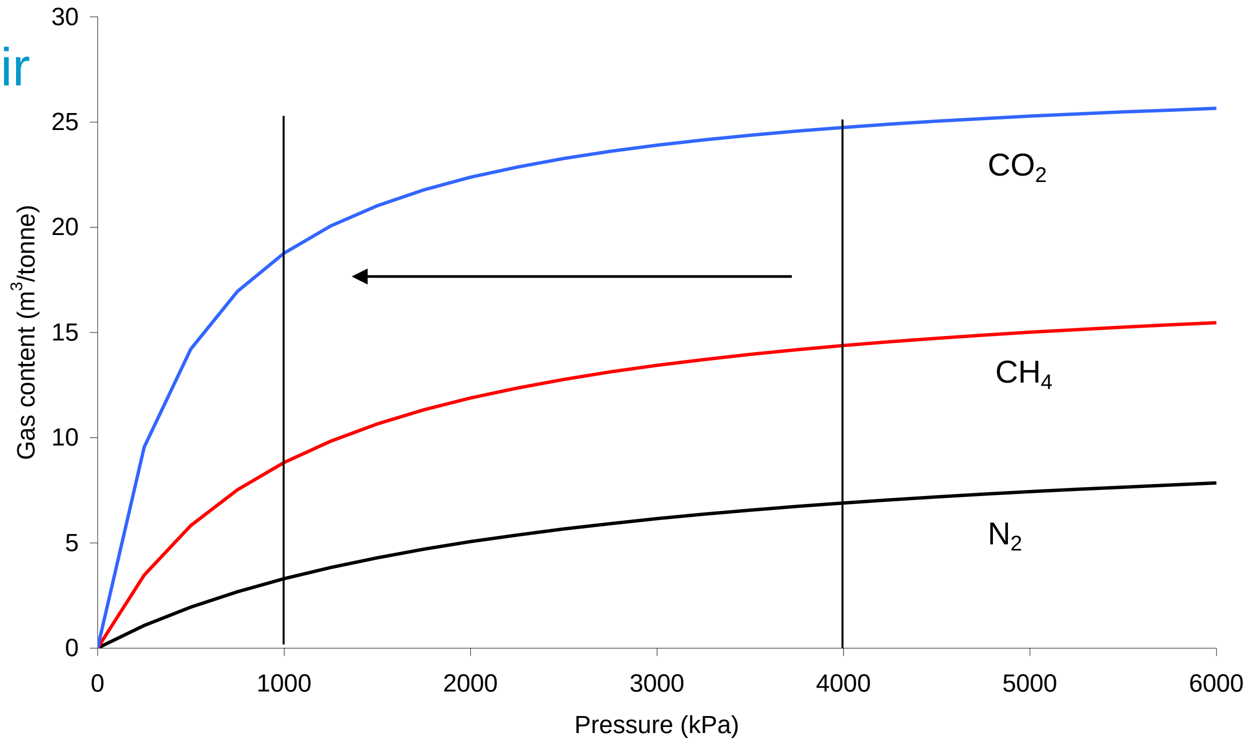




- Drainage
  - a complex function of borehole spacing, gas flow, gas desorption with pressure
    - Key reservoir properties - permeability, adsorption isotherm
  - Limited by the ability to lower the pore pressure

Pressure drawdown and gas desorption

- Drawing the reservoir pressure down from 4 MPa to 1 MPa
  - CH4 14 m^3/t to 8.8m3/t
  - CO2 25 m3/t to 19 m^3/t – much lower pressures required



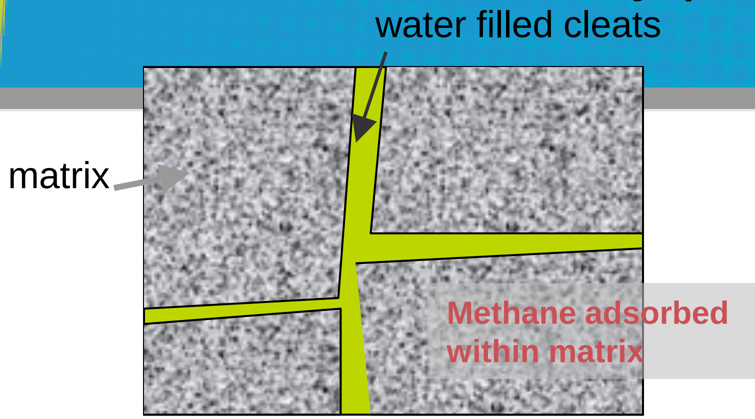
Limited by the ability to lower the pore pressure within the coal

- largest changes in gas content occur at low pressure

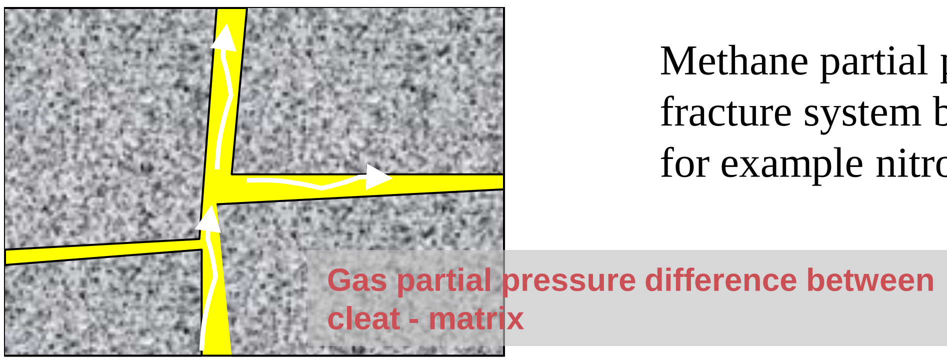
Enhanced coal seam gas recovery

- Primary coal seam gas drainage
  - Pressure drawdown and gas desorption
  - Limited by the ability to reduce the reservoir pressure
  - Drainage a function of well spacing, reservoir properties and drainage lead time
- Enhanced recovery using gas injection
  - A contrasting gas (i.e. not the coal seam gas) is injected into the coal seam and this acts to displace the coal seam gas

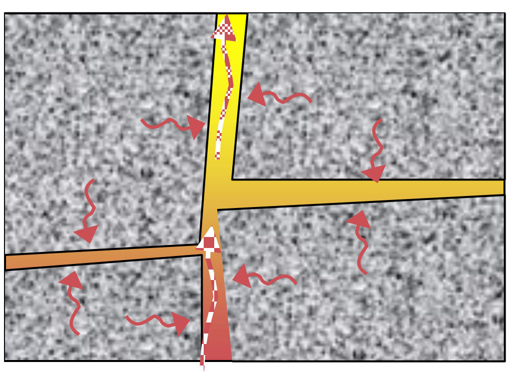
Enhanced recovery process



Initial state – pore fluid pressure maintains a certain mass of gas adsorbed

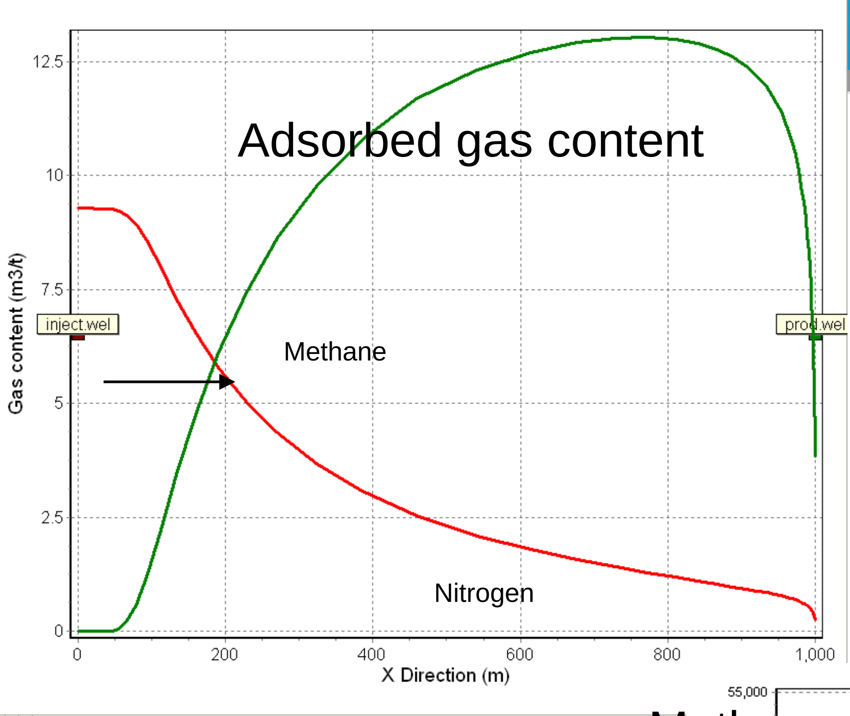


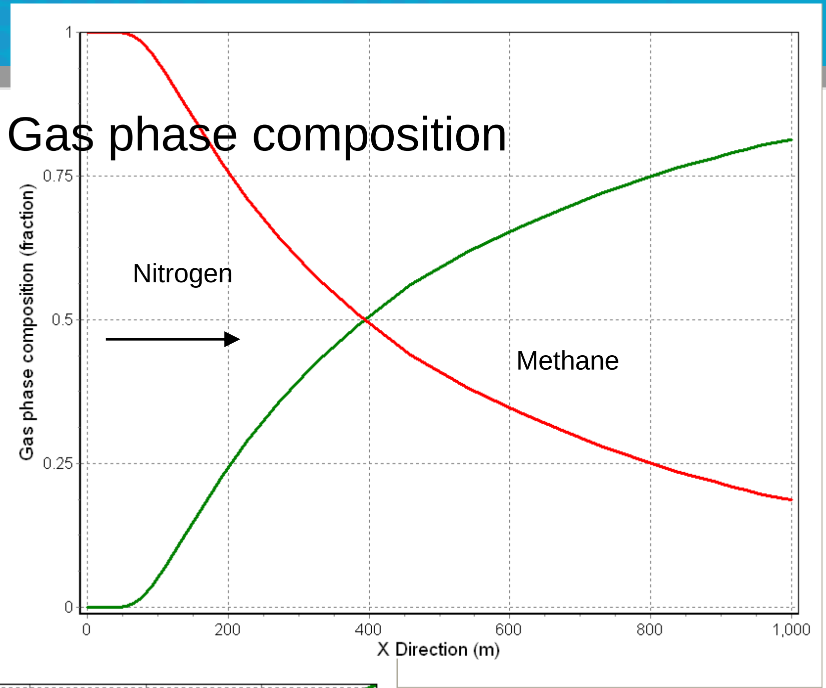
Methane partial pressure lowered in cleat/ fracture system by injection of contrasting gas, for example nitrogen

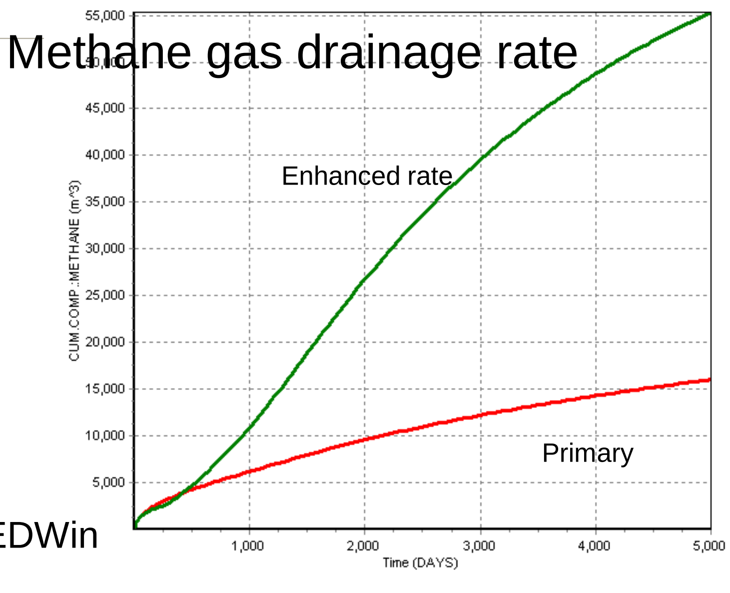


Methane pressure lowered, gas desorbs and diffuses through matrix to cleat – water and gas flow within cleats

Example: Enhanced gas drainage using nitrogen







Simulation results calculated with SIMEDWin

Enhanced coal seam gas drainage

- Potential advantages
  - Since ECBM relies on gas partial pressure difference to displace gas in place
    - Ultimate drainage can be much higher than primary recovery
  - Also the injected gas acts to maintain the reservoir pressure and increase gas drainage rates
  - Injecting a weakly adsorbing gas (i.e. nitrogen) will increase the permeability through coal shrinkage with decreased total gas content

- Candidate gases for injection
  - Weakly adsorbing gas – nitrogen
  - Gas mixtures – nitrogen & carbon dioxide - for open cut purposes
  - Pure or high percentage CO_2 not appropriate – much higher gas contents than in place methane, well known problematic gas for mine drainage, associated with low permeability, lower outburst threshold

- Additional costs of ECBM
  - Well costs (dedicated injection well)
  - Sourcing the injection gases and their compression/injection

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Enhanced recovery field trials

- N2 injection
  - Tiffany trial San Juan Basin
  - 1998-2002 (intermittent injection)
  - There was an 5x increase in the methane gas rate in response to N2 injection – due to combined effects of methane displacement, pressure maintenance and permeability enhancement

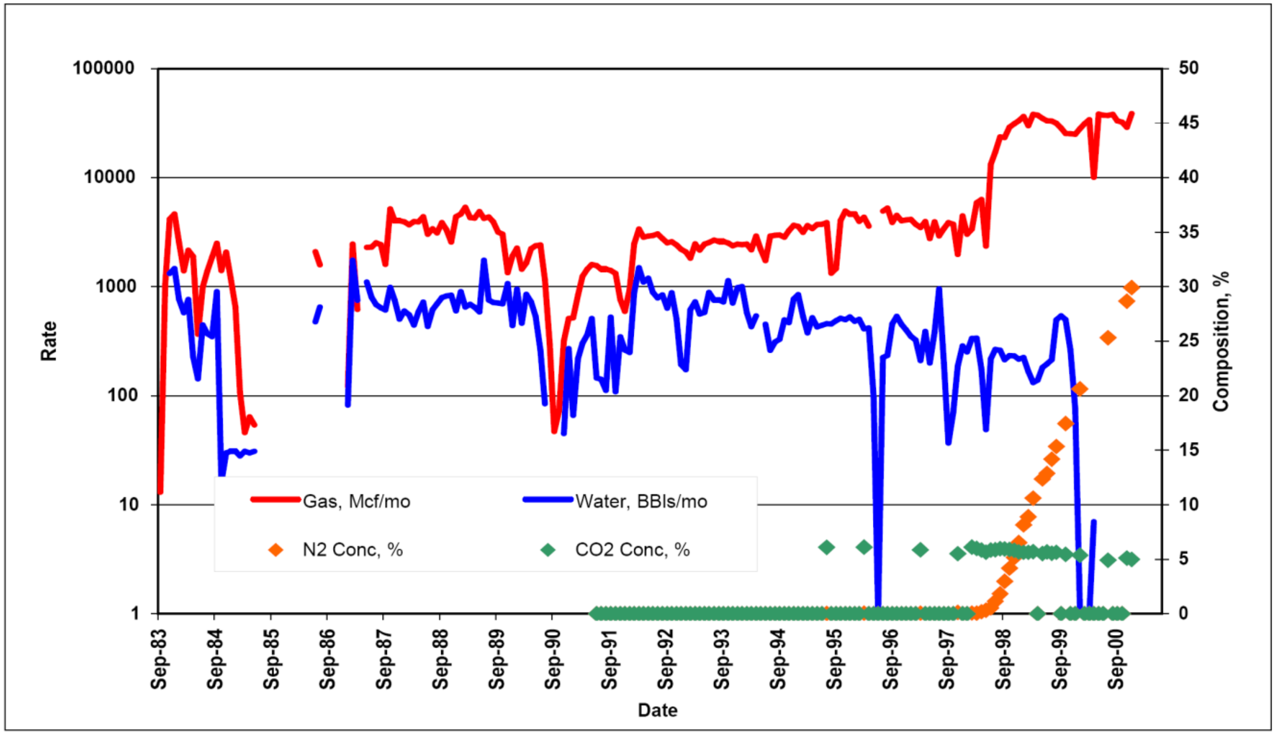

Figure 5: Producing History, Individual Tiffany Unit Well

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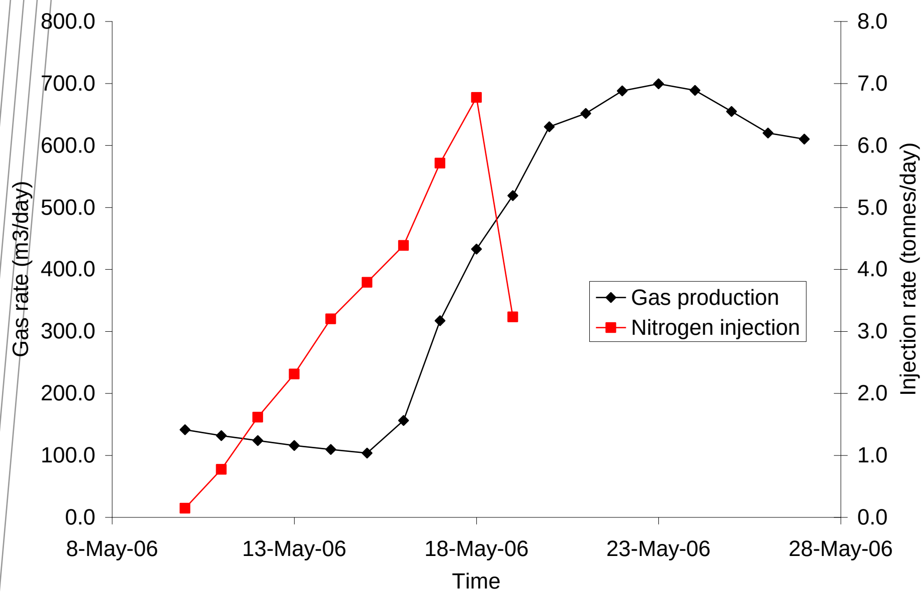
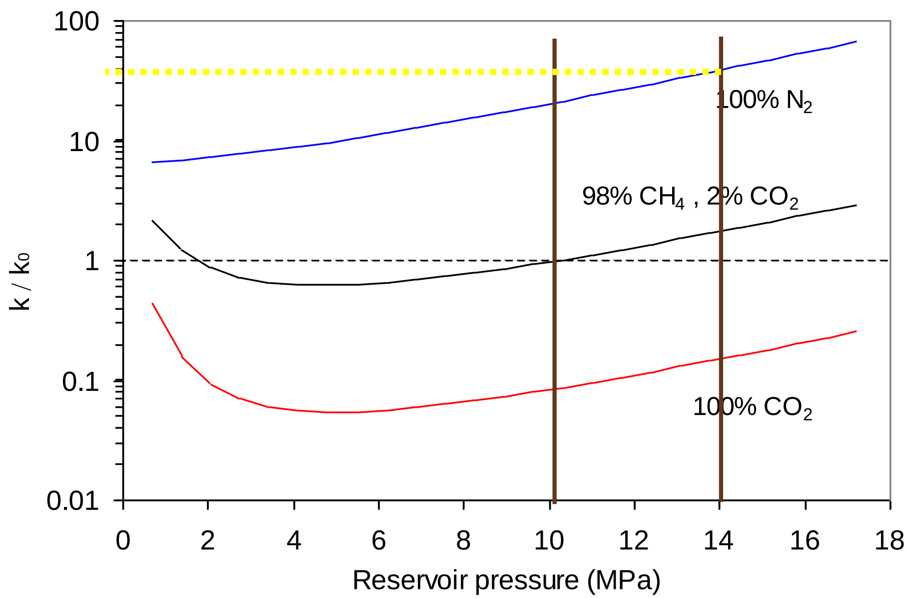
Enhance recovery field trials

- Yubari trial – JCOAL
  - Vertical injection and production wells 66m separation in target seam at 900m depth
  - Short period of N2 injection after longer duration CO2 injection
  - Also N2 breakthrough at production well

Gas injection and production rates during N2 injection





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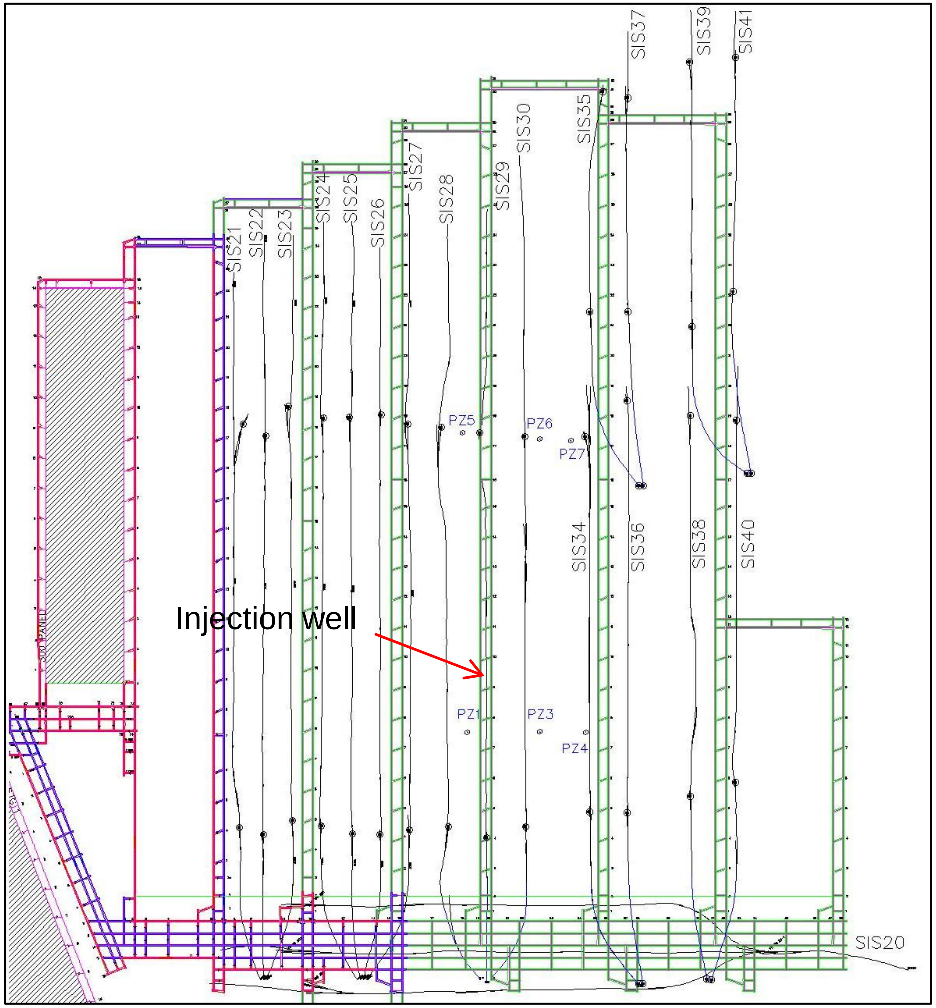
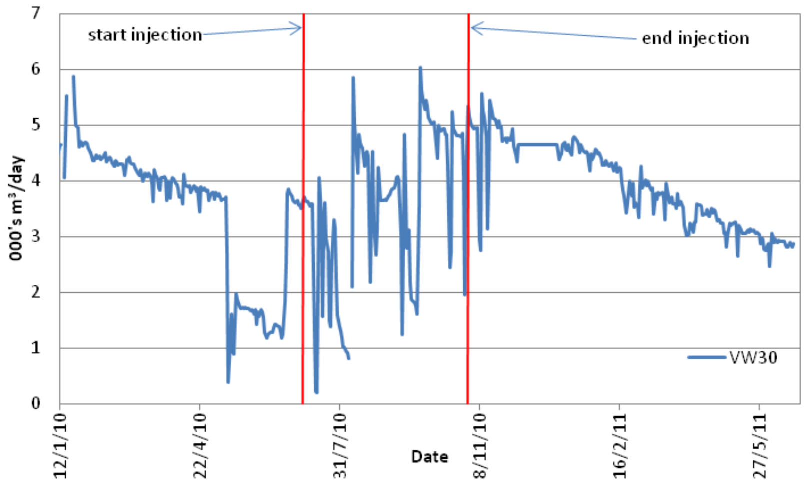
Nitrogen enhanced mine drainage

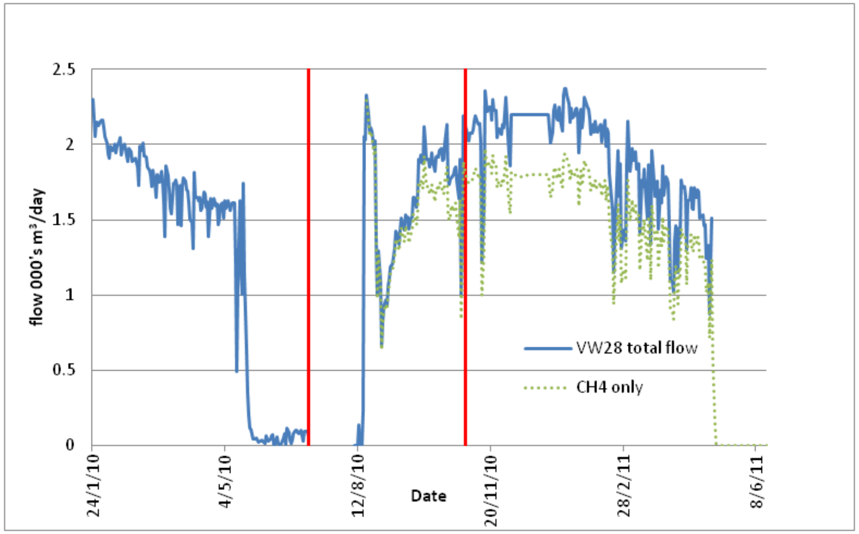
- Russell Packham as part of PhD at UNSW
- Bowen basin coal mine
- Surface to inseam wells
- An existing nitrogen membrane plant used for goaf inertisation was available for periods within the year
- Injection into one horizontal well while production maintained in neighbouring wells
- Virgin gas content ~7m^3/t

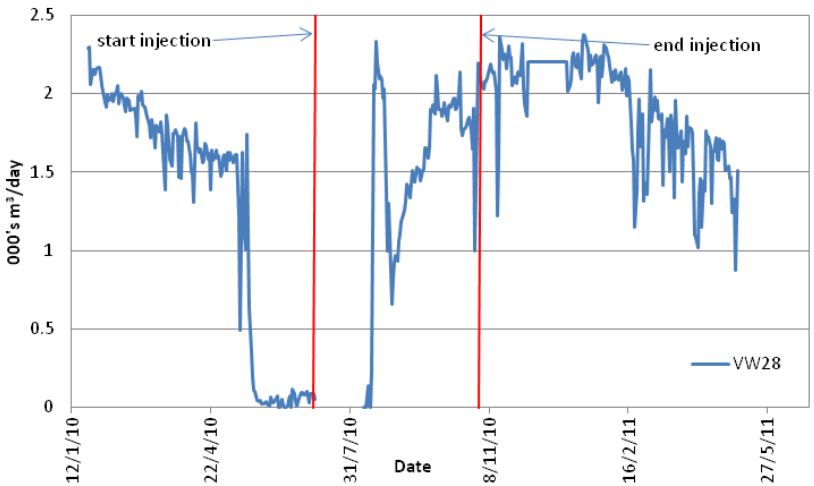


See Packham et al 2011 Int. J. Coal Geol. and Packham et al. 2012 in press

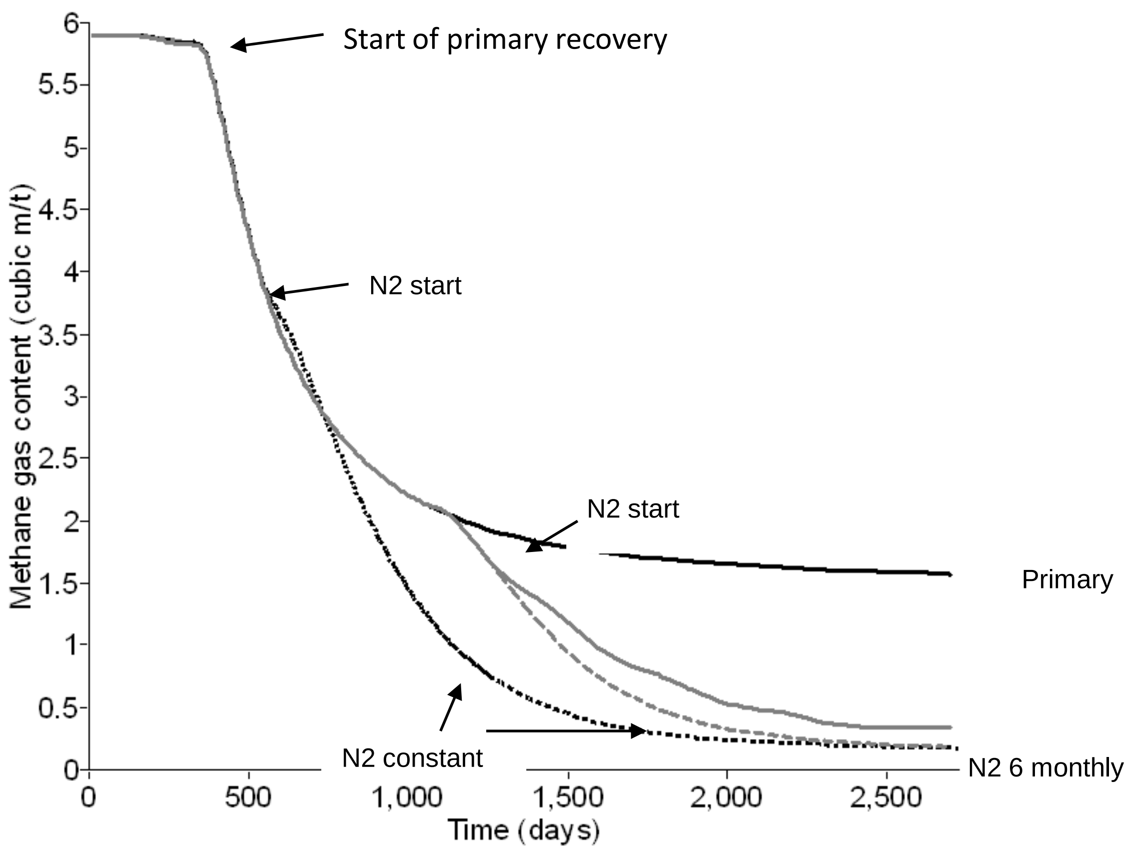
Gas drainage rates





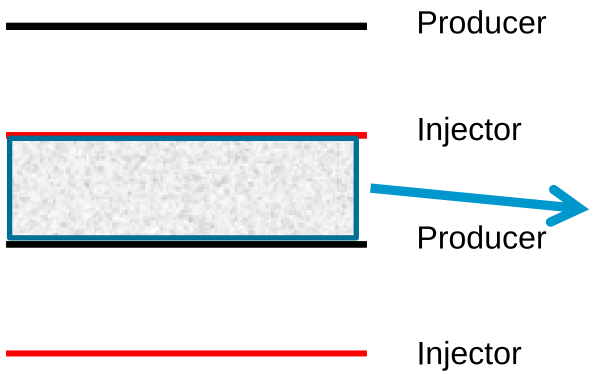


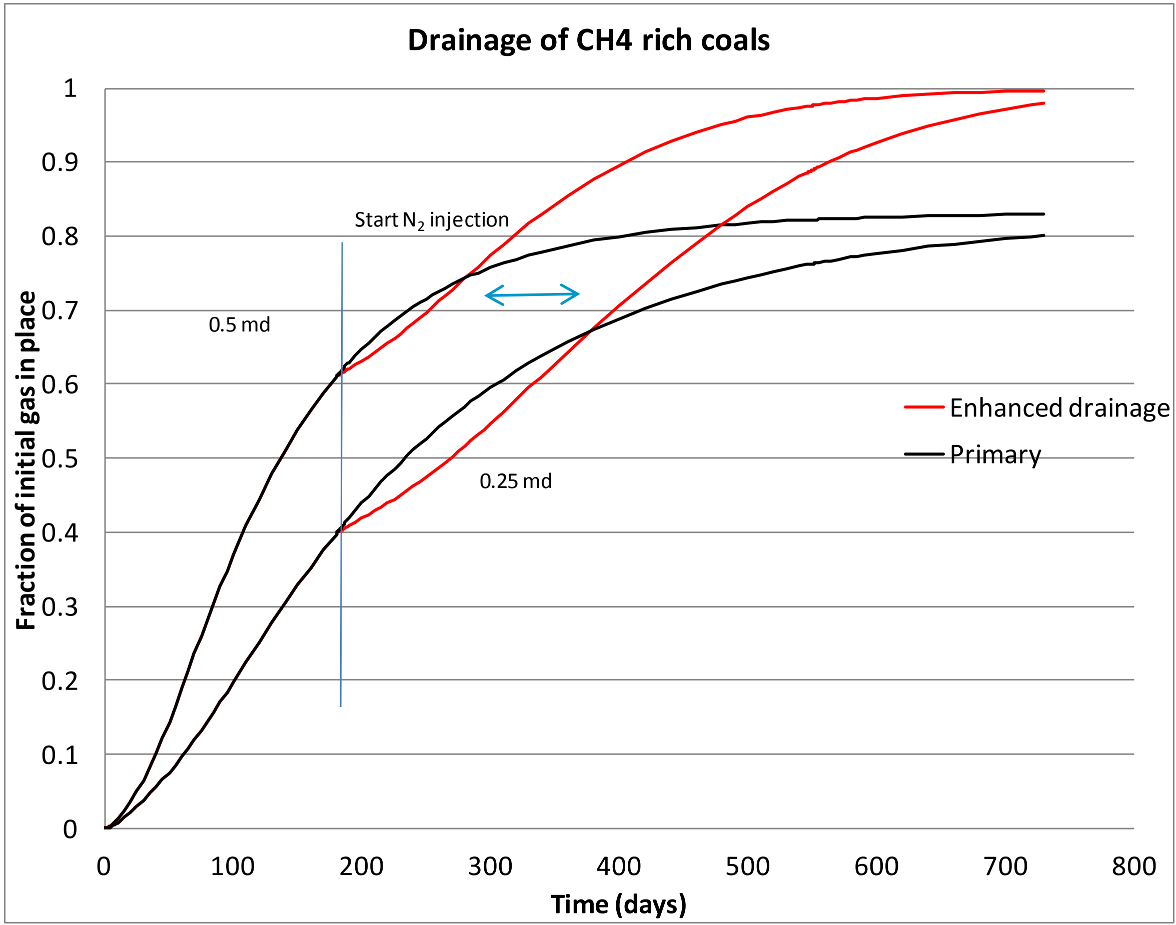
Gas drainage predictions from modelling Packham trial



Enhanced drainage and permeability

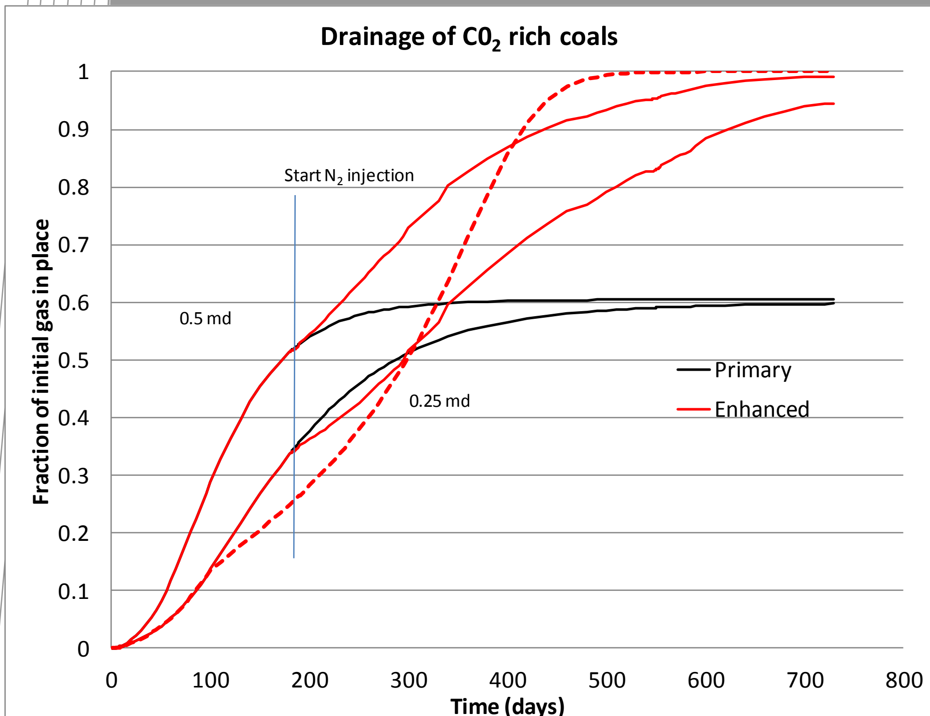
- Series of reservoir simulations comparing primary and enhanced drainage
- 100m spaced horizontal wells

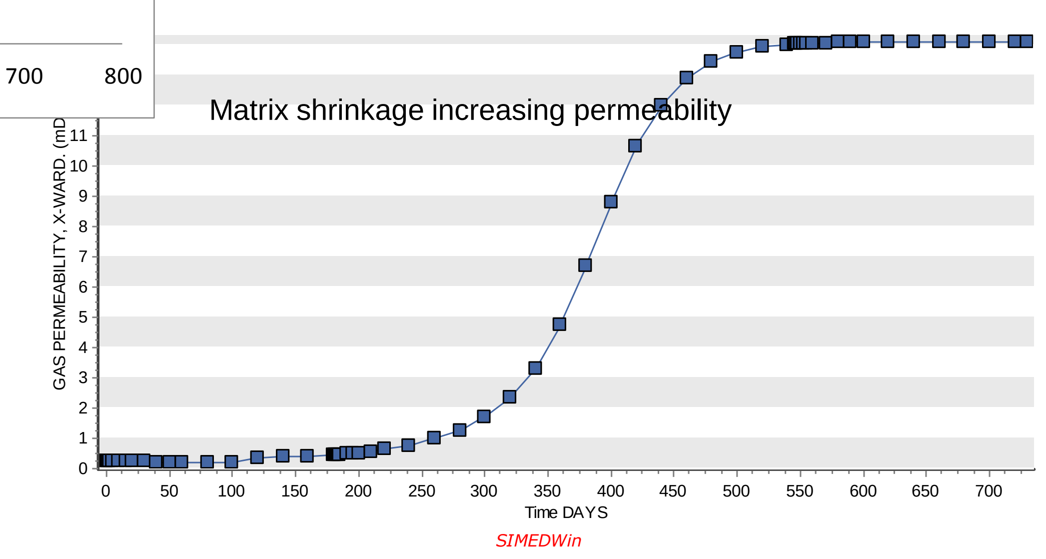




- 600m deep seam at hydrostatic pressure and gas saturated

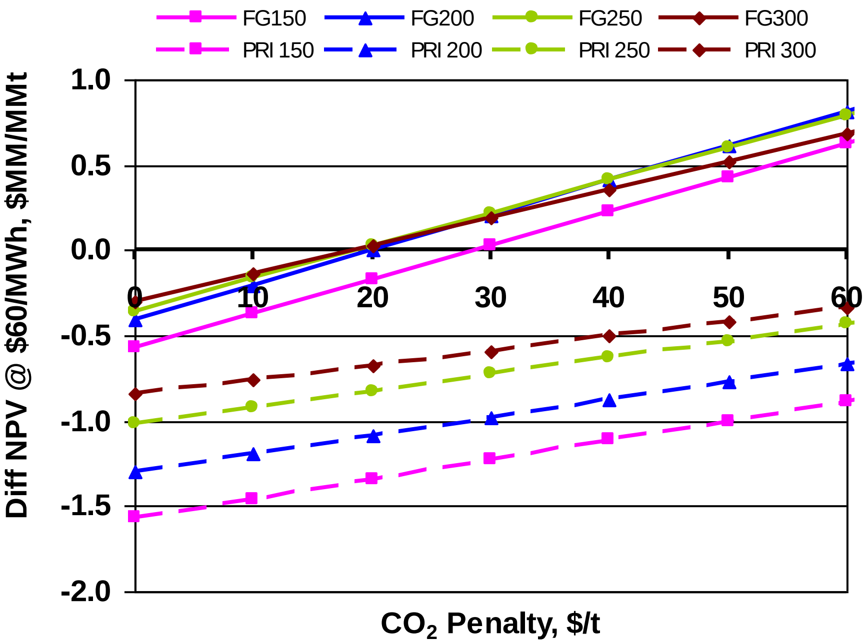
Initial gas content 50:50 CH4:CO2





Enhanced mine drainage for reducing open cut fugitives

- 130m deep seam with reservoir properties from Hunter Valley coal sample; produced gas is used in a power station
- Differential net present value after 4 years between the no drainage case and enhanced drainage or no drainage and primary drainage
- For the no drainage case the seam gases become fugitive and incur an emissions penalty
- There is a positive business case for enhanced drainage above an emissions penalty of $20/tonne CO2e.
- In contrast primary drainage never reaches breakeven and so is not feasible compared to allowing the gases to become fugitive



From ACARP C17055

Conclusions

- Enhanced drainage acts to maintain gas drainage rates and increase the proportion of gas recovered
- Nitrogen is a lower adsorbing gas than CH_4 and CO_2
- Enhanced drainage with nitrogen also would increase the permeability through coal shrinkage
- Coals rich in CO_2 may have the greatest benefit because of the low pressure drawdowns required to meet safe mining thresholds
- Initial reservoir permeability will still play an important role
- Trials are needed to evaluate this process