Underbalanced Drilling

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Why drill Underbalanced?

Gullfaks field:
- Complex
- Excessive water injection: pressure increase
- Fracturing of cap rock
- Pore pressure of cap rock approaching fracturing pressure: not possible to drill conventionally
1. Underbalanced drilling requires rock strong enough to remain open under the additional forces from fluid influx.

2. UB drilling is much faster: time-dependent strength losses in shale are low.

3. Fluid flux is inward, thus shale strength is not affected by mud filtrate.

4. Formation damage reduced (e.g. capillary blockage), giving better production.
Drilling Below the Pore Pressure

- In the upper zone of many basins, \( p_o \) is roughly hydrostatic
- If it is an eroded basin the shales are strong
- It is possible to drill with \( MW < p_o \) for substantial depths: i.e.: underbalanced
- Much faster drilling
- But: care and monitoring are essential
Advantages of Underbalanced Drlg.

- Faster drilling
  - Lower rig time costs
  - Shales are exposed for a shorter time
  - Occasionally, saving of one casing string
- Shales are not exposed to mud filtrates
  - Swelling and deterioration reduced
- Less damage in the reservoir
  - If it is possible to enter the reservoir just at the balance, far less damage takes place
  - This has resulted in many “unproductive” gas zones in Alberta becoming economical zones
Top Drive Systems

- Permit forward and backward rotation
- Excellent torque control available
- Back-reaming hole
- Good for running casing (circulation, etc.)
- And so on
- Good in UB drilling
- See materials – Harold Vance’s presentations!
Rotating BOP’s for Air Drilling

- Shaffer rotating blow-out preventor.
- 2,500 psi rotating - 5,000 psi static.

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Parasite String and Air Lift (UB)

Small injection string run simultaneously with intermediate csg.

Injected gas does not affect bit hydraulics.

Injected gas does not effect MWD.
When to Drill Underbalanced…

- If no significant gas sands will be encountered (small ones are feasible)
- If water influx is manageable
- When the shales are intact & strong enough that sloughing is manageable
- If faster drilling is saving you money
- When the rig capabilities allow UB drilling:
  - Top drive is certainly best
  - Special return line equipment is installed
  - Mud system can take foam, air…
Wellbore Stresses and Pressures

Overbalanced, $MW > p_o$

Assume $\sigma_{HMAX} = \sigma_{hmin} = \sigma$

Pore pressure $- p_o$

Mud pressure $- p_w$

$p_w \sim 1.2p_o$

Borehole stresses are higher
No mudcake support ($\sigma'_r$ is negative)

Underbalanced, $MW < p_o$

Assume $\sigma_{HMAX} = \sigma_{hmin} = \sigma$

Pore pressure $- p_o$

Mud pressure $- p_w$

$p_w \sim 0.8p_o$

perfect cake

radius
Wellbore Stresses and Pressures

- Effect on borehole wall stresses:
  - Tangential stresses are higher in UB
  - Radial stresses are lower (negative?)
- This pushes the rock closer to failure
  - Shown on the next figure, a strength plot
- $p_o > p_w$, so flow is out of, not into the shale
  - Creating a small additional destabilizing force
- Because we are not supporting the shale with positive pressure, we have to watch carefully for excessive sloughing!
  - Monitor and estimate volume of cavings…
  - Examine them for shape, stratigraphic position
UB Drilling and Shale Strength

Stresses in underbalanced drilling

Overbalanced, good shale support (OBM?)

Shear stresses are always higher in UB drilling case

\[ \sigma'_r \] can be slightly negative

\[ \sigma'_\theta \] is increased in UB case
Effect on Shale Deterioration

- When mud filtrates invade shales:
  - Swelling
  - Deterioration
  - Loss of support

- In UB drilling:
  - Flow is toward the hole
  - Shales not exposed to drilling mud filtrate
  - Diffusion is suppressed
  - Geochemical stability!

- Shales don’t suffer filtrate deterioration!

\[ p_o > p_w : \text{inward gradient} \]
This eliminates outward seepage that can further damage shales
Some Additional Comments

- Smectitic shales are usually extremely geochemically sensitive (swelling...)
- OBM is a solution, but...
  - OBM is expensive
  - Cuttings are environmentally difficult
  - OBM can block gas zones
- UB drilling: another solution for smectites
  - Providing strength is sufficient...
  - UB drilling avoids swelling
  - Chips, mud, are easier to dispose of
Why Faster in UB Drilling?

- High MW pastes chips against hole bottom
- Also increases the strength of the shale
- UB condition actually helps the shale drill chips to spall off
- Mud rings, bit balling are reduced
- Typically, time to drill the interval is thus reduced by 50-60%

\[ p_w = \text{static } p + \text{dynamic } p \]

\[ p_o = \text{pore pressure} \]

The “plastering” effect is counteracted by \( p_o > p_w \)
Approaches to UB Drilling

- Drilling with air
  - Carrying capacity may be limited
  - Very cheap
  - Low pressure in the hole, trip issues

- Drilling with inexpensive foams
  - Higher pressure in the hole = +stability
  - Foams have better hole cleaning capacities
  - Chips and foam all rejected to a pit

- Drilling with stable foams
  - Recycling chemicals
  - More expensive

- Cost-benefit analysis and experience...
Types of Fluids in Drilling

LIQUID
AERATED LIQUID
FOAM
MIST
GAS

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Density of UB Drilling Fluid

- Aerated Fluid: 0.8
- Stable Foam: 0.6
- Water: 1.0
- Air/Mist: 1.2

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Foam Gives Excellent Hole Cleaning

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The basins marked are likely to be poor candidates for UB drilling; the entire remainder of the Lower 48 may be considered because the shales are mechanically strong.

However, local stratigraphy, gas zones, etc., must be investigated in UB drilling assessment.
When Not to Use UB Drilling

- When shales are weak and will slough (i.e. a non-tectonic basin with no erosion history)
- In areas of very high tectonic stress
  - i.e.: when $\sigma_{HMAX}$ is much higher than $\sigma_{hmin}$
- When significant gas sands generate risks to drilling that cannot be managed
- When there are intensely fractured shales
- When massive water influx cannot be handled in an underbalanced mode
  - i.e. thick high k water sands
- When you don’t have the right equipment
- In horizontal or high angle wells
- Set surface casing
- Drill w air/foam through swelling shale intervals to the first serious gas/water sand, one bit only if possible
- Set casing to isolate the sensitive shales
- Drill w WBM (best for fractured shale) to TD
- Set production casing
Lessons Learned – UB Drilling

- Faster drilling, less formation damage, reduction of clay – filtrate effects
- Less differential sticking (eliminated!)
- Only suitable if shale strength is high, minimal gas, and no massive water zones
- Rock properties, sedimentary basin history, lithostratigraphy… all help in screening
- Careful surveillance and chip morphology assessment is recommended
- Less likely to be used offshore in relaxed basins that have not experienced erosion