Drilling Induced Formation Damage of Horizontal Wells in Tight Gas Reservoirs

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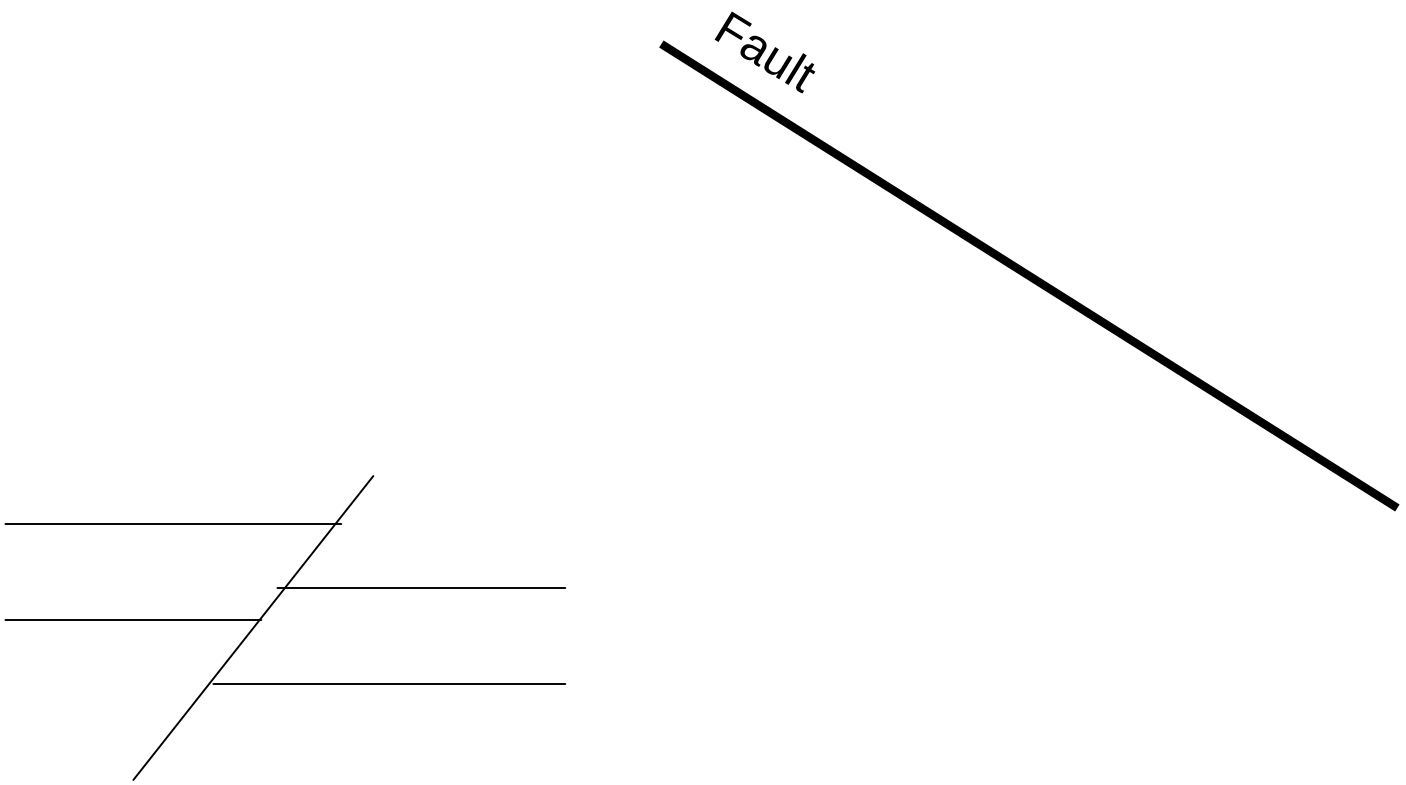
Outline

- Introduction
- Reservoir
- Underbalanced Drilling
- Conventional Drilling
- Guidelines for Drilling Fluid Selection
- Recommended Drilling Practices

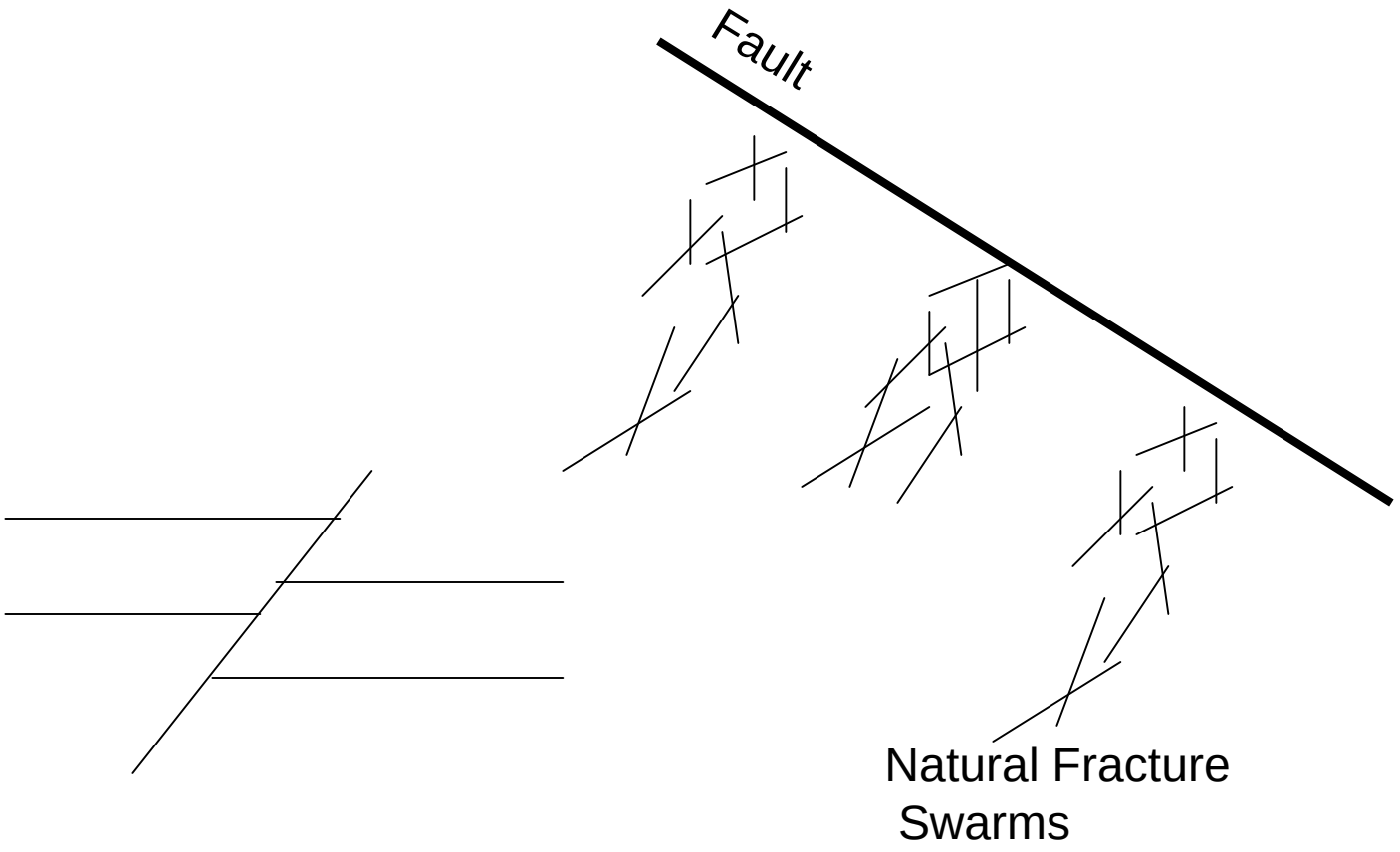
Introduction

- Industry is targeting more challenging environments : e.g. Deep Basin
- Permeabilities are in the 100 • D range
- Horizontal Wells:
  - maximize reservoir exposure
  - target multiple zones
  - reduced drawdown
  - potential to intersect natural fractures

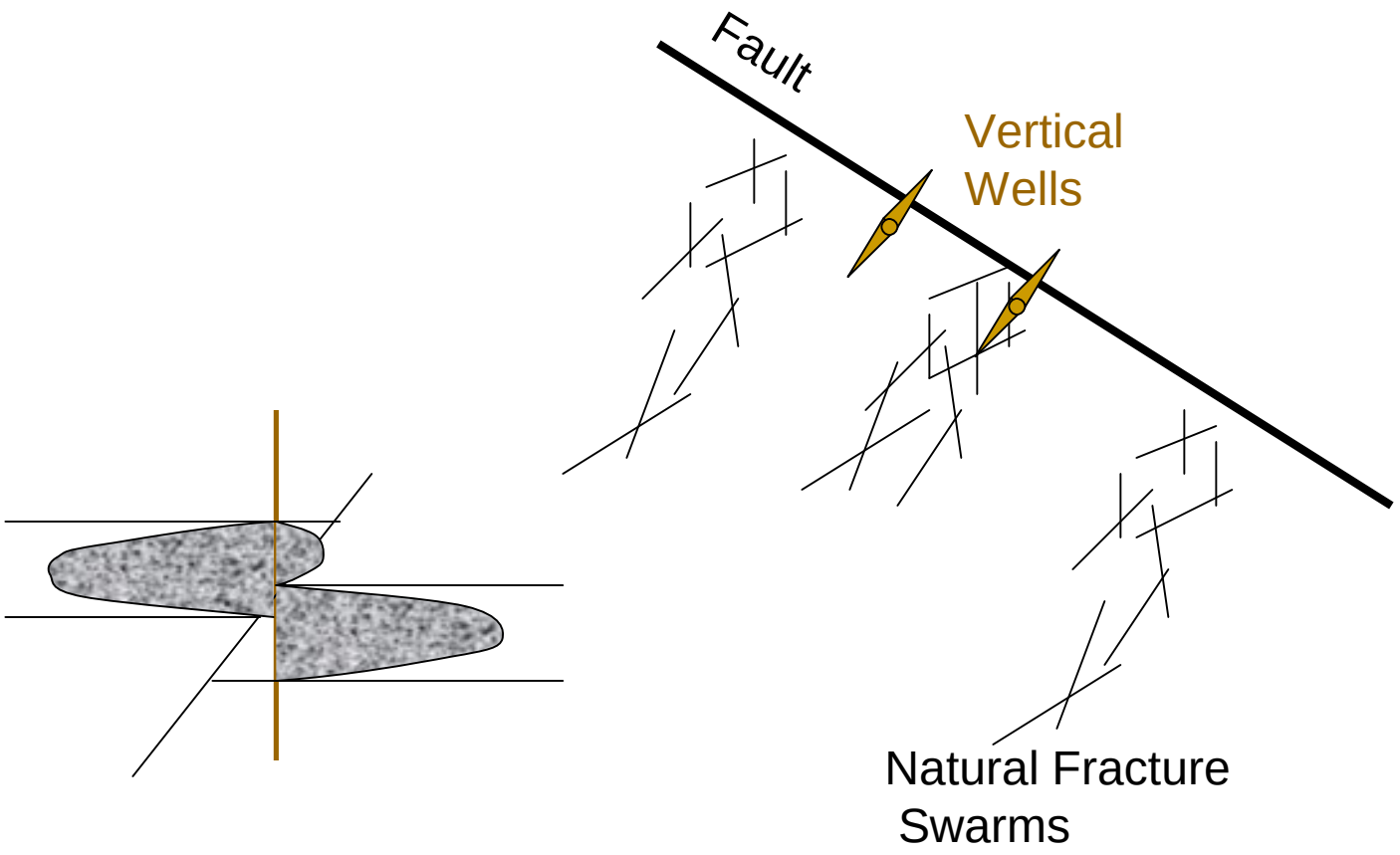
Horizontal Wells



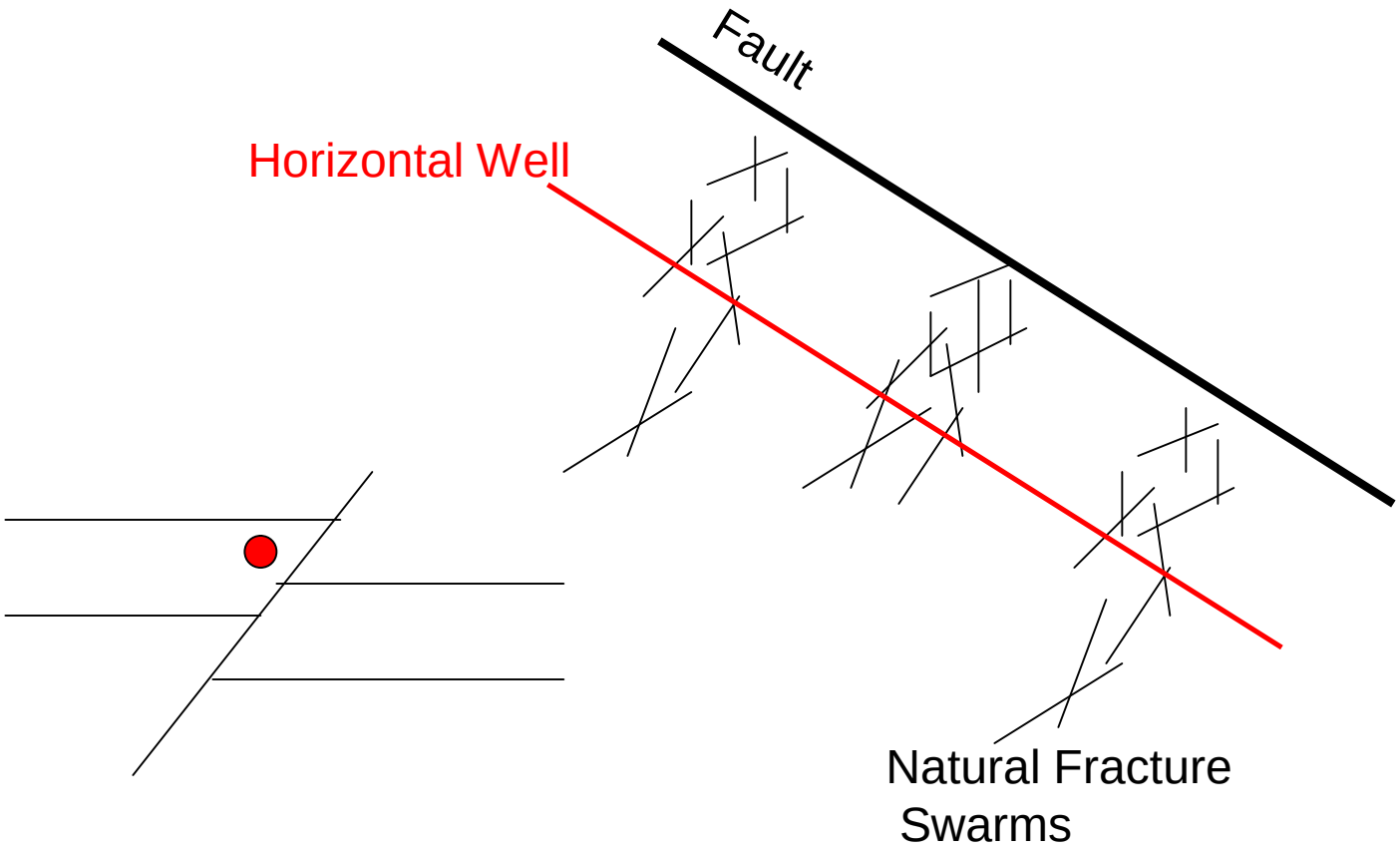
Horizontal Wells



Horizontal Wells



Horizontal Wells



Horizontal Wells

- Results can be below expectations
- Technically successful
- Economic success is more difficult to attain
  - Limitations in completions technology
  - Reservoir heterogeneity
  - Well geometry
  - *Formation damage*
- Liquids rich gas reservoirs can be complex

Formation Damage

- Vertical wells are generally stimulated

- Most horizontal wells are completed barefoot
- Even shallow invasion around the wellbore could cause significant problems

Reservoir

- Cardium sandstone formation
  - Marine sandstone, 10 to 35 m thick
  - 2300 m average depth
  - Porosity = 9 to 12% in the pay zone
  - Permeability < 0.1 mD in general
  - Thrust faulting and associated fractures
- Gas condensate
  - Avg. P& T = 21 MPa & 80 C
  - Liquids up to 450 m3/E6m3 (80 bbl/mmscf)

Underbalanced Drilling

- Horizontal wells can potentially perform better than hydraulically fractured vertical wells.
- Overbalanced conditions can lead to:
  - Fines invasion, clay reactions, phase trapping, precipitation, etc.
- Underbalanced drilling was selected to minimize formation damage :
  - Additional benefits: increase ROP, increase bit life, minimize lost circulation, reduce diff. sticking

Underbalanced Drilling

- First well was drilled with distillate
- Second and third wells were drilled with distillate + N_2 injection through drill string
- A number of fracture zones were intersected but performance was below expected

Underbalanced Drilling

- Fourth well with 1000 m leg did not intersect any fractures
- Interpreted to have 300 m productive zone
- Initially non-commercial gas rates
- Hydraulic fracturing was able to restore reasonable gas rates

Underbalanced Drilling

Operating procedures review:

- Overbalanced conditions during pipe connections and tripping
- No filter cake building agents
- Severe drilling fluid invasion
- Damage confirmed by PBU tests
- Additionally hole stability was a problem, fishing operations were conducted

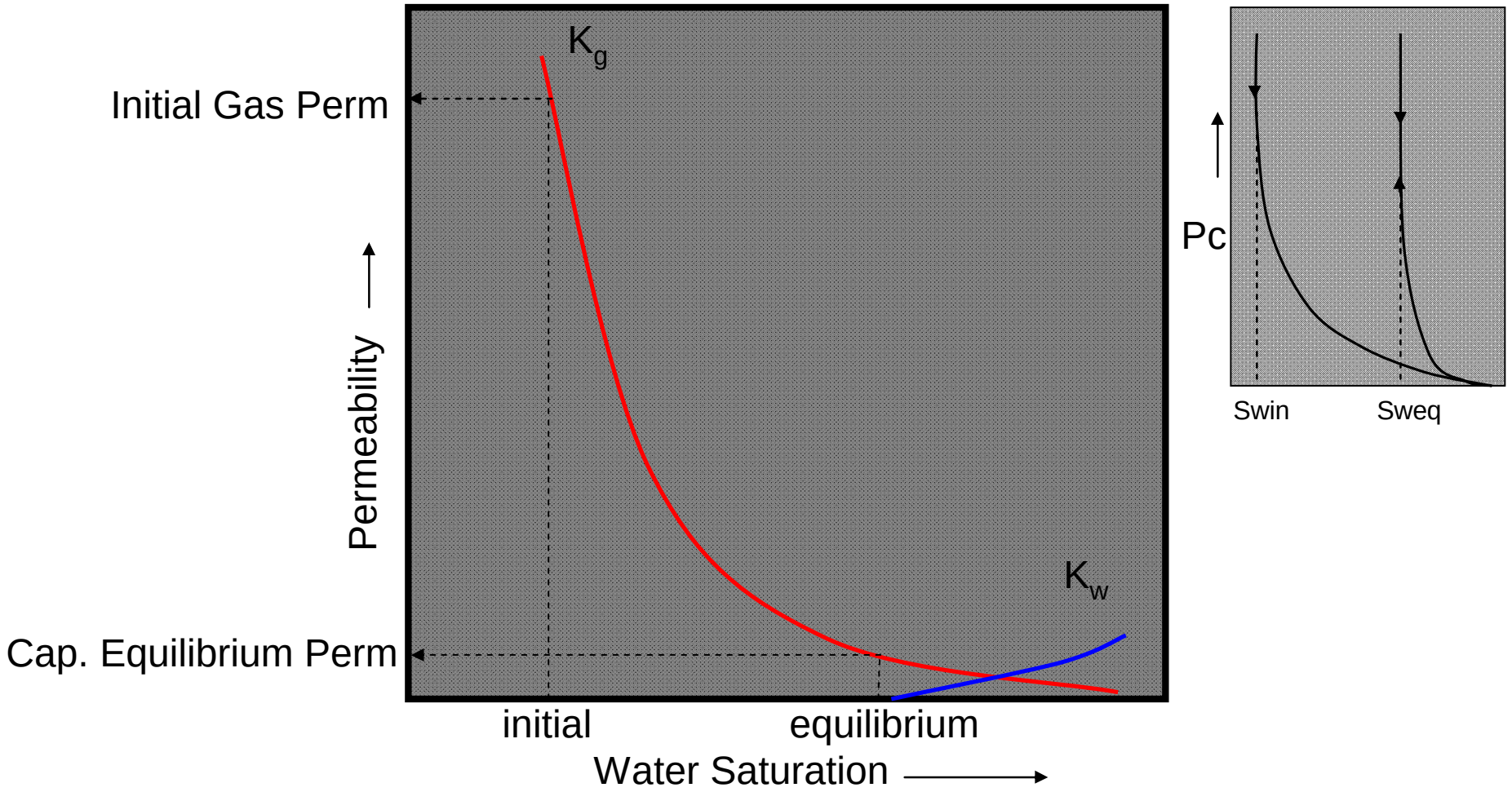
Conventional Drilling

- Additional costs incurred with underbalanced drilling were not justified
- Wellbore stability problems were making costs prohibitive
- A well designed overbalanced system with good fluid loss control would be optimum strategy

Base Fluid

- Most tight gas reservoirs are in a capillary undersaturated state
- Water is the wetting phase in most cases
- Water will imbibe to establish equilibrium saturation significantly reducing gas relative permeability
- Therefore, base fluid should be a hydrocarbon

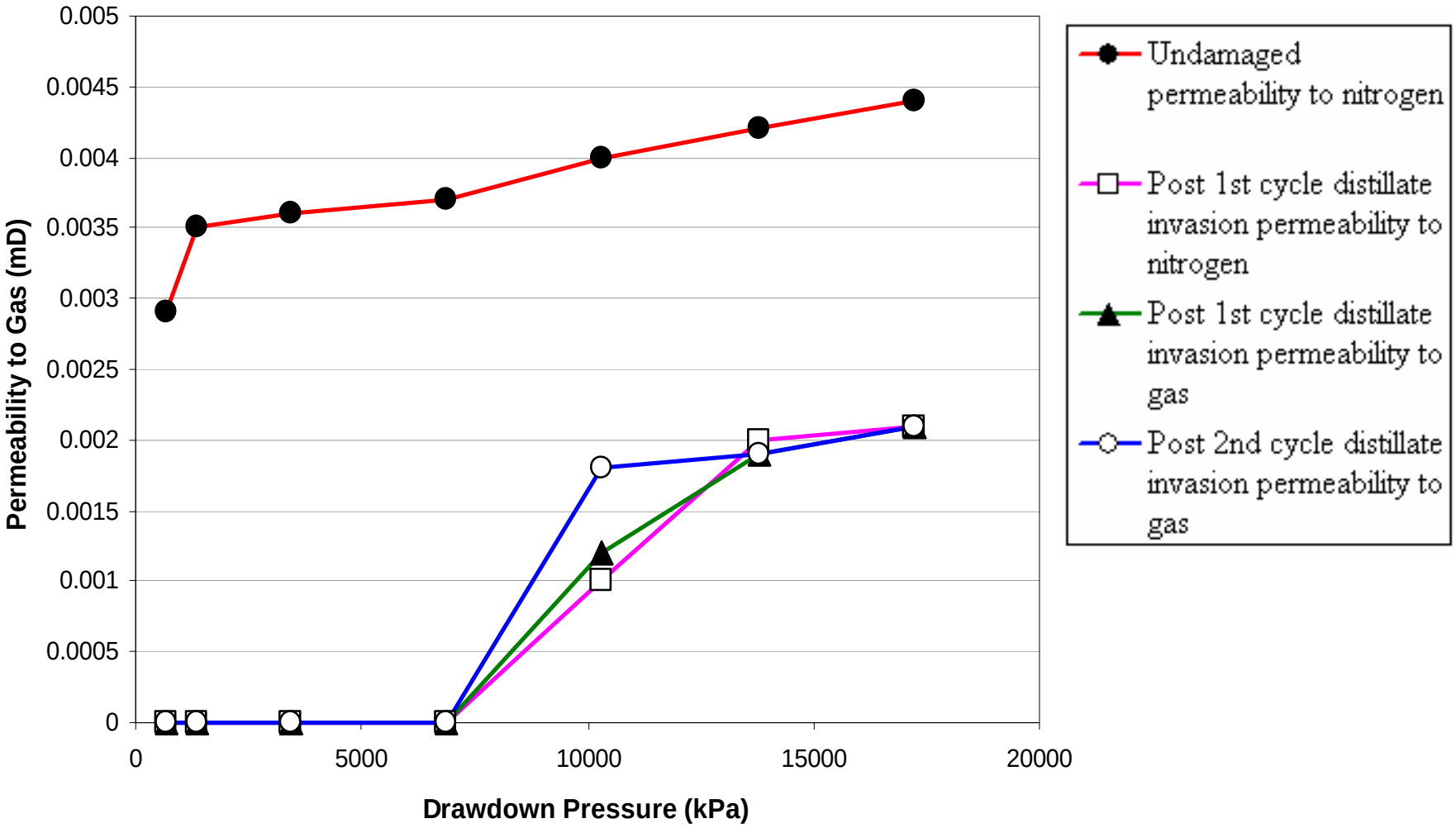
Capillary Equilibrium & Gas Perm.



Compatibility with Reservoir Fluids

- Base fluid has to be compatible with reservoir fluids (condensate and gas below DPP)
- The distillate used in first four wells has some heavy components
- PVT tests conducted suggested that there was potential for asphaltene precipitation

Regain Permeability with Distillate



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New Drill-In Fluid

- Formulate a new overbalanced drill-in fluid
  - Optimum rheology, stability and hole cleaning
  - Minimum formation damage: quickly and effectively bridge off matrix and fractures
  - Filter cake must be thin and easily removable
- The distillate cannot be used

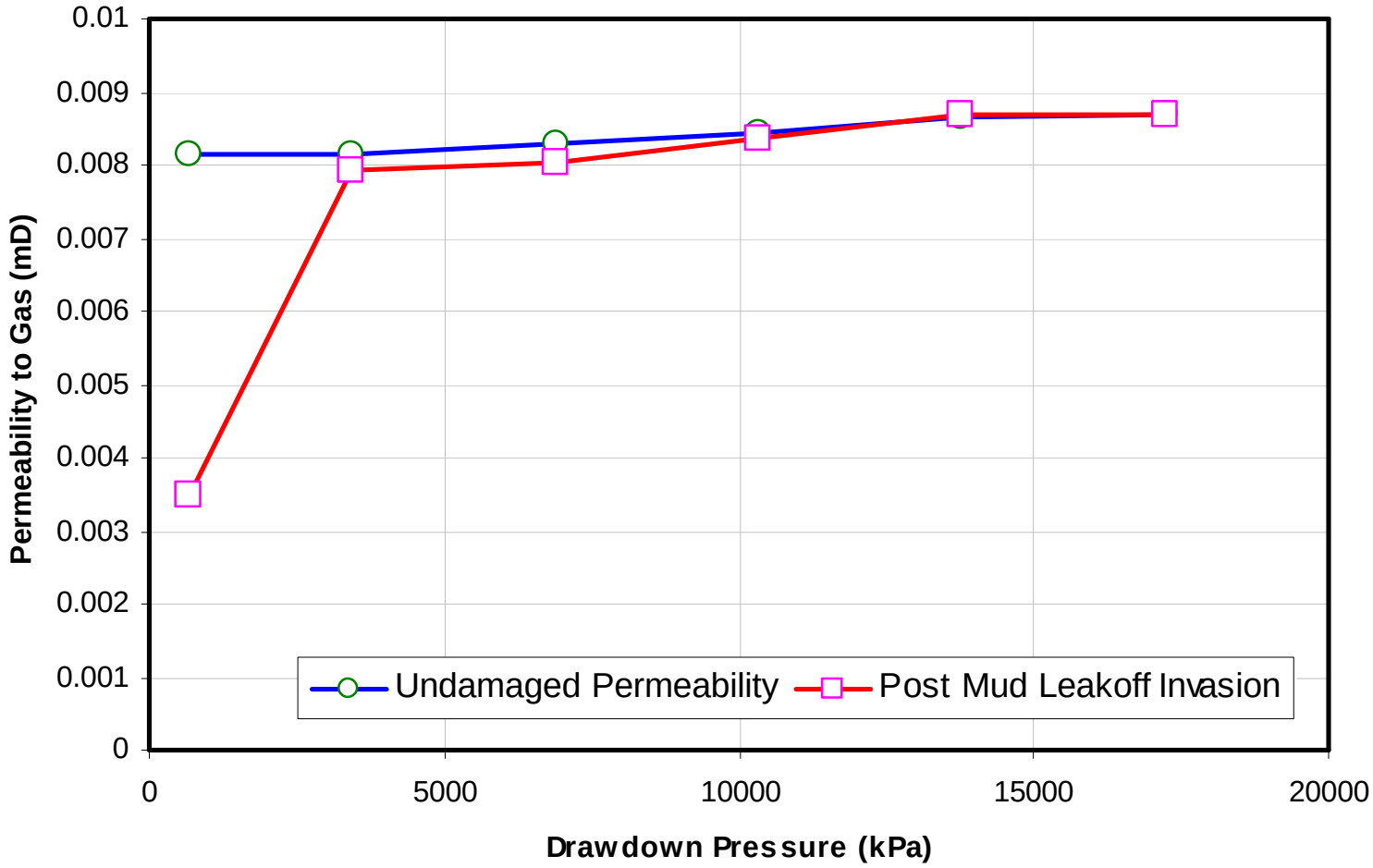
Initial Screening Study

1. Health, Safety & Environmental concerns
2. Elastomer compatibility
3. Reservoir fluid compatibility
4. Rock compatibility
5. Economics

New Drill-In Fluid

- One hydrocarbon that met the criteria was identified as base fluid
- Add various chemicals for desired fluid properties
- Add bridging agent: Calcium Carbonate particles

Whole Mud Leak Off Test - Designed



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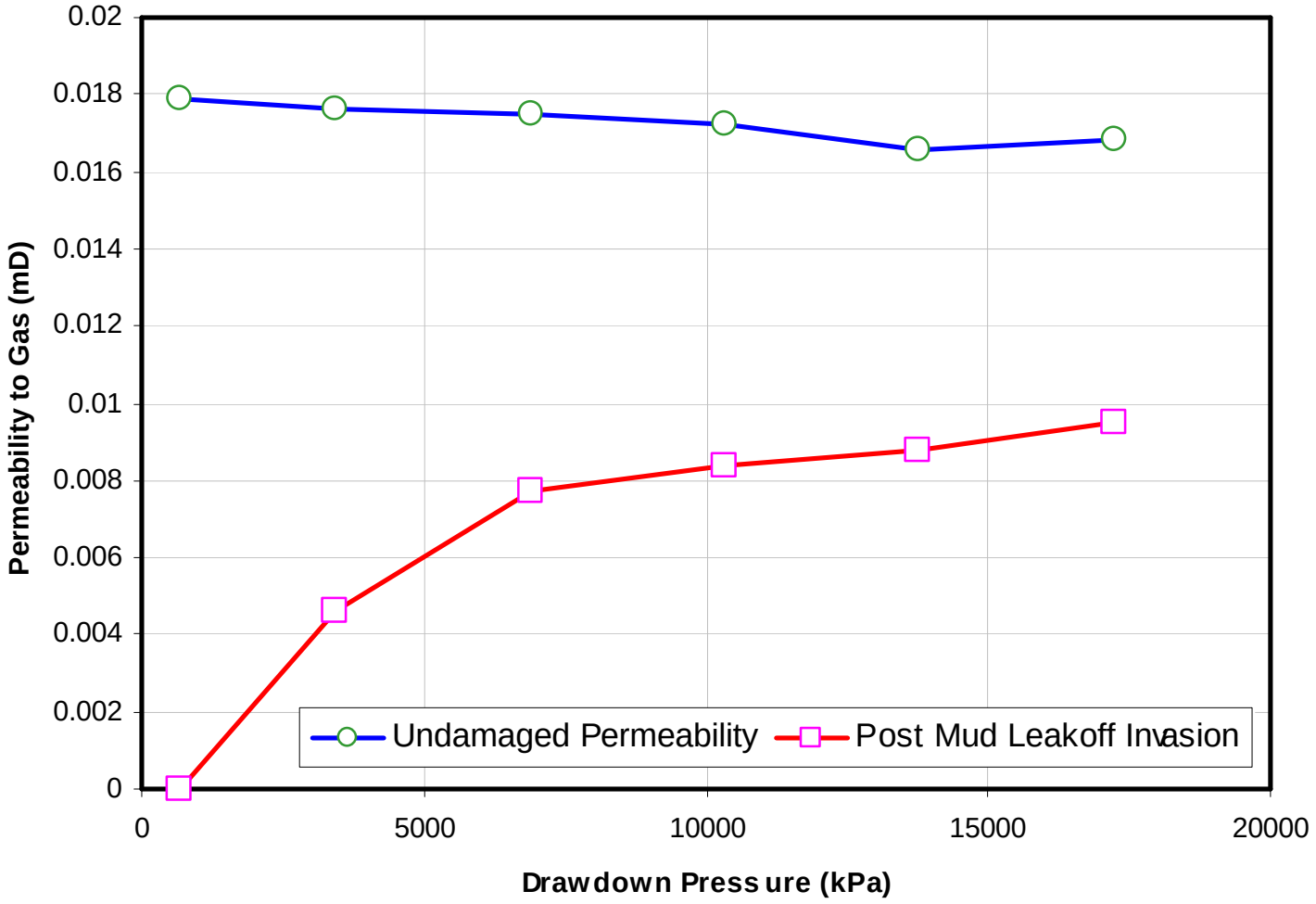
Field Mud Leak Off Test - Actual



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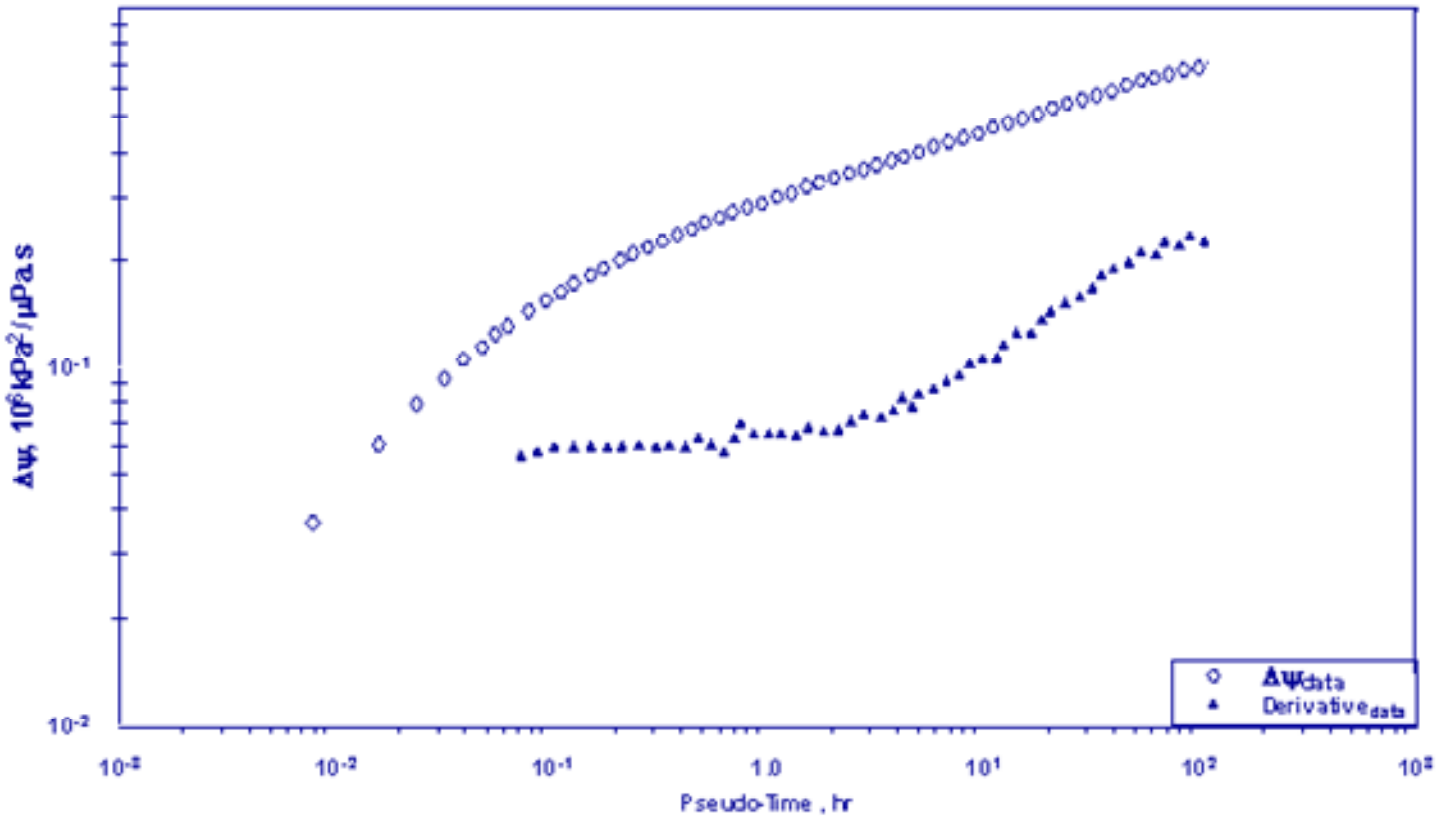
Why Is Field Mud Different ?

- Presence of actual drilling solids
- Small quantities of dispersants and lime was added (not in the design)
- Wells drilled since this well performed well and were drilled with minimum formation damage

Pressure Build Up Analysis



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Guidelines for Drill-In Fluid Selection

- HS&E and economical considerations
- Fluid-fluid compatibility
- Fluid-solid compatibility
- Fluid-elastomer compatibility
- Relative permeability effects
- Whole drill-in fluid leak off tests

Recommended Drilling Practices

- Maintain overbalance at all times
- Avoid operations that cause underbalance
- Minimize wiper trips and washing/reaming
- Verify overbalance by mud logs
- Complete as quickly as possible

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J. Can. Pet. Tech., Nov. 2004, 13-18

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