Coal Bed Methane
(black coal, green future....)

Coal bed methane
CBM

Also known as:
- Coalbed gas
- Coal seam gas (CSM)
- Kohleflözmethan (German)
Global coal distribution

What is CMB?

In the old days CBM was mainly a safety risk!

→ Canary in a coal mine.
Formation of CBM

- Biogenic methane is produced by anaerobic bacteria in the early stage of coalification.
- Thermogenic methane is mainly during coalification at temperatures of 120 – 150°C.

Conventional natural gas

Rock formations important to oil and gas:
- Source rock → formation that contains the organic matter
- Reservoir rock → formation with pore volume capable of containing commercial quantities of hydrocarbons
- Cap rock → impermeable formation that inhibits flow of fluids and gases
Conventional natural gas

Schematic view of a conventional gas deposit

Reservoir rock:
porous sandstone
porosity 10-20%
Conventional gas vs unconventional gas

Conventional gas ≠ Unconventional gas

CBM = unconventional gas

- CBM did not migrate from the source rock into the reservoir rock
- Coal is the source rock and the reservoir rock
- The methane does not occur as free gas in the pore space of coal (only 1 – 2 %)
- CBM does not conform to the ideal gas law ($pV=nRT$)
CBM = unconventional gas

- Coal is adsorbed to the coal matrix
- Coal can store around 6 to 7 times more methane than the equivalent volume of rock in a conventional reservoir
- Adsorption/desorption of gas to/from the surface of a solid can be described by the Langmuir Isotherm

\[
\Gamma = \Gamma_{\text{max}} \left( \frac{K_c}{1 + K_c} \right)
\]

- \(K = \) Langmuir equilibrium constant,
- \(c = \) aqueous concentration (or gaseous partial pressure),
- \(\Gamma = \) amount adsorbed
- \(\Gamma_{\text{max}} = \) maximum amount adsorbed as \(c\) increases

Desorption from internal coal surfaces
Diffusion through the matrix and micropores
Fluid flow into natural fracture network
Face cleats

Butt cleats

- Cleats form an interconnected network in the coal, normal to bedding
- Angle between face cleats and butt cleats is around 90°
- Spacing between cleats is normally less than 25 mm and the aperture is 0.1 – 2 mm
- Butt cleats (shorter) terminate at a face cleat
- Cleats are formed due to intrinsic tensile force (shrinkage), fluid pressure and tectonic stress
- Tectonic stress controls the geometric pattern of the cleats
- Permeability ratio face cleats : butt cleats may range from 1:1 to 17:1
CBM production

http://www.ugcenter.com/Video/item36842.php
CBM production

Two factors are important for CBM production

• Gas content and adsorption capacity of the coal
• Hydraulic permeability of the coal
Gas content / Adsorption capacity

Results of Gas Content Analysis

Gas Composition Analysis
Measured Gas
Lost Gas; Direct Method
Desorption Terminated; Sample Is Pulverized And Residual Gas Is Measured

Elapsed Time, hours

Gas Content, units

Gas content / Adsorption capacity

Typical Gas Storage Capacity Results

In-Situ Gas Storage Capacity, units

Pressure, psia
Gas content / Adsorption capacity

Critical Desorption Pressure

- Gas storage capacity determined from adsorption isotherm analysis
- If the gas content is equal to gas storage capacity then the CBM reservoir is saturated
- If the gas content is less than the gas storage capacity then the CBM reservoir is undersaturated
- If CBM reservoir is undersaturated then reservoir pressure must be decreased until the matrix can no longer physically retain gas
- Gas content determined from canister measurements is plotted at reservoir pressure

Example

- Region 1, Declining Pressure
- Region 2, Transition
- Region 3, Declining Reserves

% of OgP

% of P(i)
Coal bed methane project in India

Drilling of an exploratory borehole
Coal bed methane project in India

Drilling of an exploratory borehole

Permeability testing
→ Assembling of packer system
Coal bed methane project in India

Permeability testing
→ Installation of packer system
Type of tests

Injection test

Pressure and flow in test zone

Type of tests

Falloff test
(after injection test)

Pressure and flow in test zone
Type of tests

**Falloff** (after injection test)

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**Injection**

![Injection Diagram](image)

**Falloff**

![Falloff Diagram](image)

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**DST (Drill Stem Test)**

Consists of a drawdown phase and a buildup phase

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![DST Diagram](image)
Understanding pressure diagrams of DSTs

Position of gauges:
- blue: fluid recorder
- red: outside recorder
- green: below recorder
Hydraulic fracturing

Increase permeability
Hydraulic fracturing

Carrying out a first injection cycle → breakdown cycle
... thus creating an induced fracture

Potential problems with CBM

- Water management of pumped water
- Impact on groundwater level/quality
- Noise from compressors
- Use of land for exploration
CO2 sequestration

Potential storage in:

- Deep saline formations; could contain minerals that form solid carbonates with CO2
- Depleted oil and gas fields (porous reservoir rock that is capped with nonpermeable cap rock)
- Unminable coal seams (sorption of CO2 to the coal)
CO2 sequestration

Extended Leakoff Test (hydraulic fracturing test)
Aim: Determine the frac pressure of the cap rock

Large scale water injection
ECBM
Enhanced coal bed methane

http://www.ipe.ethz.ch/laboratories/spl/research/adsorption/project03

UCG
Underground coal gasification

Principle of UCG
Injection of oxygen (55%) and steam
Extraction of syngas
UCG
Underground coal gasification

Set-up of injection wells and production well
→ Directional drilling

UCG-CCS
Underground coal gasification / carbon capture and storage
UCG-CCS
Underground coal gasification / carbon capture and storage

Thank you for your attention!