

# Geomechanical-induced 4D time shifts

 **FORCE**

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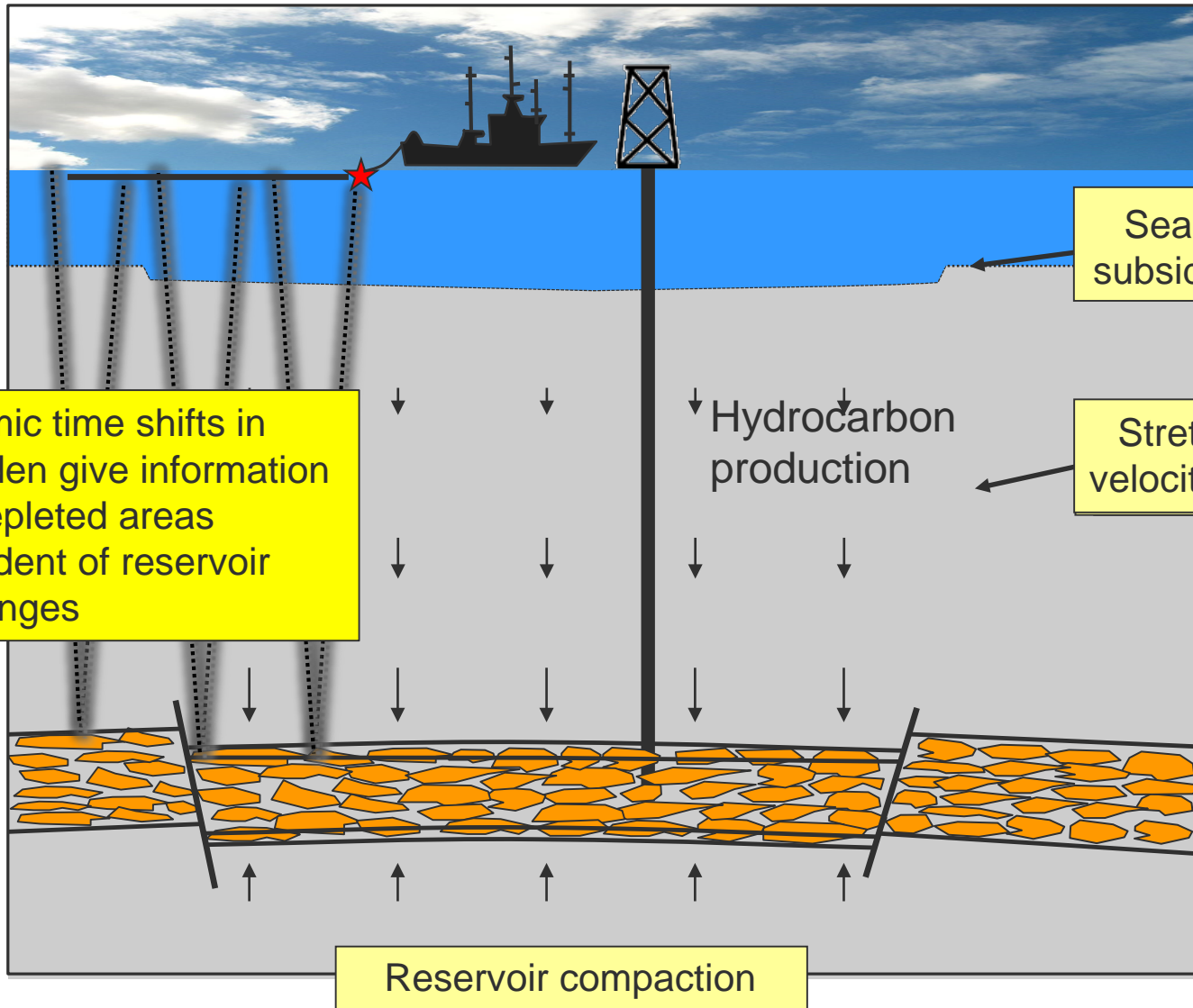


equinor

# Outline

- Why monitor overburden?
- Time shifts and geomechanics
- Field examples
- Summary

# Why monitor overburden



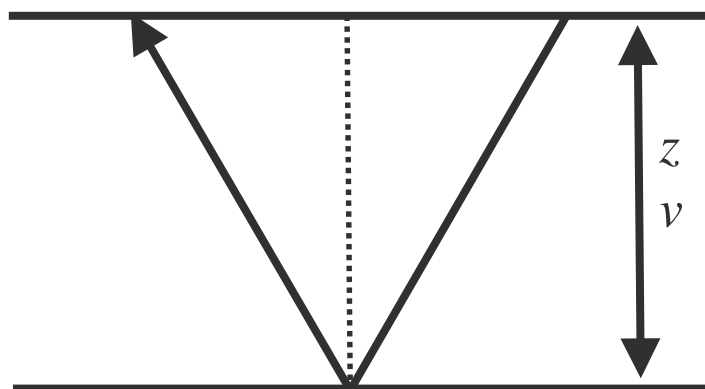
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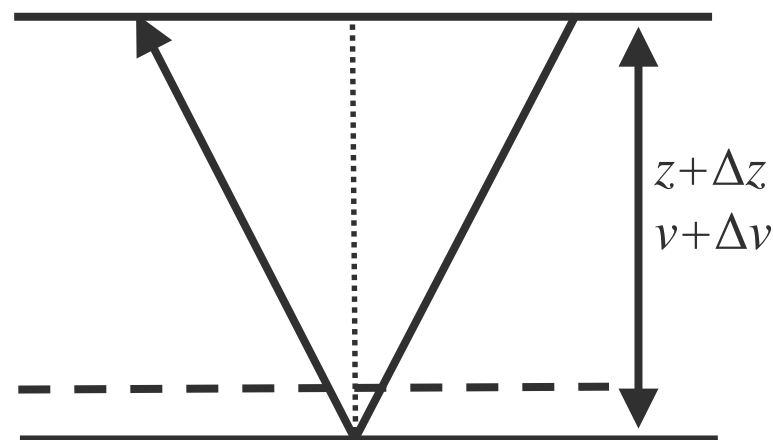
# Time shifts and geomechanics

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

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



Baseline



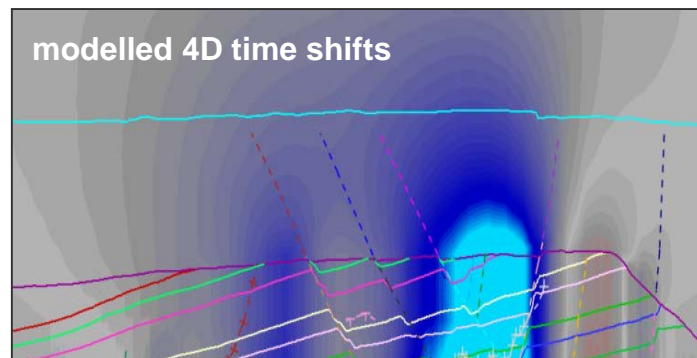
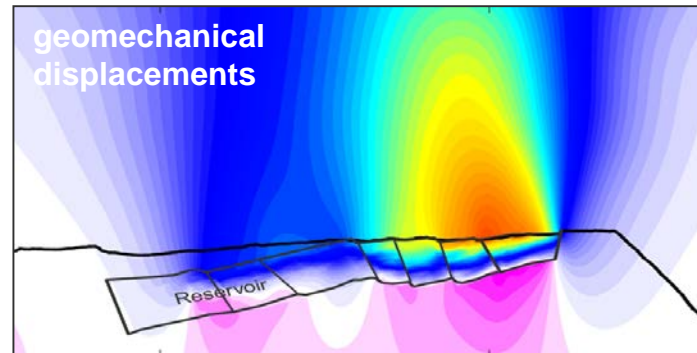
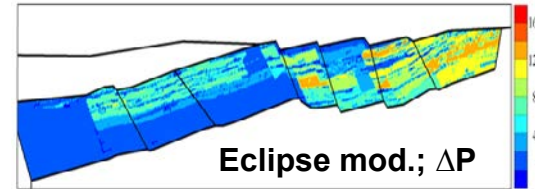
Monitor

\* 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 ( $\epsilon_{zz}$ )
- ↓
- Output:
  - Velocity changes ( $\Delta v$ )
  - ↓
  - Time shifts

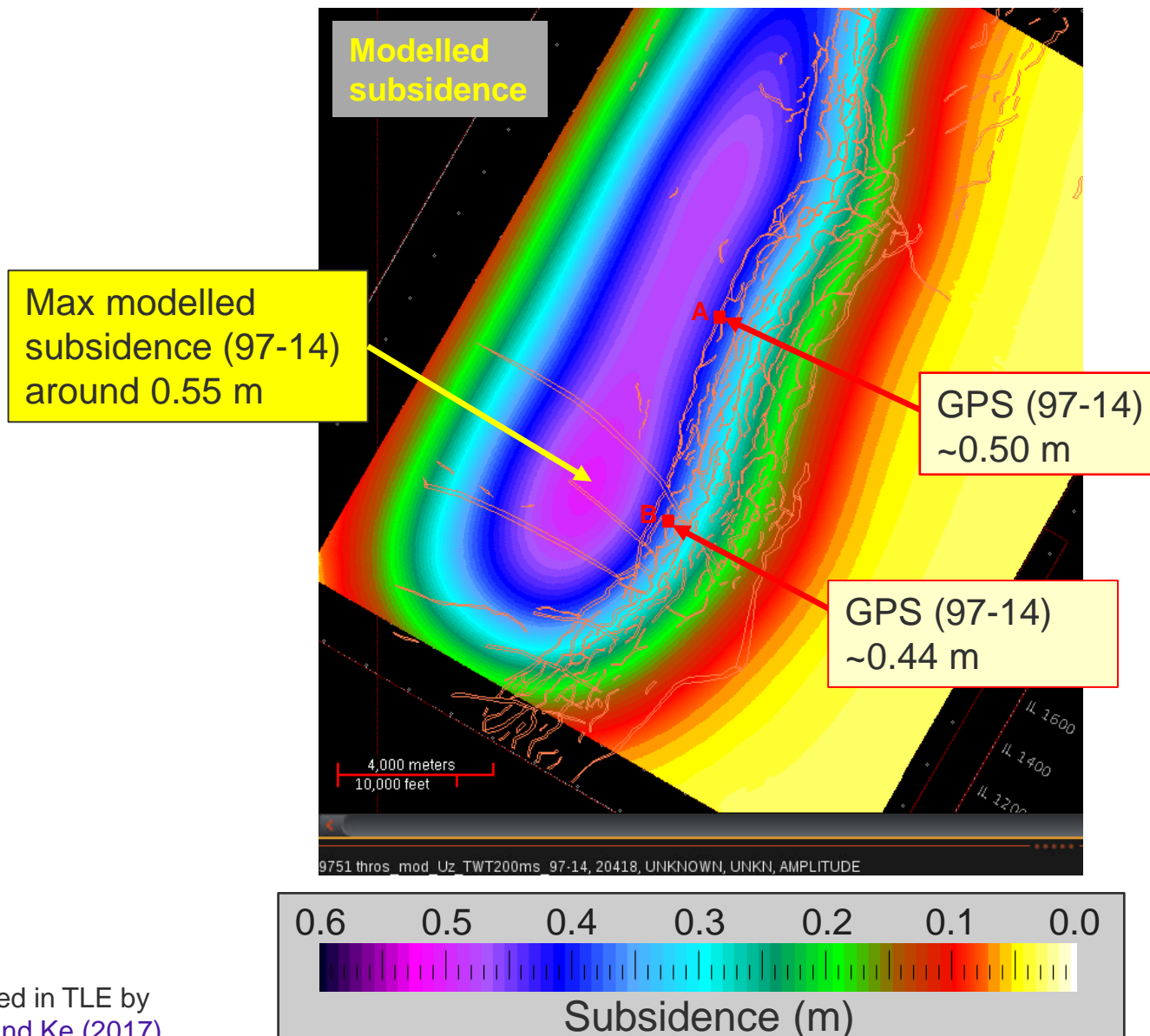
*R*-factor model:  
 $\Delta v/v \approx -R\epsilon_{zz}$



# Outline

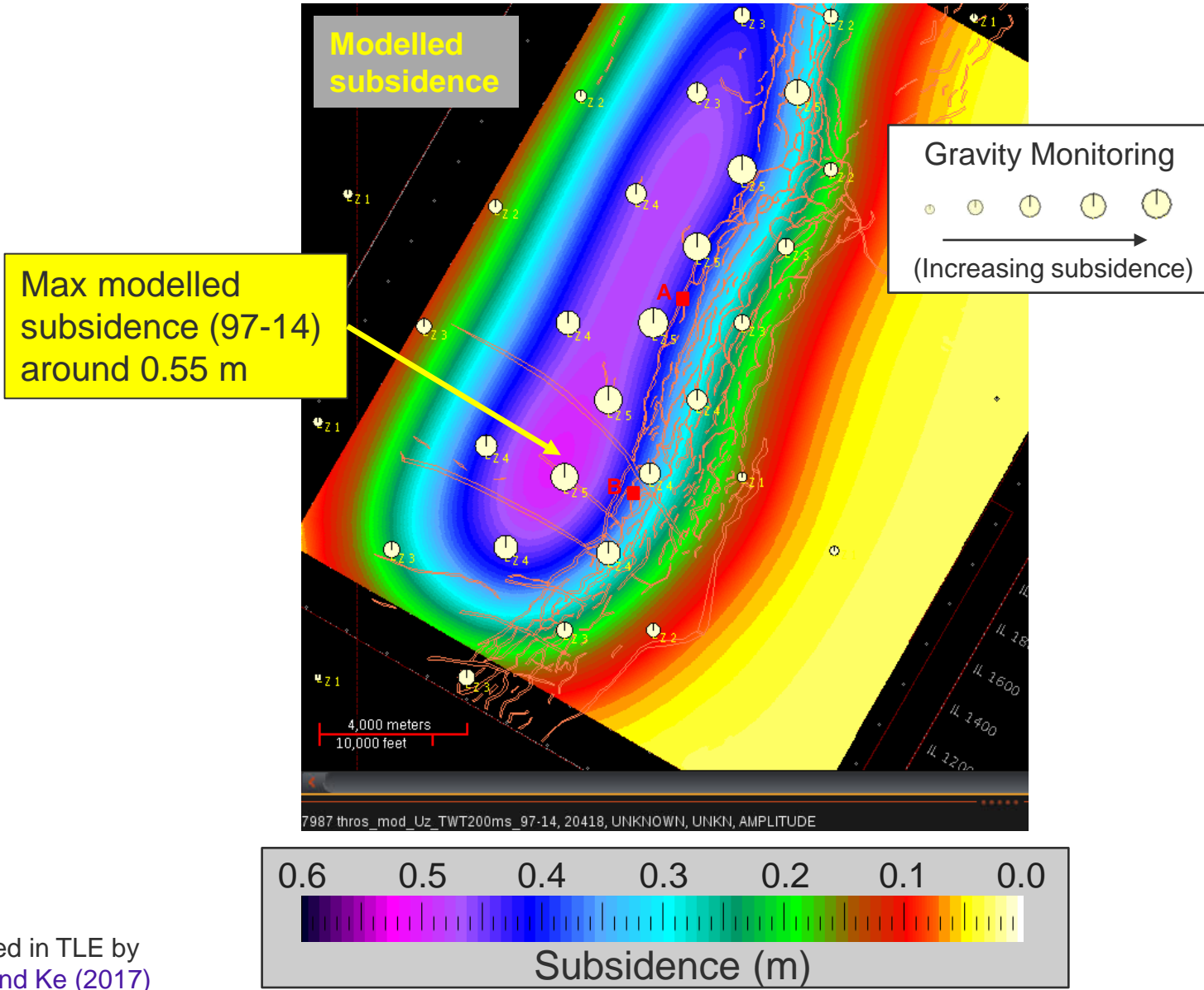
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# Geomechanical model (97-14)



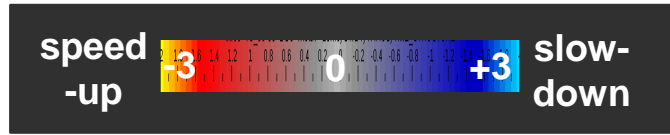
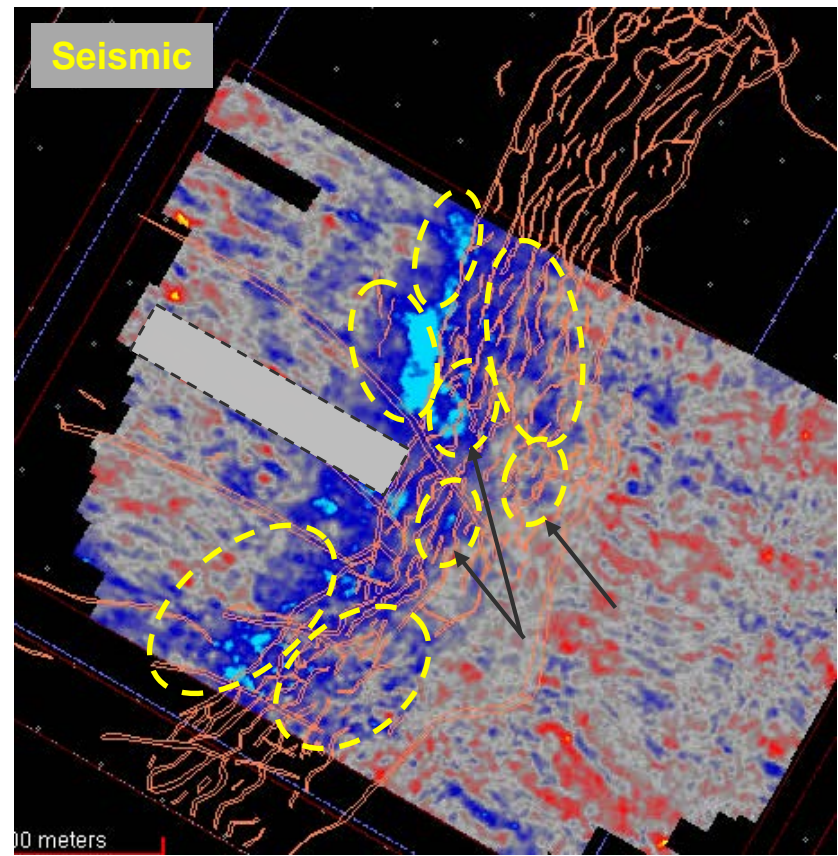
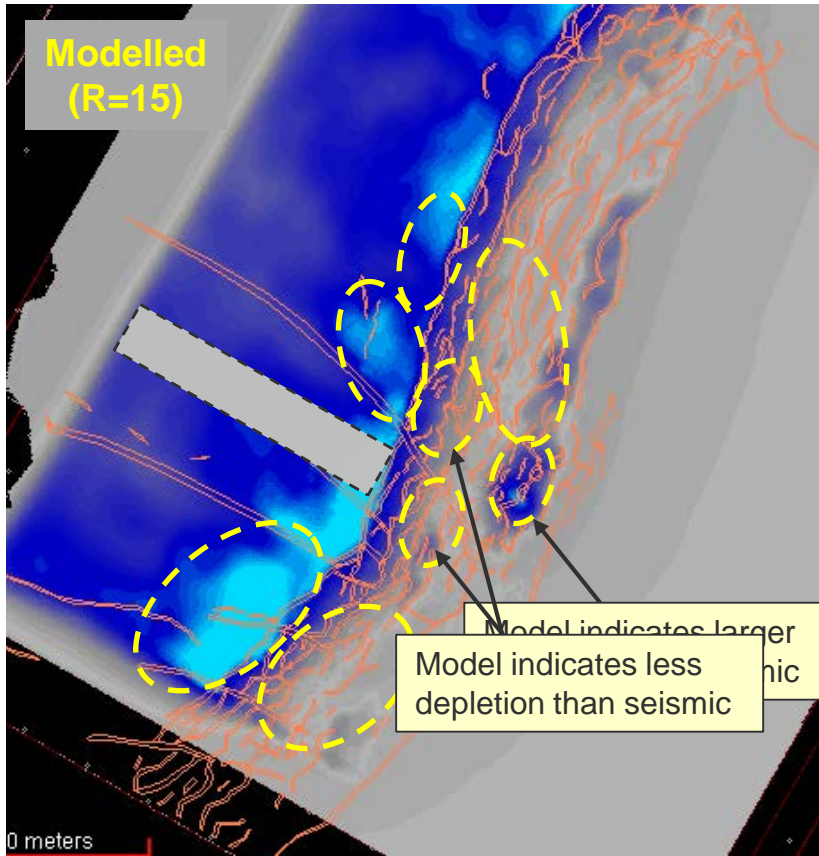


# Geomechanical model (97-14)

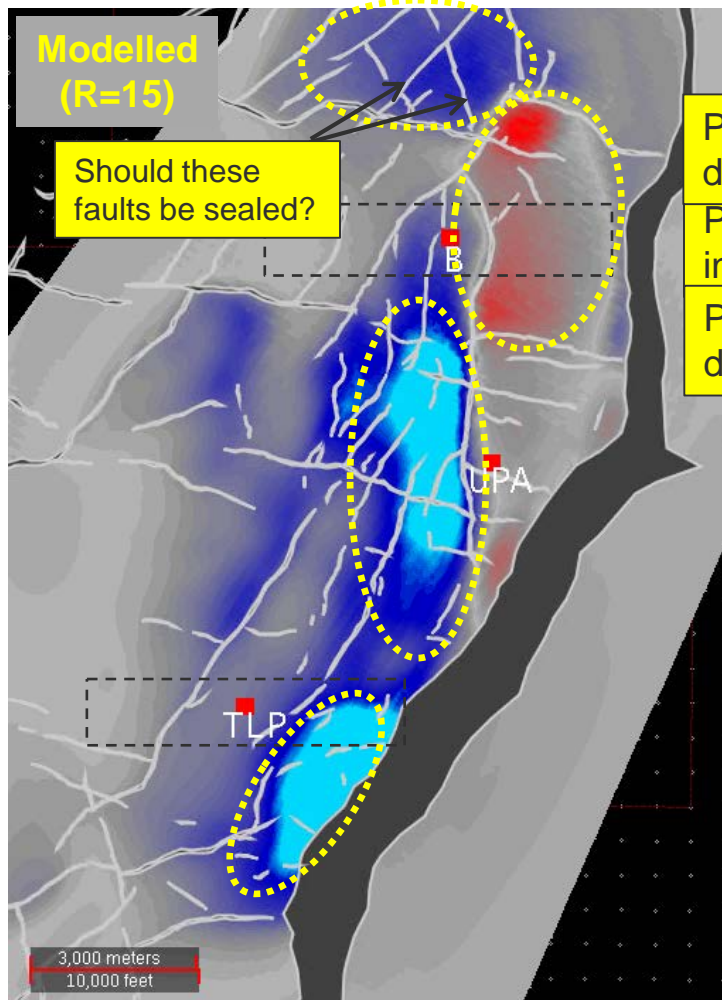


# Time Shifts (97-14) @BCU

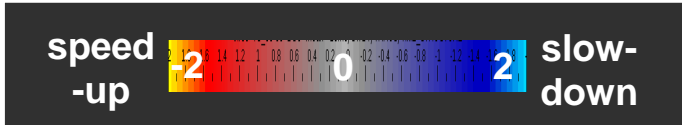
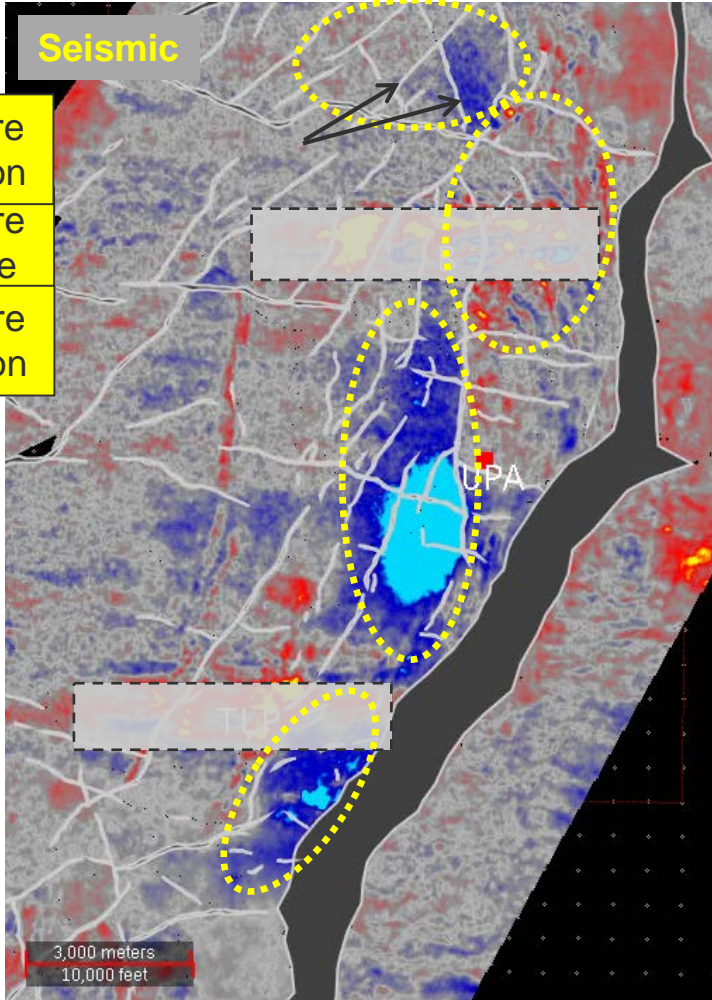
Statfjord



# Time Shifts (97-09) @BCU

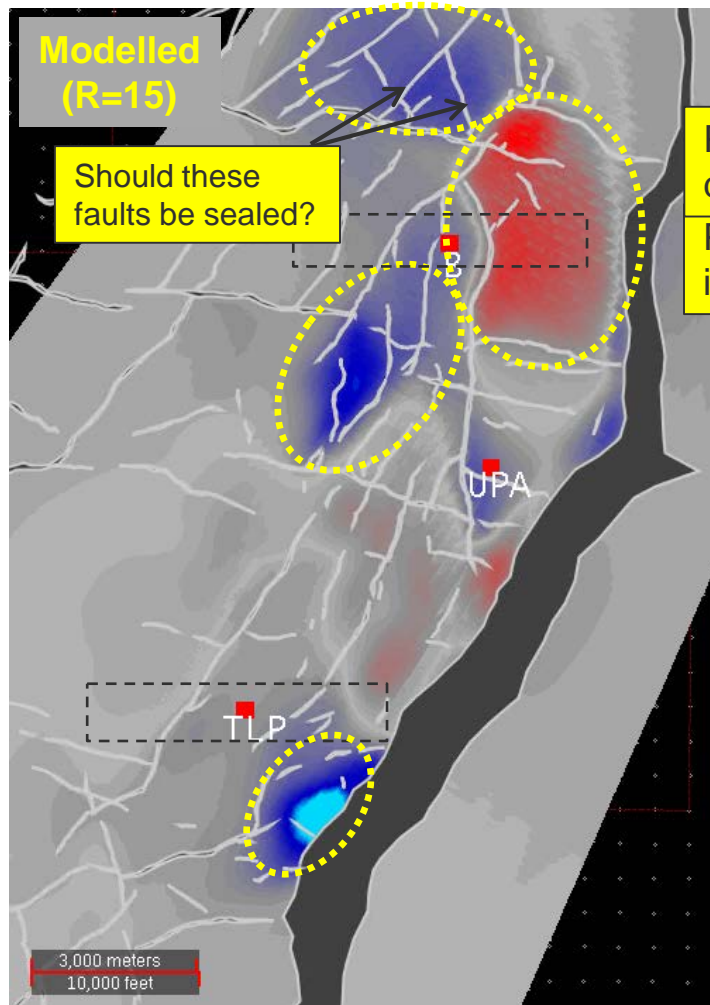


Pressure depletion  
Pressure increase  
Pressure depletion

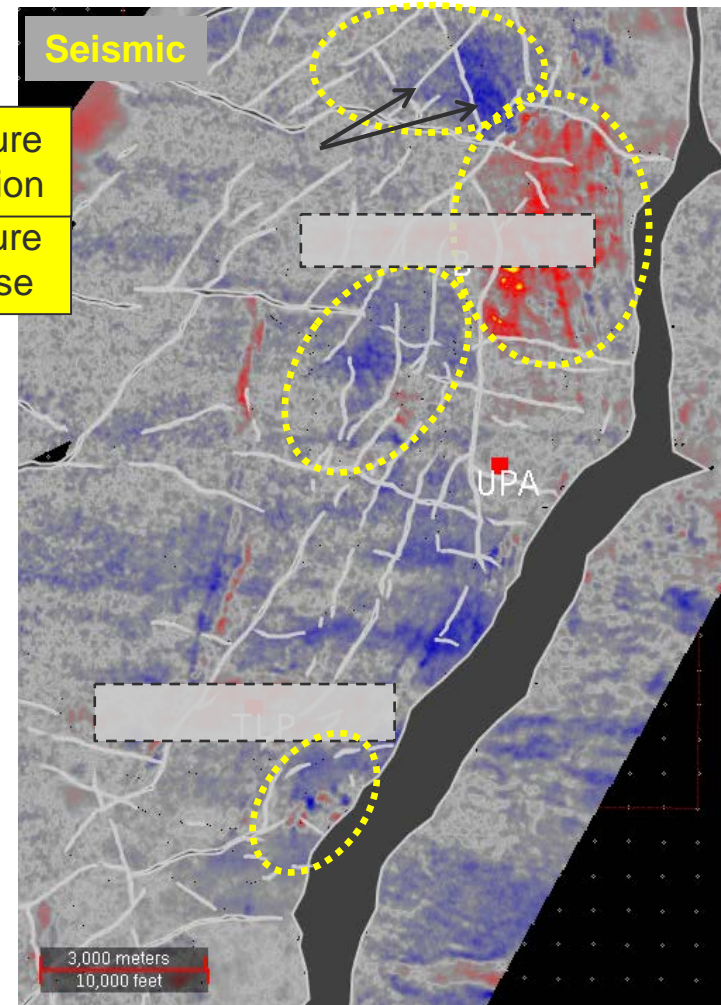


# Time Shifts (06-09) @BCU

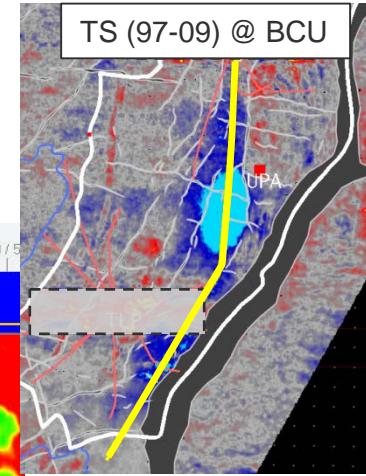
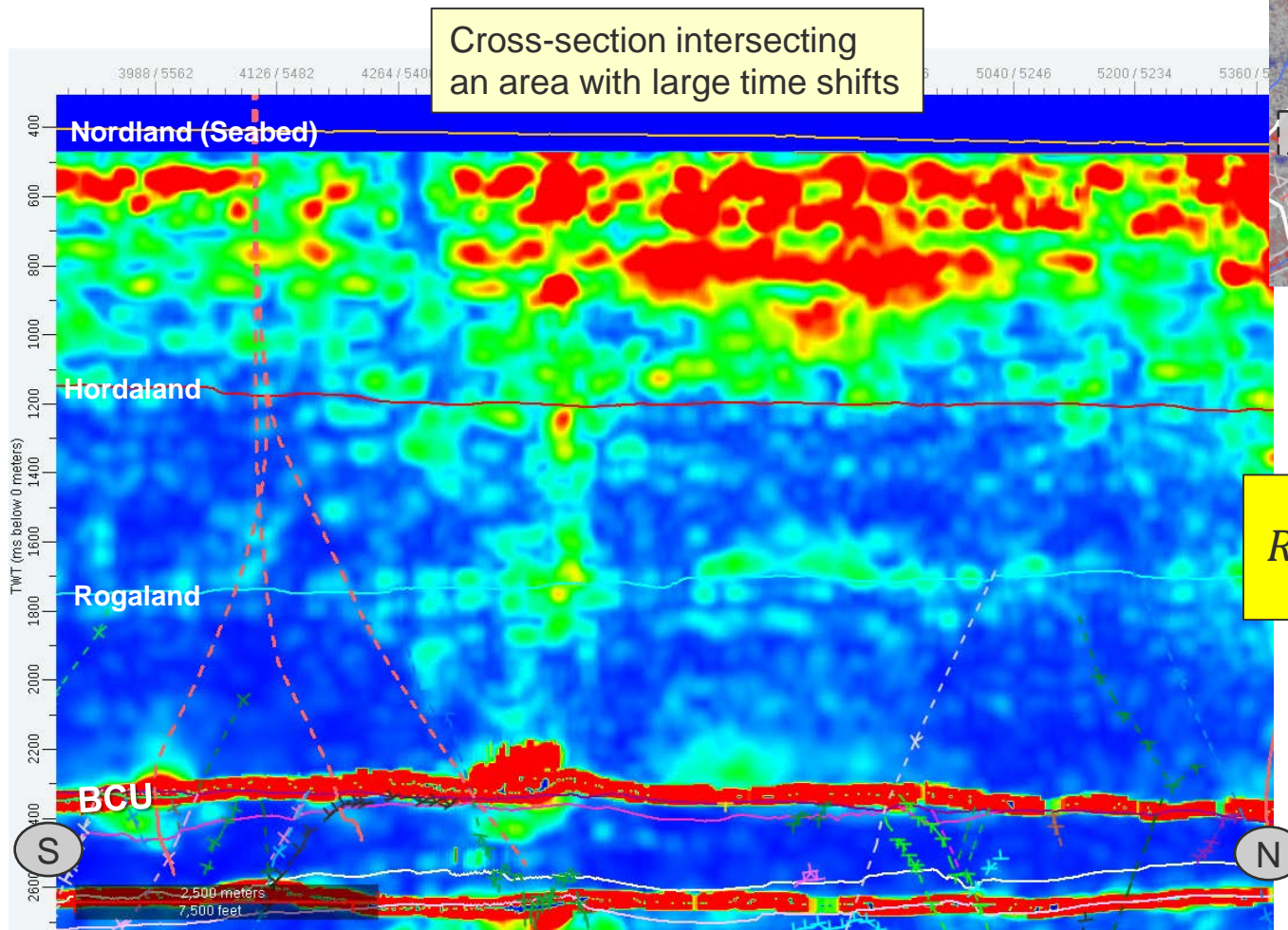
Snorre



Pressure depletion  
Pressure increase



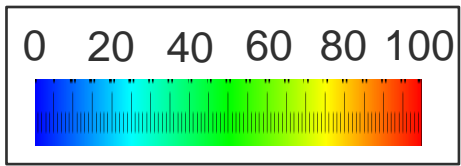
# R inverted - Snorre



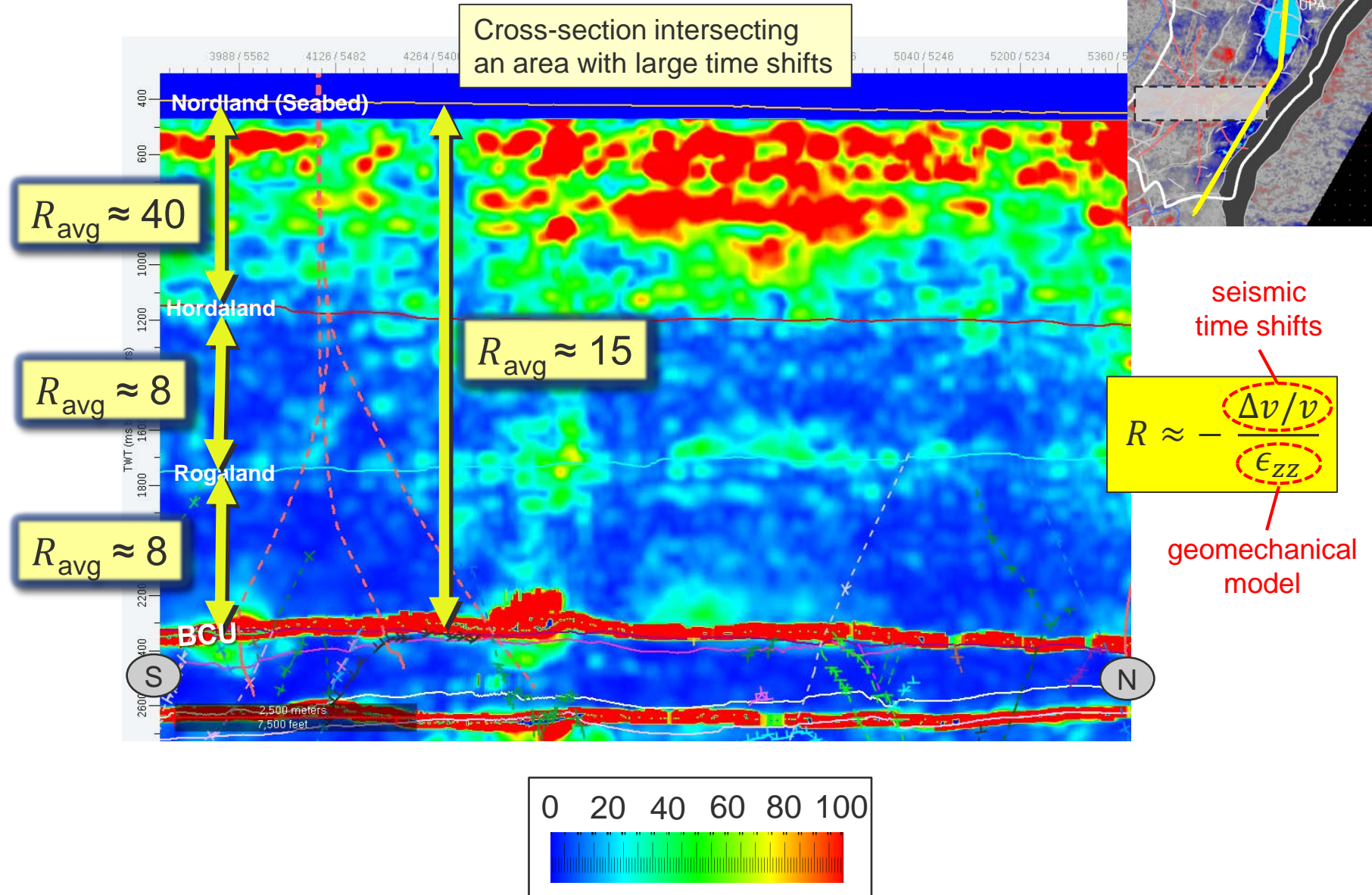
seismic time shifts

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

geomechanical model



# R inverted - Snorre

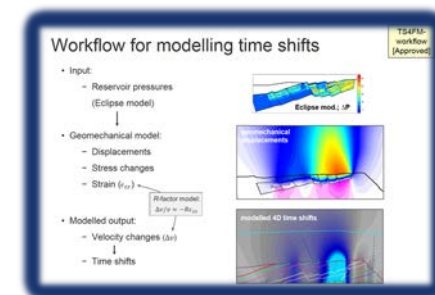
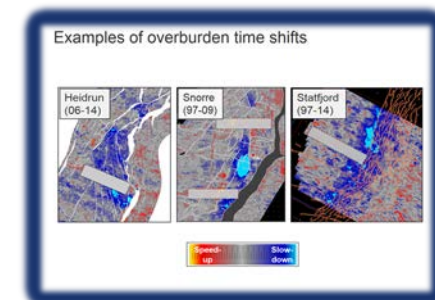
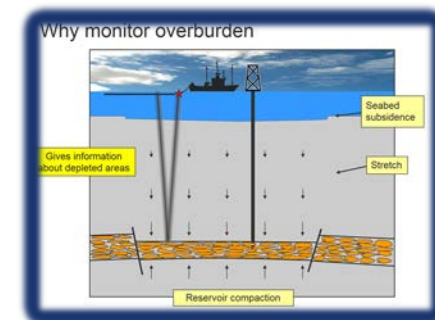


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# Summary

- 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





# Acknowledgments

- Ganpan Ke for fruitful discussions and geomechanical modelling input
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- The Snorre, Statfjord, and Heidrun partnerships for permission to present this data



# References

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- Røste, T., O.P. Dybvik, and O.K. Søreide, 2015, Overburden 4D time shifts induced by reservoir compaction at Snorre field: *The Leading Edge*.
- Røste, T., A. Stovas, and M. Landrø, 2005, Estimation of layer thickness and velocity changes using 4D prestack seismic data: *67th EAGE, Extended Abstracts, C010*.
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