Reservoir Management and Well Integrity

Well Integrity Master Class

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Presentation Overview

- Field-wide pre-production stress state
- Effects of depletion / injection
- Reservoir compaction
- Geomechanical well integrity issues
- Mitigation measures
- 3D near wellbore coupled numerical modelling
- Summary
Pre-Production Stress State

Knowledge of pre-production stress state throughout field and overburden from the construction of 3D Mechanical Earth Model
3D Stability Volume

Optimum Drilling Direction

3D Mud Window
Effects of Depletion

- \( \sigma_{\text{vertical}} \)
- \( \sigma_{\text{horizontal}} \)
- \( \sigma_V = \text{constant} \)
- \( \sigma_h \) reduction

Pressure reduction

- Magnitudes (and perhaps order) of stresses will change
- Compaction will occur
- Petro-physical properties will change
- Stress transfer to over/underburden
Stress Transfer to Overburden from Injection

Injection can lead to loss of containment

- New $\sigma_h$
- Region of reduced $\sigma_h$
- Permeable horizon
- Potential fracturing
- Pressurized zone
- Cap rock

![Injection schematic](image)
Coupled Numerical Modeling

![Diagram showing coupled numerical modeling with WBHP (psia) vs. time (years). The diagram includes a 2-way coupling mechanism between the reservoir simulator and the geomechanical simulator, highlighting changes in permeability ($\Delta K$), porosity ($\Delta \phi$), pressure ($\Delta P$), and temperature ($\Delta T$). The graph shows field data, no history match, and geomechanics results.](image-url)
Dynamic Reservoir Behaviour

Changes in stress leading to possible:

- Compaction / expansion
- Subsidence / heave
- Cap-rock integrity
- Fault reactivation
- Induced fracturing

All of which may have a direct bearing on well integrity
Reservoir Compaction and Subsidence
Strain-Induced Well Integrity Issues

Any stretch in overburden causes extension in casing etc.

Micro-seismic monitoring can detect slipping beds, shearing fractures etc.

Compacting reservoir

Shear induced deformation

Worst at flanks

Shear & local plastic deformation

Worst at crest

Euler buckling

Compaction induced
Strain-Induced Well Integrity Issues

- **High σ_h region** (low angle shear)
- **Slip planes in overburden**
- **Reservoir compaction**
- **High τ region**

Diagram showing:
- Flanks
- Shoulders
- Crest
- Shoulders
- Flanks

Map showing collapsed wells with a scale of 5 km and a North orientation.
Casing and Compaction

compaction

original shape

deformed horizontally oriented borehole

a. radial deformations

casing-cement

compacting reservoir

extension neutral axis

compression

b. axial load changes
Casing Impairment

a. Pressure impairment
- extensional strain leading to casing rips
- thread stripping, axial or lateral displacements
- compression buckling and cracking

b. Access impairment
- lateral shearing displacement in the rock mass
- pinched or dog-legged casing
- stuck tools

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Compaction: Distorted Casing

(original casing)  (bent casing)  (after Veeken et al., 1994)
Mitigation of Casing Failure

- Increased section modulus and casing weight (but of little help against shear at interface)
- Slip joints for compacting crestal regions
- Well trajectory
- Compliant cement
- Hole openers and compliant well design to delay onset of shear failure
High resolution 3-D wellbore stability analysis
3-D Wellbore Stability Analysis

- Mud weight window incorporating plasticity
- Optimal mud weight program & casing point depths
- Extent of wellbore failure including width & depth
- Extent of wellbore radial deformation
3-D Completion Integrity Analysis

- Stress state & deformation of completions including cement, casing, ESS, production tubing etc
- Optimal completion design
- Life of well completion integrity
- Effects of depletion & injection including near wellbore pressure profile with time
- Effects of fault re-activation
- Effects of reservoir compaction & expansion
Summary

- Field-wide knowledge of the pre-production stress state is required for well trajectory optimization in terms of geomechanical well stability.
- Depletion/injection will lead to changes in stress and impose additional load to well casing / cement / completions.
- Geomechanical well integrity issues are associated with compaction and shear strains occurring within reservoir and overburden.
- 3D coupled analysis utilizing near wellbore models will predict regions of concern leading to an optimized well design for life-of-field stability.