Geomechanical-induced 4D time shifts

Thomas Røste
Outline

• Why monitor overburden?

• Time shifts and geomechanics

• Field examples

• Summary
Why monitor overburden

- 4D seismic time shifts in overburden give information about depleted areas
- Independent of reservoir fluid changes
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Time shifts and geomechanics

- 4D seismic time shifts capture changes in both thickness ($z$) and velocity ($v$)
- Røste et al. (2005) and Hatchell et al. (2005) independently assumed*:

$$\frac{\Delta v}{v} \approx -R\epsilon_{zz}$$

* The dilation factor $R$ is sometimes referred to as $\alpha$. The relation is $R = -\alpha$.
Workflow for modelling time shifts

- Input:
  - Reservoir pressures
    (Eclipse model)
  - 4D geomechanical model:
    - Displacements
    - Stress changes
    - Strain ($\varepsilon_{zz}$)

- Output:
  - Velocity changes ($\Delta v$)
  - Time shifts

$\Delta v / v \approx -R\varepsilon_{zz}$

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Røste and Ke (2017)
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Max modelled subsidence (97-14) around 0.55 m

GPS (97-14) ~0.50 m

GPS (97-14) ~0.44 m

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Geomechanical model (97-14)

Max modelled subsidence (97-14) around 0.55 m

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Time Shifts (97-14) @BCU

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Time Shifts (97-09) @BCU

Should these faults be sealed?

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Modelled (R=15)

Should these faults be sealed?

Pressure depletion
Pressure increase

Seismic

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Cross-section intersecting an area with large time shifts

$$R \approx - \frac{\Delta v}{v} \frac{\epsilon_{zz}}{\epsilon_{zz}}$$
$R$ inverted - Snorre

Cross-section intersecting an area with large time shifts

$R_{avg} \approx 40$

$R_{avg} \approx 8$

$R_{avg} \approx 8$

Seismic time shifts

Geomechanical model

$R \approx -\frac{\Delta v/v}{\epsilon_{zz}}$
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• Overburden geomechanical changes:
  - Occur for all fields
  - Might indicate depleted areas
  - Detected as 4D seismic time shifts

• Time shift workflow:
  - Useful for updating reservoir model
  - Indicates $R_{avg} \approx 15$ for overburden
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