Low Permeability Coal, Investigation and Management
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Key Parameters-1

Gas Content
Sorption Pressure – Linked by Sorption Isotherm to the Gas Content
Reservoir Pressure – Usually initially water pressure but then sorption pressure
Diffusion Coefficient
Permeability
Key Parameters-2

- Permeability
- Permeability change with effective stress
- Coal mechanical properties
  - stiffness which is dependent on stress
  - Poisson’s Ratio
  - strength
  - toughness = energy to cause breakage
THE IMPORTANCE OF THE SORPTION ISOTHERM

• The sorption isotherm is the relationship between gas content at reservoir pressure

• It is dependent on
  – Coal Type
  – Gas composition
  – Order by which the gas got into the coal?
Mixed Gas Isotherms

• Water and Gas competing for storage
• CH4 vs CO2 vs H2O
• Isotherms obtained by re-absorbtion process
• Have to calculate mixed gas behaviour?
• Need for
• NATIVE SORPTION ISOTHERMS
  – MEASURE WHAT YOU GET OUT OF COAL
DIFFUSION IS IMPORTANT

• DIFFUSION RATE IS DEPENDENT ON
• GAS CONCENTRATION GRADIENT
• DIFFUSION COEFFICIENT

• Diffusion is the key to gas release from broken coal
  – In an outburst
  – On the face or belt
  – From the goaf
Desorbed Gas Measurement

![Graph showing the volume of desorbed gas over time. The graph depicts a curve that increases rapidly in the initial stages and then levels off as time progresses.](graph.png)
Core Desorption and Theoretical Diffusion Curves from a Uniform Cylinder
Lost Gas Determination Plot

\[ y = 294.63x - 1047.8 \]
SHORT TERM DIFFUSION COEFFICIENT

• MAY BE CALCULATED FROM THE SLOPE OF THE INITIAL DESORPTION PROCESS AND THE TOTAL GAS CONTENT OF THE CORE

• IS IN ALL PRACTICALITY A COMBINED MEASUREMENT OF DIFFUSION COEFFICIENT AND CORE FRACTURING

• IN HIGHLY FRACTURED CORE WE SHOULD SIMPLY NOTE THE RATE OF DESORPTION OF THE SAMPLE MASS OF COAL
Estimate of Lost Gas is Frequently Wrong!

- Need to pay attention to this if lost gas fraction estimate > 10%
- But lost gas is frequently > 10% and sometimes reaches 50%
- Need a better process of estimating what is happening
- Sigra simulate the process of core withdrawal to find gas loss under varying pressure in the borehole and on surface.
DIFFUSION COEFFICIENT IS AN IMPORTANT OUTBURST PARAMETER

• HIGH GAS CONTENT

+ HIGH DIFFUSION RATES
+ SMALL PARTICLES (brittle or broken coal)

= HIGH OUTBURST RISK
Gas Content Without Coring Process
Dry Drilling Sampling System

Dry drilling sampling system
Modelled Gas Desorption vs. Recorded Gas Desorption

\[ D = 1.5381 \times 10^{-12} \text{ m}^2/\text{s} \]
\[ M_\infty = 18.426 \text{ m}^3/\text{T} \]
\[ Q_1 = 3.1888 \text{ m}^3/\text{T} \]
\[ \text{error} = 8.7879 \times 10^{-2} \text{ m}^3/\text{T} \]
\[ N = 100 \]
Gas Flow In Coal

Darcy Flow

\[ V = -\frac{k}{\mu} \frac{dp}{dx} \]

Diffusion

\[ F = -D \frac{dC}{dx} \]
INvolves water and gas
though some dry seams do exist

Dropping water pressure to achieve desorption must be achieved first in a wet coal.

The rate limiting step in gas drainage may then be either diffusive flow or permeability.

Diffusion governs if the cleat spacing is high.
LOW PERMEABILITY COALS

• NO CLEATS

• FILLED CLEATS

• HIGHLY STRESSED
  – PERMEABILITY MAY CHANGE BY ORDERS OF MAGNITUDE WITH CHANGES IN EFFECTIVE STRESS
Sigra Stress Measurement Tool
Layered Sedimentary Strata with Varying Stiffness and Poisson’s Ratio

Major and Minor Stress (MPa) and Tectonic Strain Through a Typical Sedimentary Sequence
THE IMPORTANCE OF STRESS PATH

- THE EFFECTIVE STRESS IN COALS CHANGES WITH DRAINAGE DUE TO LOWERING FLUID PRESSURE AND DUE TO THE EFFECTS OF SHRINKAGE

- WHICH DOMINATES?
Horizontal Coal Strains vs. Sorption Pressure

Horizontal Coal Strain Vs Sorption Pressure

Ellensfield
Not all seams show reducing stress

• In higher stress environments (deeper – higher tectonic strain) the stress path will show increasing effective stress.
• The same applies to cases where the sorption pressure is low
• fluid pressure reduction = increase in effective stress without shrinkage
Carbonates in cleats

• Carbonates in cleating reduces permeability
  But

• If the carbonate can be removed by acid (leaching through acid hydrofracturing)

• Then a small amount of carbonate that can be removed will de-stress the coal leading to improved pathways for fluid and de-stressing

• 0.25 % carbonate removal may equal total de-stressing
Mining Tight Highly Gassy Coals

- Old European Practise to mine an initial seam in a sequence
- Mining of one seam de-stresses adjacent seams and permits gas drainage
- Assumes that one seam can be mined safely
- This is rate dependent – traditionally the rates are low
Tight Shale Gas Extraction

- Formation must be gassy
- Drill sub horizontal wells in tight formation
- Undertake multiple hydrofracturing from horizontal well
- Create primary permeability
Combine Old European and Tight Gas Practise
Ideal Concept - Horizontal Wells with Transverse Fractures – This is not a normal fracture initiation orientation from a hole.
Drainage times Vs frac spacing for 15 to 3 cu.m/tonne methane
Drilling in coal may not be possible

- High effective stresses and weak coals make it impossible to maintain an open hole.
- If it is possible to drill it is not possible to maintain the hole – as the fluid pressure decreases the effective stress at the borehole wall increases and the hole collapses.
- Casing in coal is not practical option in coals and certainly not steel casing for hydrofracture.
Drill out of the Coal and Hydrofracture

- The minimum stress must be horizontal to get a vertical fracture
  - Dependent on tectonic strain and stiffness
  - High stiffness and tectonic strain lead to the minor stress being vertical = horizontal fracture

- The hole can be cased, cemented and perforated.

- Multiple fracturing points from hole into the seam
Degassing Block an Issue

• Typically Europeans & Asian mines use abutment stress ahead of the longwall to crush the coal
• Gas is gathered by multiple holes in seam (which may crush out) or by cross measure holes (expensive).
• Consider slot cutting
Mining Method

- Multi level mining
- Improves reserve
- Need to mine and entry seam
- Uses mining to de stress other seams
- Need for good goaf drainage
- Consider all drainage from rock drivage
Large Diameter Goaf Drainage Hole (0.5 m Tunnel Borer ?)

Upper Seam

Drainage Adits

Lower Seam

De-Stressing Slot

Longwall Equipment

Borehole, Cased, Cemented and perforated

Hydrofractures From Hole Extending Into Seam
Thank You

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