4D interpretation of gas migration in shallow sand layers – compared to reservoir simulation

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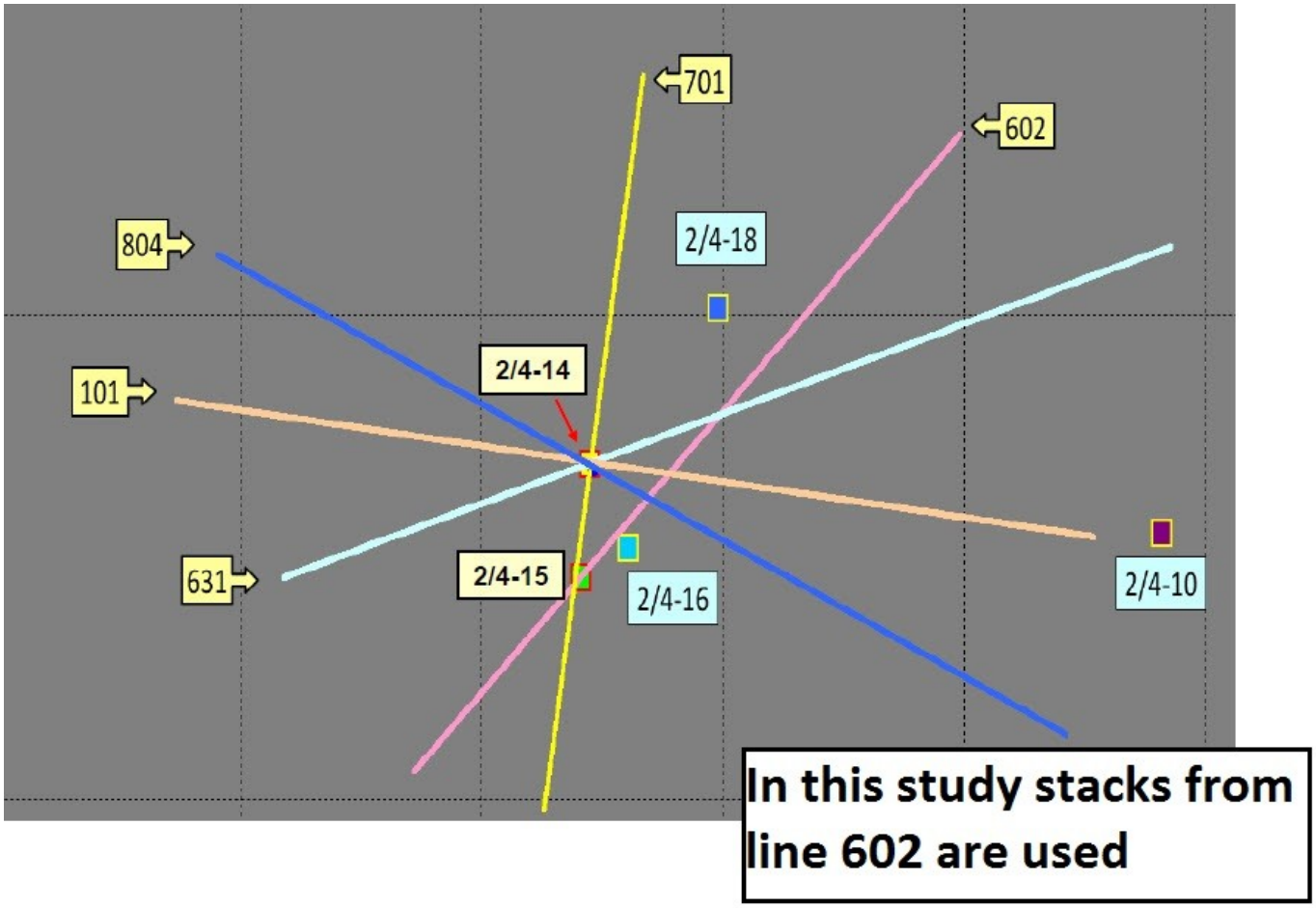
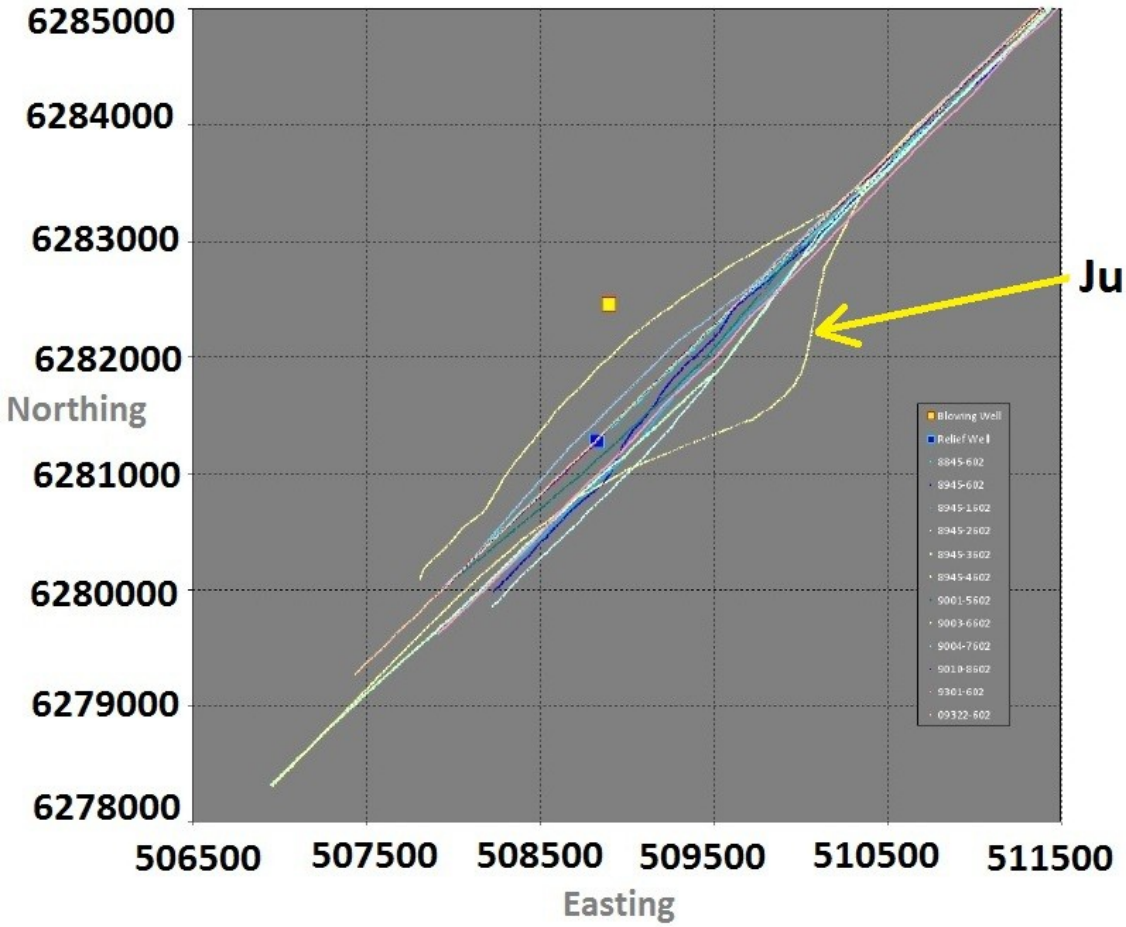
Introduction

- Well 2/4-14 drilled by Saga Petroleum
- Drill pipe cut on January 20th 1989
- Large pressure drop indicated underground blow-out
- Blow out killed in December 1989
- 9 seismic site surveys acquired
- Comparison of 4D observations and reservoir simulations

Repeated 2D lines



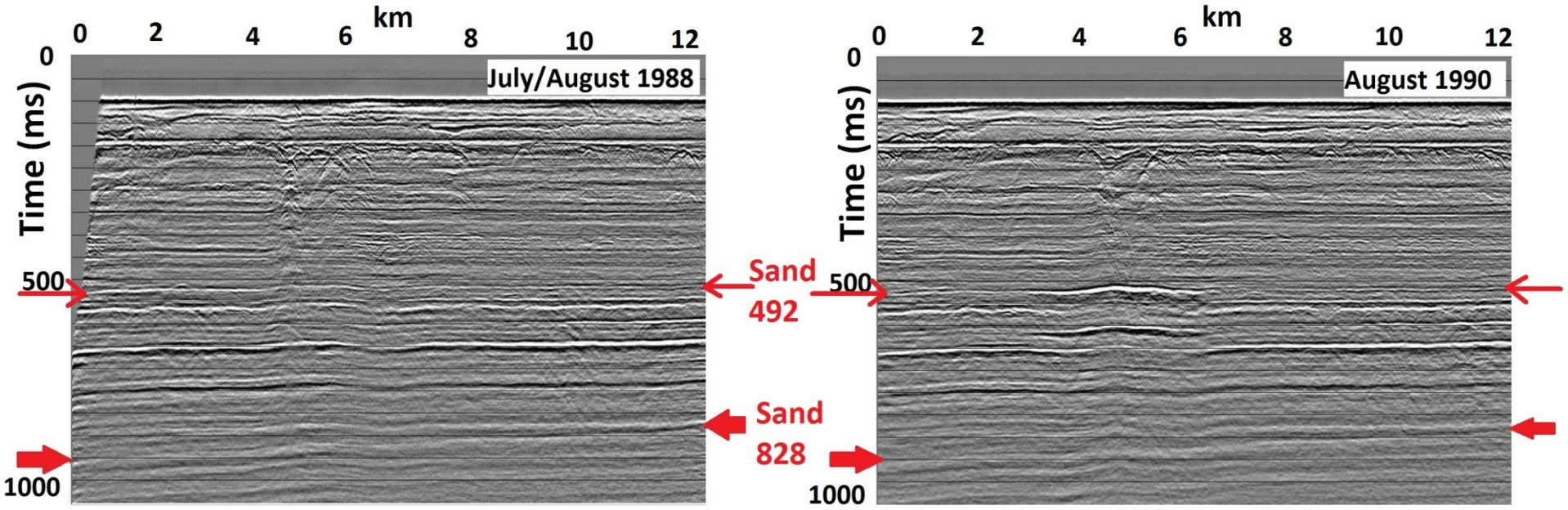
Line 602 – Acqusition overview



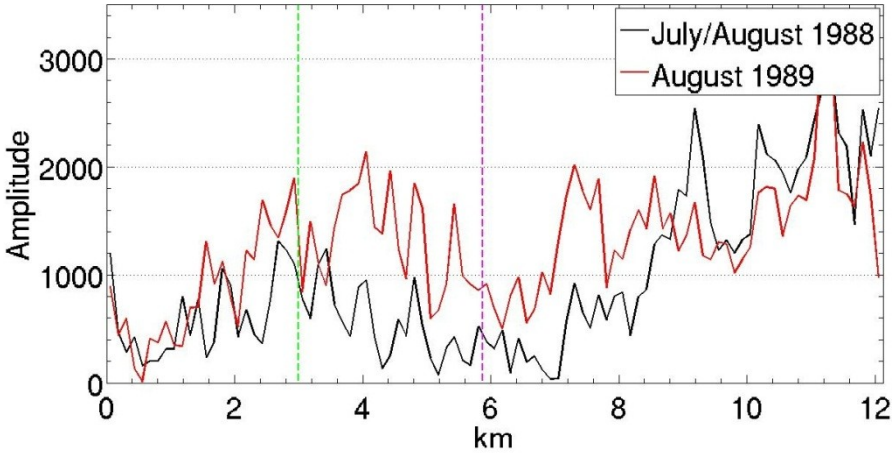
June '90

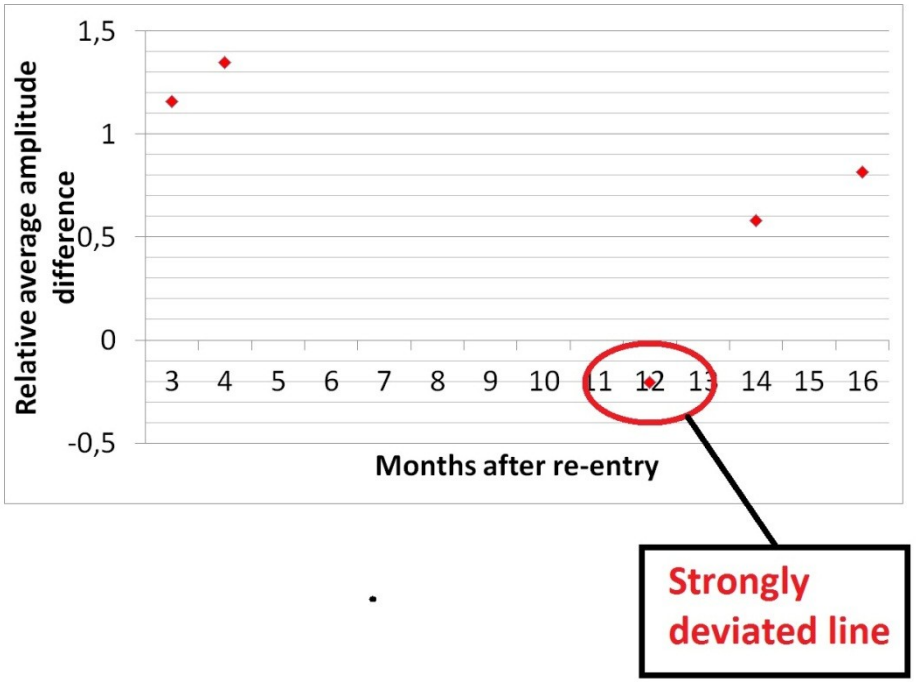
Base survey and acquisition from October '90 passes through well 2/4-15

August '90 is within 100 m of well position



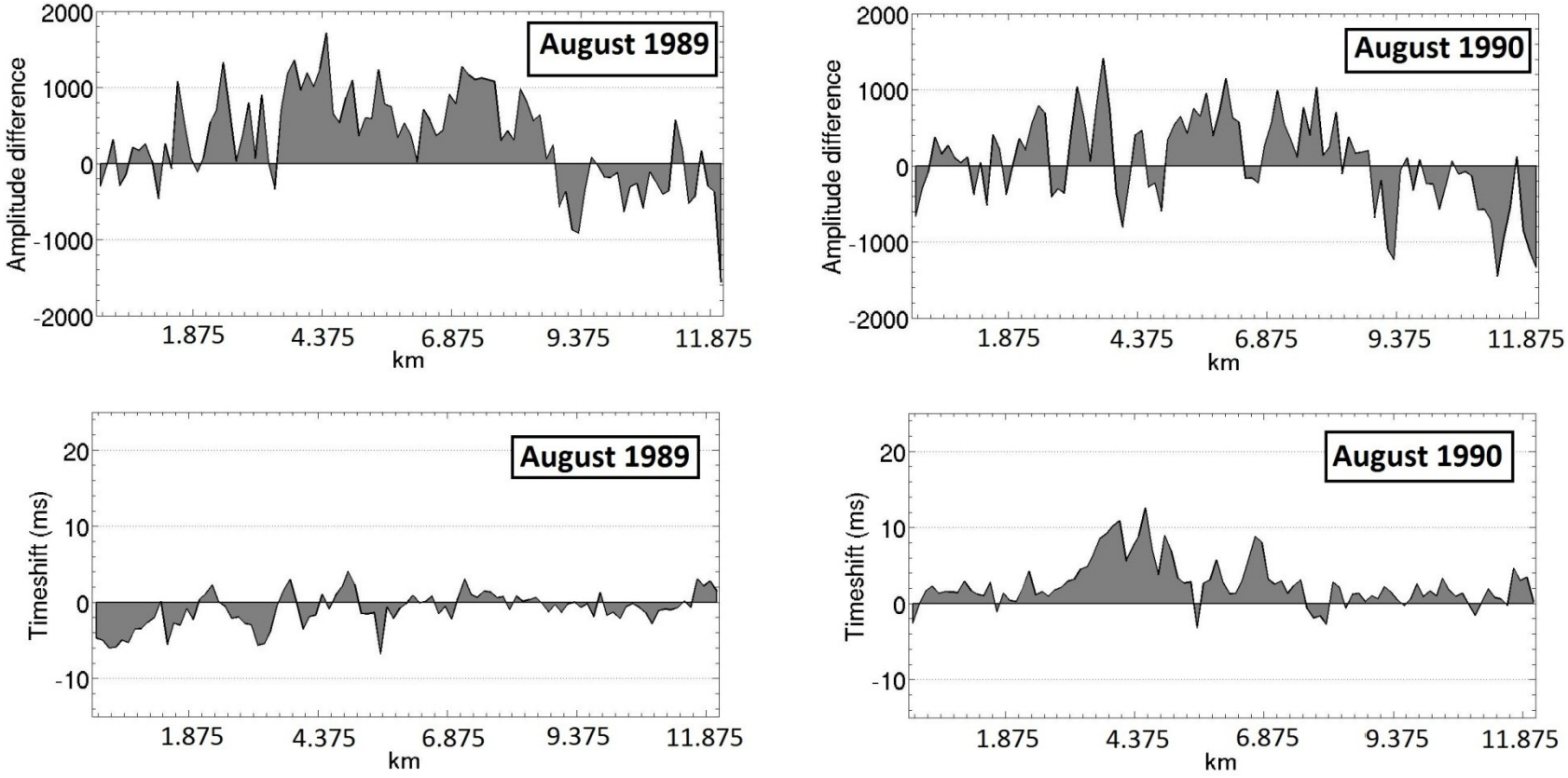
- Investigated distance over 12 km long
- No multiple removal
- Reflector of sand at 828 meters is relatively weak
- New seismic anomaly observed in August 1990
- First order multiple observable at approximately 610 ms





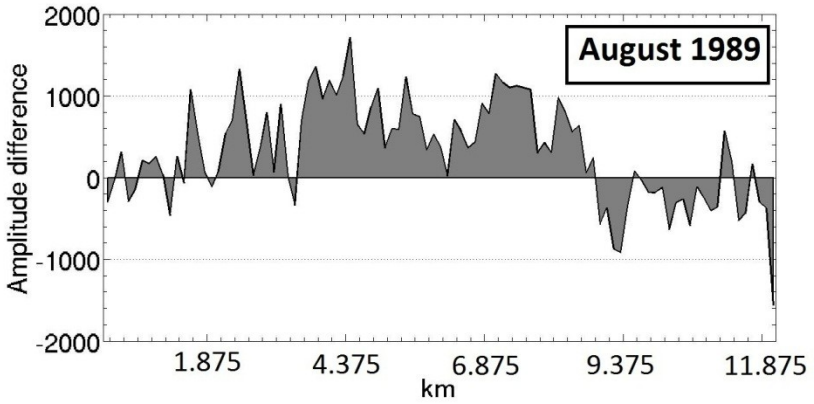
- Amplitude increase
- 4D difference
- June 1990 survey not comparable

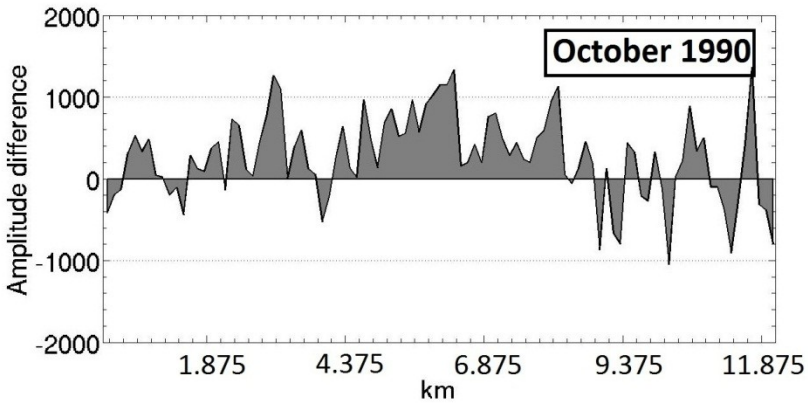
Amplitude differences and timeshifts August 1989 and August 1990

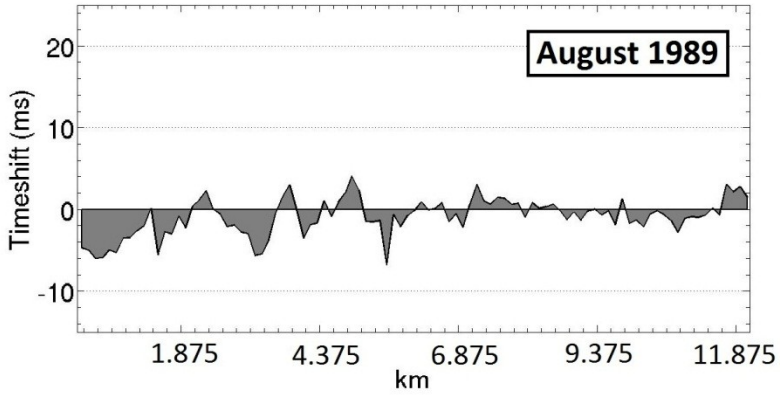


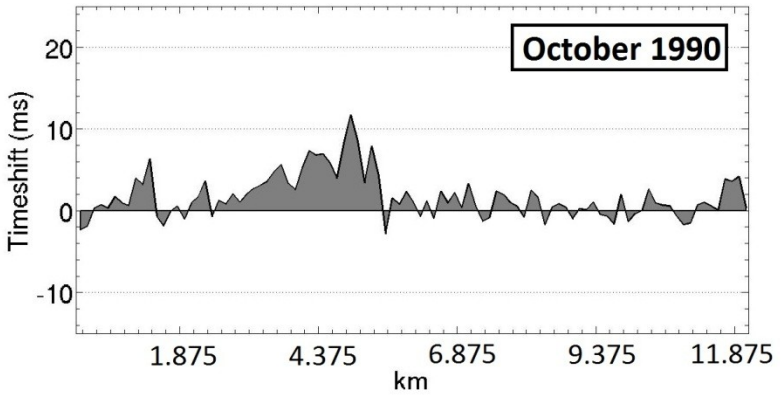
- Damping of amplitude difference
- Increase in timeshift
- Indicate gas charging of shallower layers

Amplitude differences and timeshifts August 1989 and October 1990







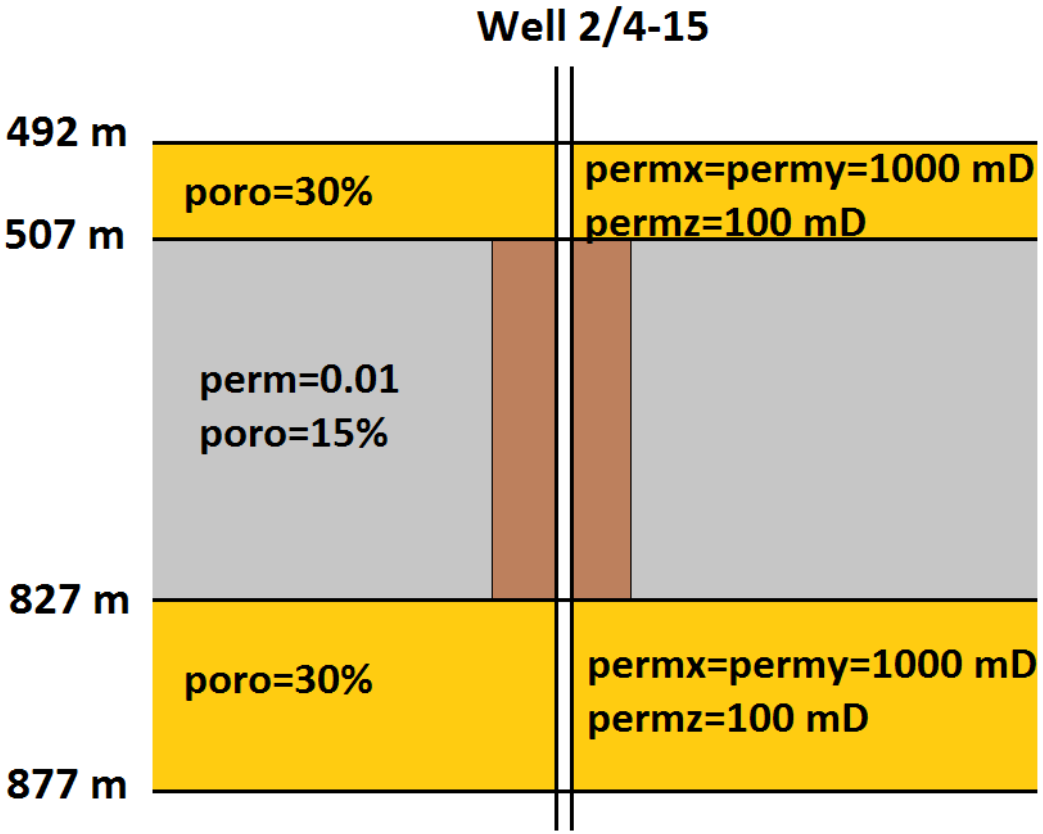


- Increase in amplitude difference and decrease in timeshift compared to August 1990
- Indication of lateral migration of gas in

Evidence for gas charging

- Opposite polarity of the seabed, negative reflection coefficient
- Significant increase in amplitude between base and monitor survey
- Timeshifts interpreted as evidence for gas charging in shallower layers
- Development of timeshifts and amplitudes in time indicate lateral migration of gas

Reservoir model



Eclipse 100
- black oil simulator

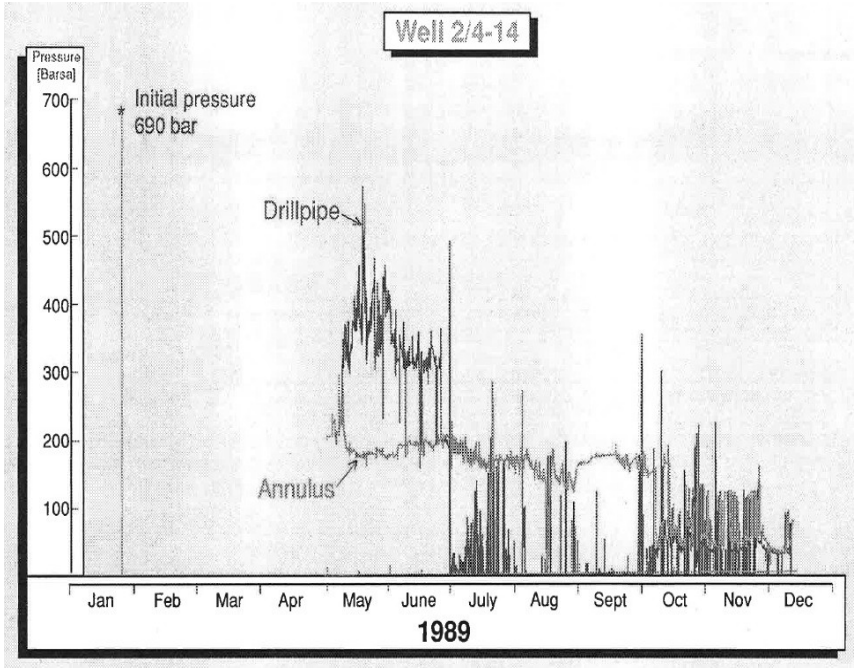
Model dimensions:
41.25 km * 19.25 km * 385 m

Permeable zone close to the well:
permx = permy = 8 mD
permz = 4 mD

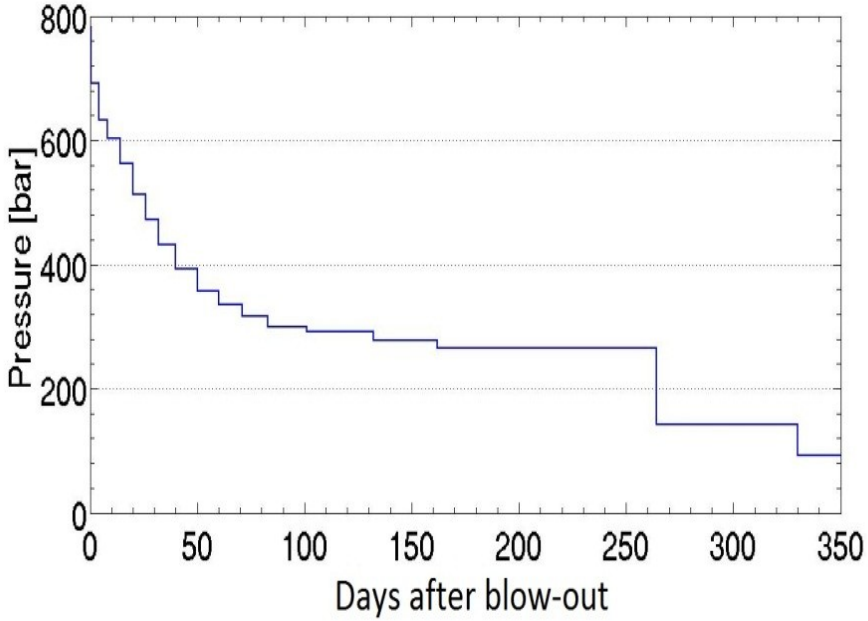
All 50 meters of the lowest sand are perforated

Injection of gas controlled by Bottom Hole Pressure (BHP)

Recorded wellhead pressure as a function of time



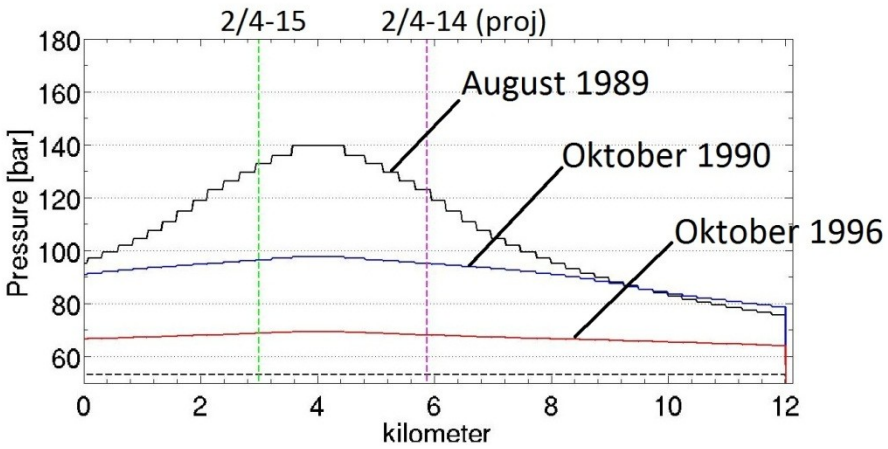
Bottom hole pressure used in reservoir simulation

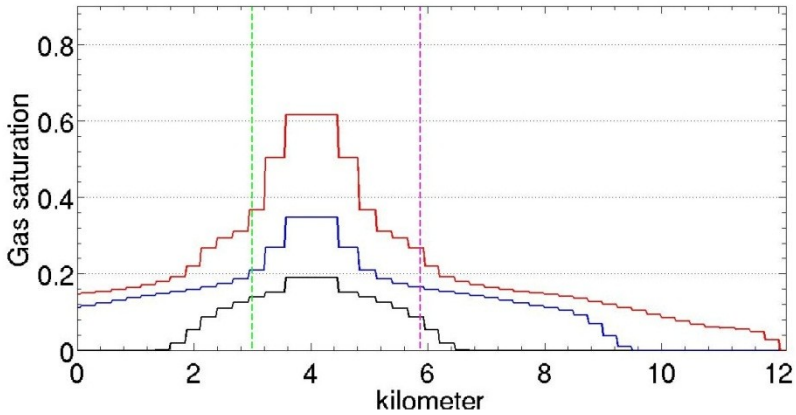


- Bottom Hole Pressure estimated from recorded wellhead pressure

Comparison of base case with a reduction in permeablity

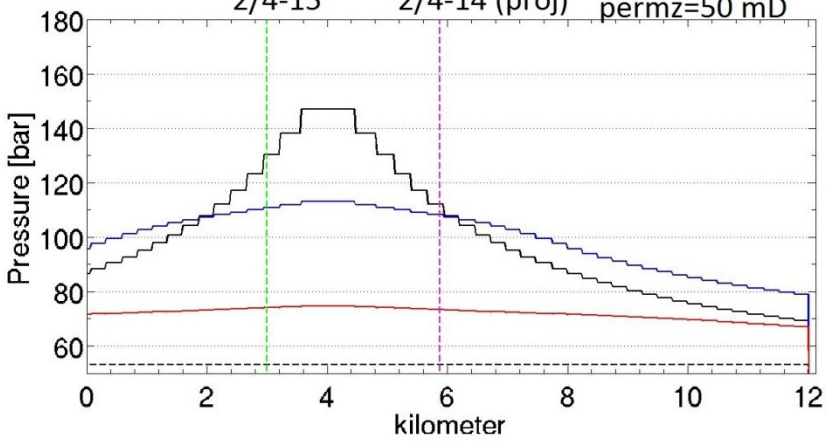
Base Case

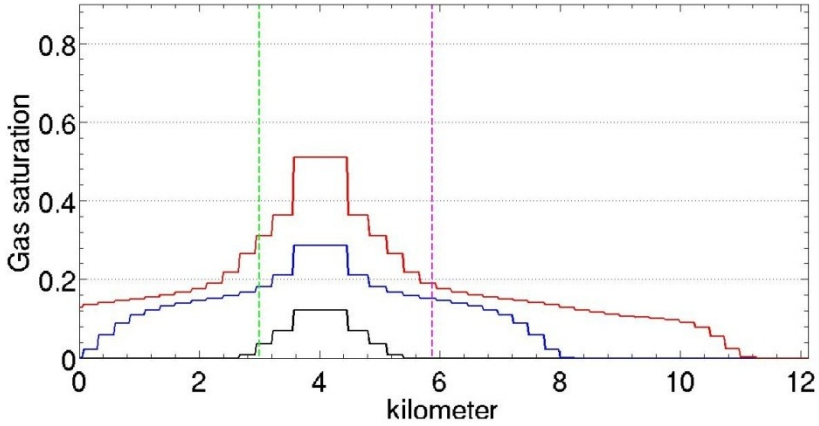




Case where permeability is halved

permx=permy=500 mD
permz=50 mD

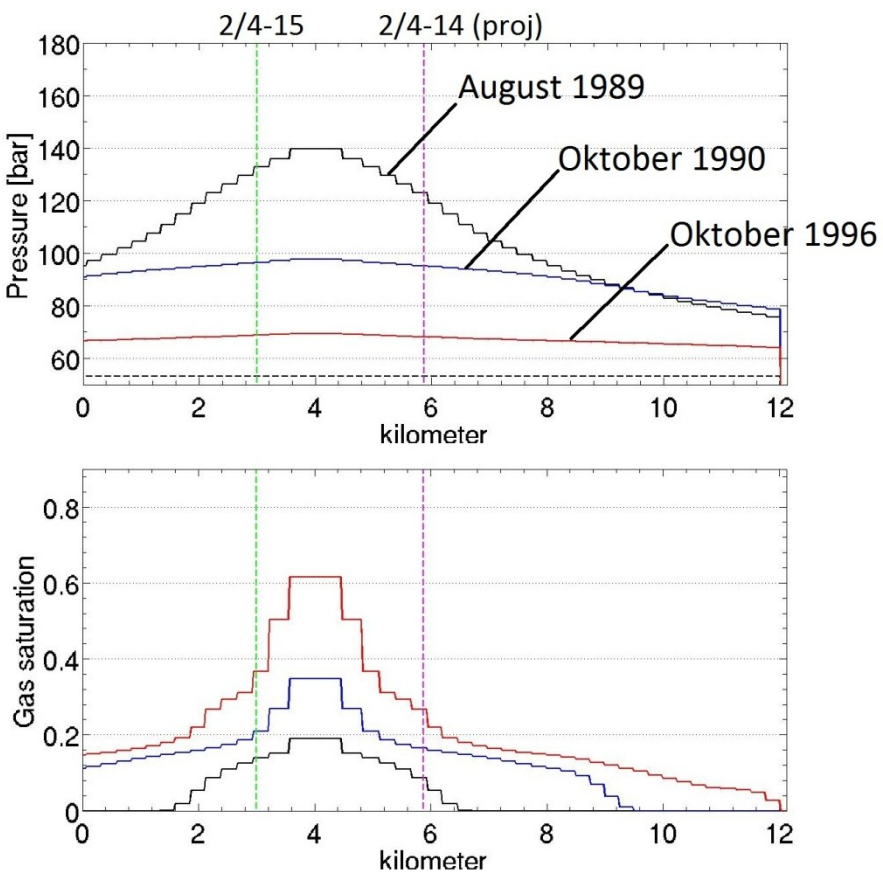




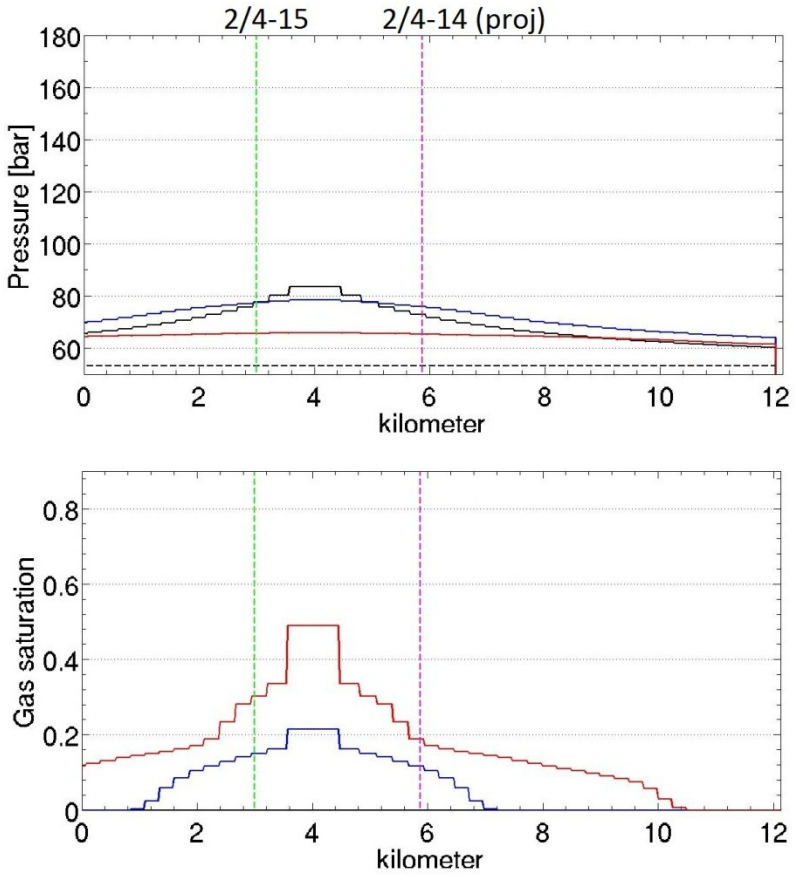
- Increase in pressure
- Slowdown in gas migration

Comparison of base case with a reduction in injection pressure

Base Case



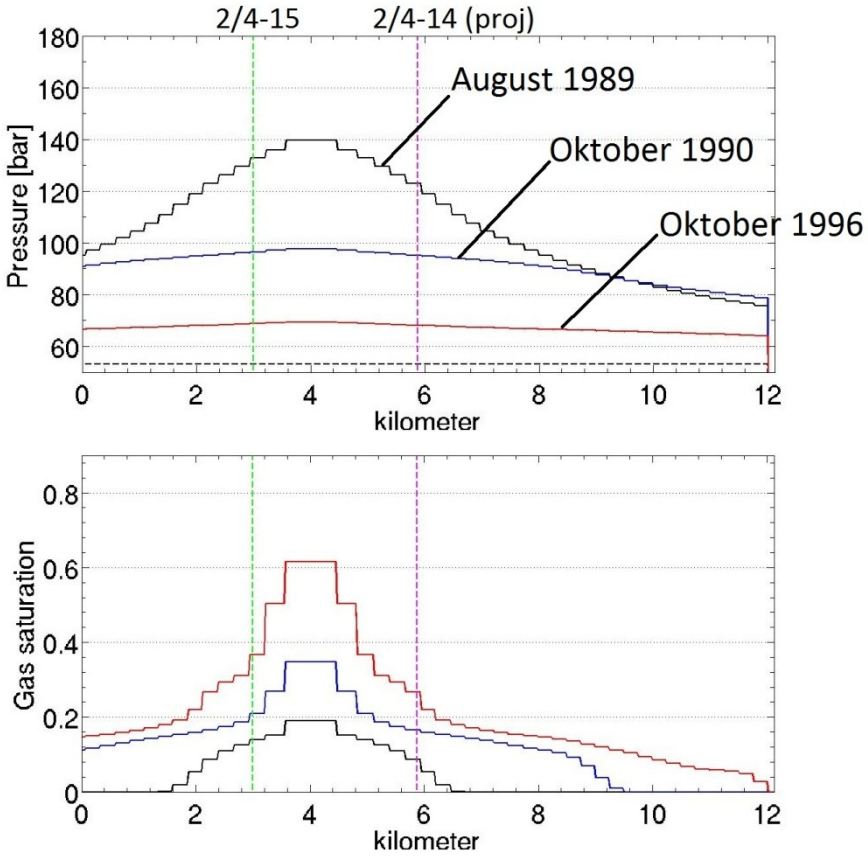
Case where injection pressure is halved



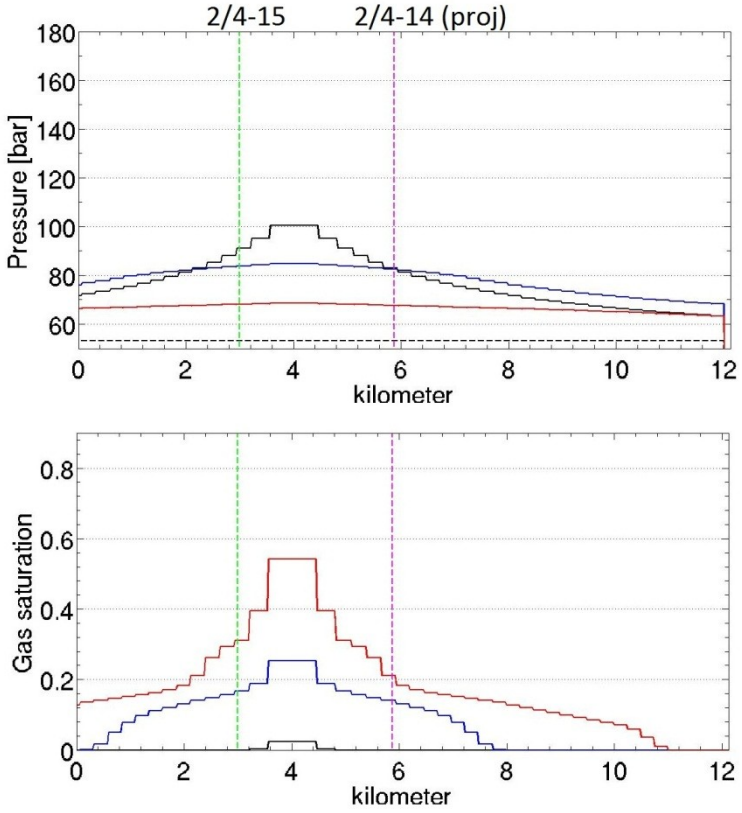
- Reduction in formation pressure
- Slowdown in gas migration

Comparison of base case with a reduction in the perforation interval

Base Case



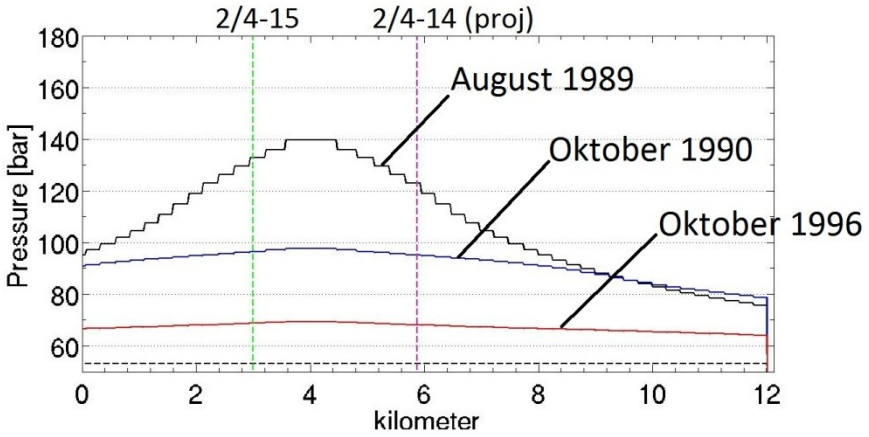
Case where only the 10 lowest meters of the bottom sand are perforated

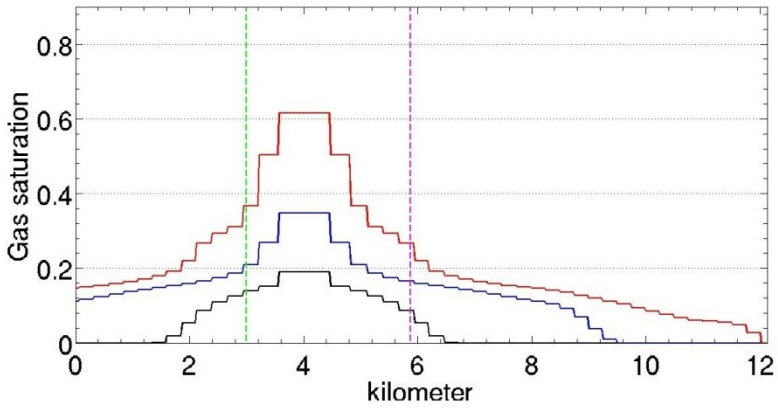


- Decrease in pressure
- Lower saturations and less propagation

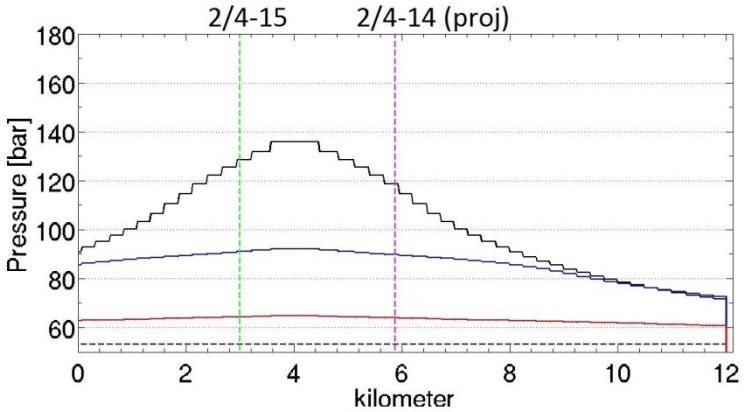
Comparison of base case with a case where the gas is allowed to flow up bevond the sand at 492 meters

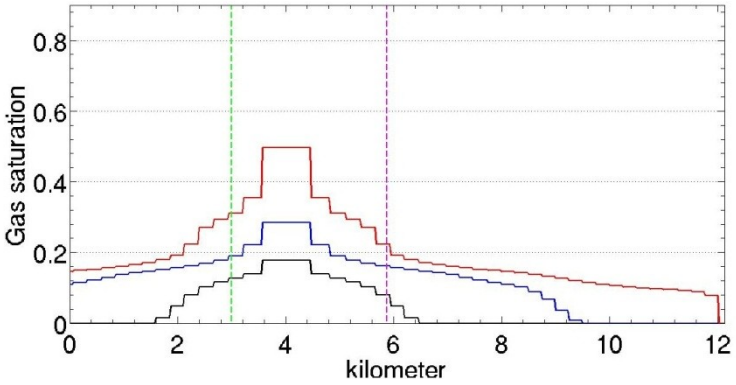
Base Case





Case where gas is allowed to flow up beyond the sand at 492 meters

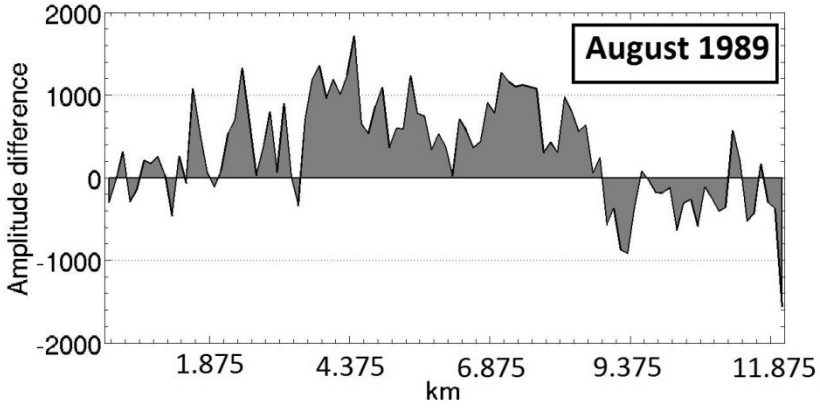


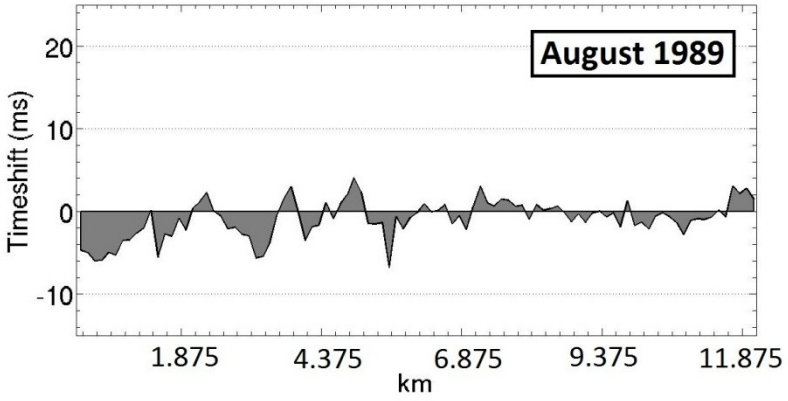


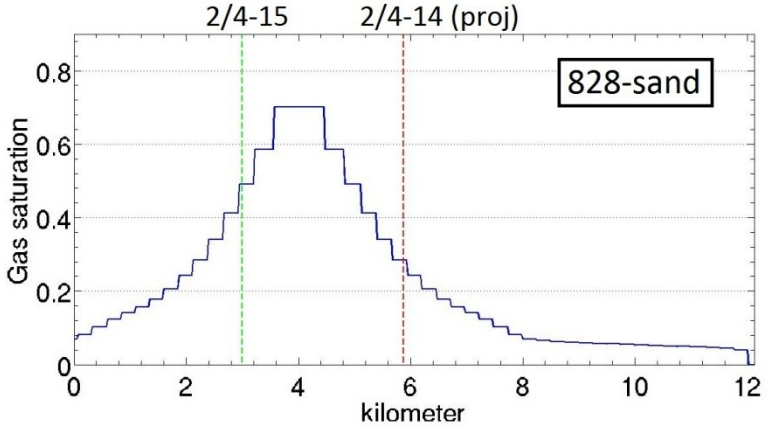
- Slight decrease in pressure and saturation

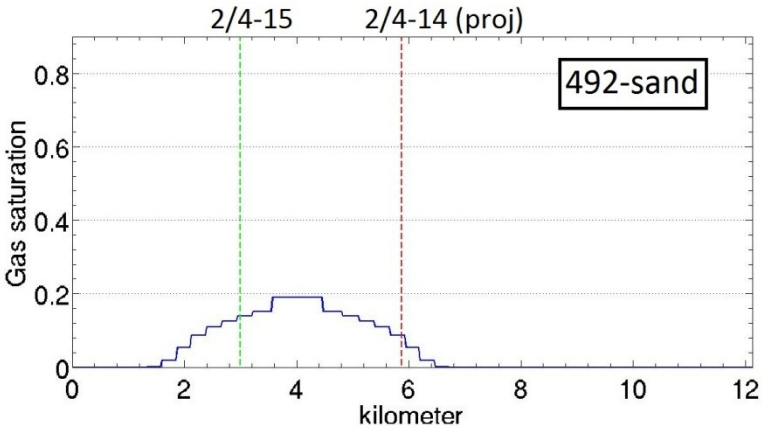
- From simulations, pressure in formation is relatively high
- Both pressure and fluid effects can lead to 4D effects
- Different spatial behaviour
- 4D analysis – pressure does not seem to affect seismic
- Focus on relation between saturation in both sand layers and 4D observations

Comparison of results for August 1989



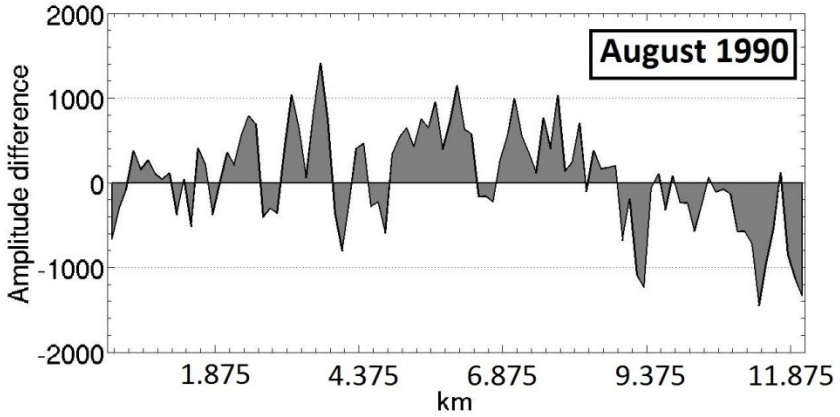


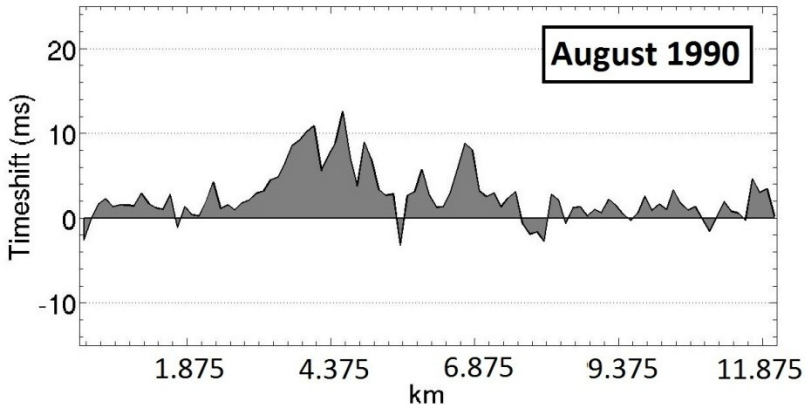


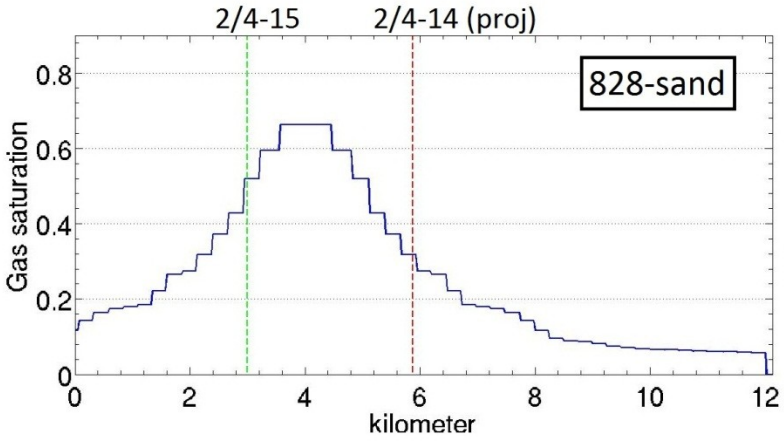


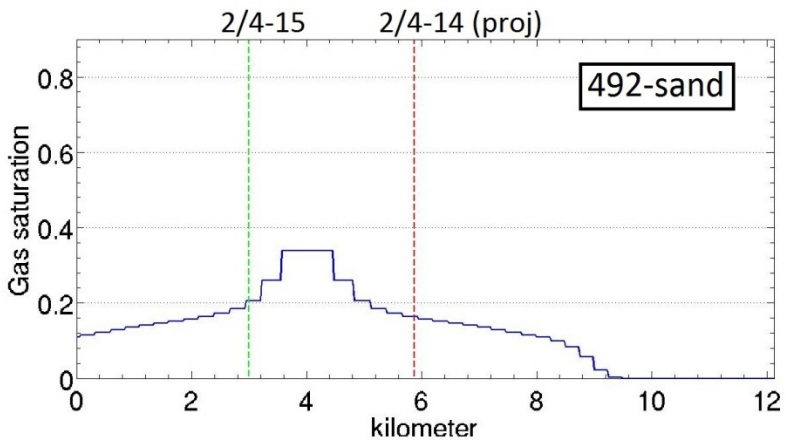
- High gas saturation in lower layer, and large increase in amplitude
- Little influx of gas in upper layer, no significant timeshifts

Comparison of results for August 1990



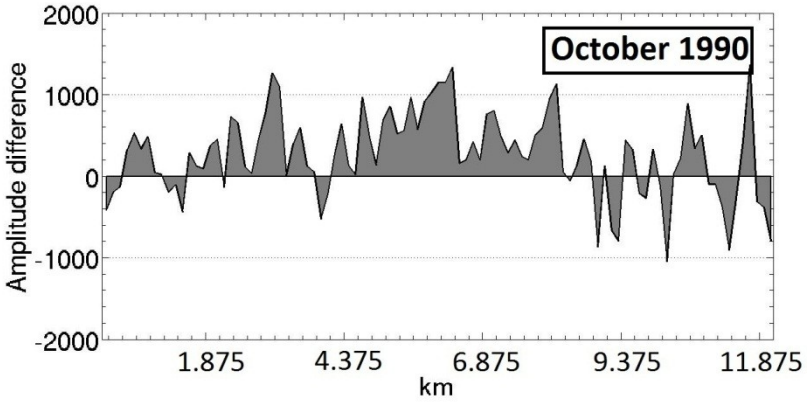


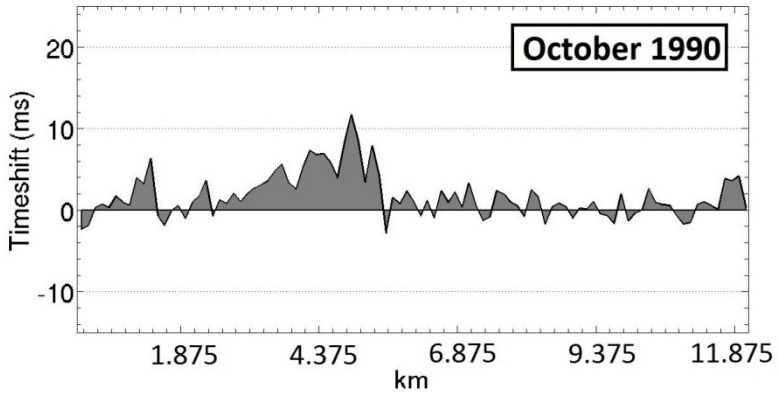


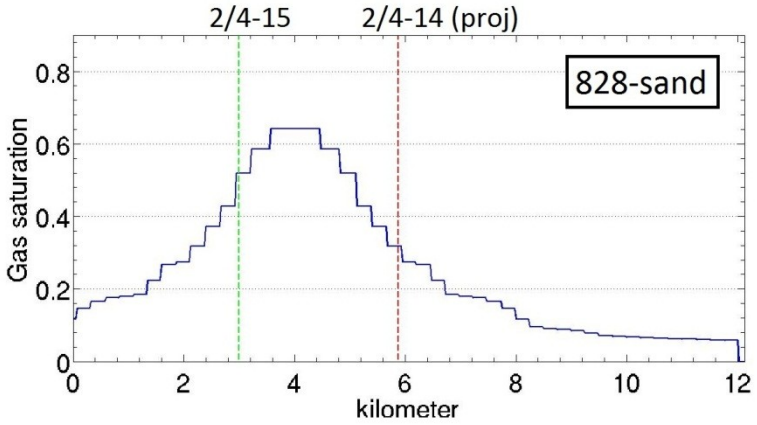


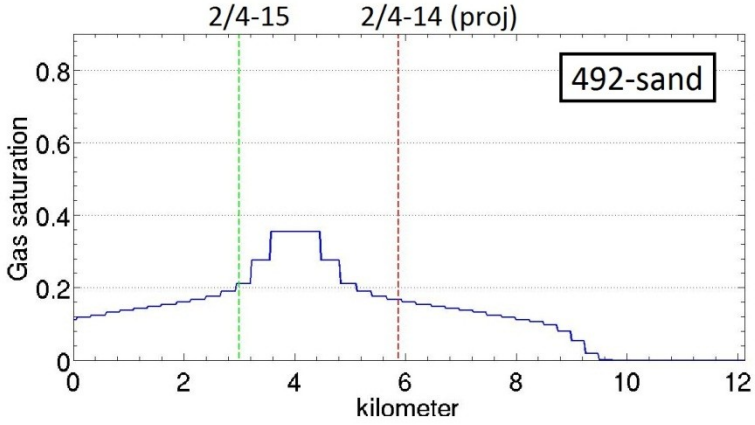
- Max saturation in 828-sand is lower than in August 1989
- Higher gas influence 492-sand
- Decreased amplitude difference

Comparison of results for October 1990









- Max saturation in 828-sand is lower than in August 1989
- Higher gas influence 492-sand
- Decreased amplitude difference

- August 1989:
  - no significant timeshift, low gas saturation in the 492-sand
  - large amplitude difference, high gas saturation in the 828-sand
- August 1990 and October 1990:
  - dominantly positive timeshifts, significant gas saturation in interval where the highest timeshifts are observed
  - amplitudes are damped, gas saturation in 828-sand is slightly lower than in August 1989

Conclusions

- 4D and reservoir simulation match
  - Fit with gas saturation
- Pressure effects not detectable

Acknowledgments

- The LOSEM partners supporting the project at NTNU: Bayern Gas, BP, Det Norske, Lundin Petroleum, Statoil and Total
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