Discrimination between pressure and fluid saturation using direct non-linear inversion method: *an application to time-lapse seismic data*

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Statement of the problem

• Distinguishing pressure changes from reservoir fluid changes is difficult with conventional seismic time-lapse attributes.

• Pressure changes or fluid changes?
  – shear modulus sensitive to pressure changes
  – Vp/Vs sensitive to fluid changes

• A direct non-linear inversion method may be useful for accomplishing this goal.
# Introduction of the method

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<th>Time-lapse seismic monitoring</th>
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<td>Initial reservoir condition</td>
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<td>Actual medium $L$</td>
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<td>space $V=L_0-L$</td>
<td>in <strong>time</strong></td>
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Outline

• Comparing the first and second order algorithms in estimating shear modulus and Vp/Vs contrasts.
  – Core data tests (A. R. Gregory, 1976)
  – Heidrun well log data tests

• Conclusions and Plan

• Acknowledgements
Core data tests

Fixing the **fluid** as 100% water saturation, while the pressure changes from 1000 to 9000psi.

- Baseline: pressure = 5000psi
- Monitor: other different pressures

Fixing the **pressure** at 5000psi, while the fluid changes from 0 to 100 percent.

- Baseline: 100% saturation
- Monitor: other different water saturations
Core data tests

• Compare effects of pressure and fluid changes on the elastic properties.

• Compare first order and second order approximations.
Effects of pressure changes on the elastic properties

Fluid fixed (100% water saturation)

A. R. Gregory 1976

Baseline: 5000 psi
Effects of fluid changes on the elastic properties

Pressure fixed (5000 psi)

A. R. Gregory 1976

Baseline: 100% $S_w$
Comparison of 1\textsuperscript{st} and 2\textsuperscript{nd} order approximation for pressure changes

Fluid fixed (100\% water saturation)  

A. R. Gregory 1976
Comparison of 1\textsuperscript{st} and 2\textsuperscript{nd} order approximation for pressure changes

Fluid fixed (100\% water saturation)  
A. R. Gregory 1976

-4000 -3000 -2000 -1000 0 1000 2000 3000 4000

Relative change in velocity ratio ($V_p/V_s$)

-0.04 -0.03 -0.02 -0.01 0.00 0.01 0.02

Pressure change (psi)

- Actual value
- First order approximation
- Second order approximation
Comparison of 1\textsuperscript{st} and 2\textsuperscript{nd} order approximation for fluid changes

Pressure fixed (5000 psi)

A. R. Gregory 1976

- Actual value
- First order approximation
- Second order approximation

Water saturation, percent

relative change in shear modulus
Comparison of 1st and 2nd order approximation for fluid changes

Pressure fixed (5000 psi)

A. R. Gregory 1976

Relative change in velocity ratio ($V_p/V_s$)

-0.02
-0.04
-0.06
-0.08
-0.10
-0.12

Water saturation, percent

0 10 20 30 40 50 60 70 80 90 100

- Actual value
- First order approximation
- Second order approximation
Outline

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Synthetic Modeling -- A-52

Depth (m)

3150 Garn
90% oil
10% water
3185

3200 Ile
90% oil
10% water
3220

3245 Initial (1986)
50% gas
50% water
2001

Wet

50% gas
50% water

100% water

100% water

Baishali Roy (ConocoPhillips)
Heidrun well log data tests

• Compare effects of pressure and fluid changes on the elastic properties.

• Compare first order and second order approximations.
Heidrun well log data tests

- Shear modulus
- Velocity ratio $V_p/V_s$
- P impedance $\rho V_p$
Heidrun well log data tests

Graph showing relative change in shear modulus vs depth (m). The graph includes three lines:
- Actual value
- First order approximation
- Second order approximation

The x-axis represents depth in meters (m) ranging from 3160 to 3280, and the y-axis represents the relative change in shear modulus ranging from 0.000 to 0.020.
Heidrun well log data tests
Heidrun well log data tests

Relative change in velocity ratio ($V_p/V_s$)

Depth (m)

- Actual value
- First order approximation
- Second order approximation
Observations

- The second order approximation provides improvements in the earth property predictions.

- In this well log data case, the second order approximation is more helpful for predicting shear modulus compared to Vp/Vs.
Plan

• Comparing the first and second order algorithms in estimating shear modulus and Vp/Vs contrasts.
  – Heidrun synthetic data
  – Real seismic data tests (Heidrun)
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