FLUID SUBSTITUTION IN COALBEDS

by

Diane Lespinasse
Robert Ferguson
• Objective
• Introduction
• Theory
  - Palmer and Mansoori permeability model
  - Gassmann Fluid Substitution
• Area of study
• Methodology
• Results
• Conclusions
Objective

Evaluate the seismic response due to fluids in the pore space of coalbeds. We perform a fluid substitution in two coalbeds of the Mannville Group in the Corbett Field.
Coalbed Methane

- Unconventional resource
- Dual porosity system
- Methane production
- Coal matrix deformation
Permeability model

Changes in coal permeability:

• Increase of the effective stress
• Shrinkage of the matrix

Palmer and Mansoori (1998):

\[
\frac{\phi}{\phi_i} = 1 + \frac{C_f}{\phi_i} (P - P_i) + \frac{\varepsilon_\infty}{\phi_i} \left( \frac{K}{M} - 1 \right) \left( \frac{P}{P + P_\varepsilon} - \frac{P_i}{P_i + P_\varepsilon} \right)
\]

\[
\frac{k}{k_i} = \phi_3^3
\]

\(\phi = \) Porosity \hspace{1cm} \(K = \) Bulk modulus \hspace{1cm} \(C_f = \) Fracture Compresibility \hspace{1cm} \(\varepsilon_\infty = \) Volumetric strain at \(P_\infty\)

\(P = \) Pressure \hspace{1cm} \(k = \) permeability \hspace{1cm} \(M = \) Constrained Axial Modulus \hspace{1cm} \(P_\varepsilon = \) Pressure at \(\varepsilon_\infty / 2\)
Gassmann fluid substitution

Gassmann’s equation (1951):

\[ K_{sat} = K^* + \frac{\left(1 - \frac{K^*}{K_0}\right)^2}{\frac{\phi}{K_{fl}} + \frac{(1 - \phi)}{K_0} - \frac{K^*}{K_0^2}} \]

Applications:

- Information for well data analysis
- AVO Response
- 4D surveys
Area of study

• Corbett Field
• Corbett Creek area
• Central Alberta,
• 145Km NW of Edmonton
• Extension of 558 Km²
Area of study

- Low density and high sonic response
- Upper Mannville Group
- 825m (NE) - 1080m(SW)
- Main Seam: 3.6m
- Lower Seam: 1.5-2m

Well 100-03-22-062-06W500
Methodology

• Data selection: Horseshoe Canyon vs Mannville Group

• Fluid Simulation (F.A.S.T Software)
  - Langmuir isotherm
  - Matrix shrinkage
  - Deliverability and production forecast

Porosity Ratio → Sw → Pressure
Methodology

- Gassmann Fluid Substitution

- Synthetic Seismograms (Syngram)
  - Time and Depth domain
  - 30Hz and 60Hz Ricker
  - Different coal thickness
## Results

<table>
<thead>
<tr>
<th>Pore Fluids</th>
<th>Ricker Wavelet</th>
<th>Coal Thickness</th>
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<tbody>
<tr>
<td>Brine 100%</td>
<td>Freq 30 Hz</td>
<td>Main seam 3.65m</td>
<td>Depth</td>
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<td>Lower seam 1.67m</td>
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![Graph showing seismic data with depth and offset measurements]
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**Graph**

- **Depth**: 850
- **Offset**: 2100 3700
- **Amplitude**: 0.16 0.185

**Wavelet**

- **Vp**
- **Vs**
- **rho**
### Results

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#### Graphical Data

- **Depth** range: 2100 - 3700
- **Offset** range: 0 - 2000
- **Amplitude** range: 0.12 - 0.20

The graph shows variations in Vp, Vs, and rho with depth and offset, indicating changes in the geological properties.
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### Diagram

- **Depth** (meters): 850, 900, 950, 1000, 1050, 1100, 1150
- **Offset** (meters): 0, 500, 1000, 1500, 2000
- **Amplitude**
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Graph showing seismic data with labels for Vp, Vs, rho, and offset.
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### Graph

- **Vp**
- **Vs**
- **rho**

**Offset** from 0 to 2000 meters, **Time** from 0.55 to 0.75 seconds.
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### Diagram

- **Depth**: 850 - 1150 m
- **Offset**: 0 - 2000 m
- **Amplitude**: 0.1 - 0.2
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**Diagram:**

- **Pore Fluids:** Brine 82%, CH₄ 18%
- **Ricker Wavelet:** Freq 30 Hz, Phase 0°
- **Coal Thickness:** Coal seam 21m
- **Domain:** Depth
Results

- **CREWES** Zoeppritz Explorer
- Average Vp, Vs and density
- Upper Layer: Overburden
- Lower Layer: Coal
- No critical angle
Conclusions

• Corbett Field: Not enough resolution to identify Main Seam and Lower Seam. Subtle changes after fluid substitution.

• 10m coalbed: was resolved with the 30Hz Ricker wavelet. More evident changes in the wavelet character.

• 21m coalbed: Accentuated changes in wavelet character.

• 21m coalbed: The changes due to fluid substitution are more evident in seismograms in depth domain.
Conclusions

• Transmission Loss and Spherical Divergence were not considered

Future work:

• Reuss and Voight bounds to have a better control of the parameters used in the fluid substitution

• Fluid substitution with a San Juan basin data set
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