Log-based Mechanical Earth Modeling for Wellbore Stability

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Cost of Wellbore Instability (1998)

- **AMOCO**: $600MM to $1 Billion per Year
- **ARCO**: 17% of Total Well Cost
- **MOBIL**: Min. 10% of Total Well Cost
- **Western-Atlas**: >$6.4 Billion per Year
- **HES & Shell**: ~$8 Bil. ‘96 & ~30% Total Budget
- **Soloman Bros**: 15% of Total Drilling. Cost in ‘96
- **API Survey**: 19-24% Holes w/ Sign. Mud Loss
- **GRI & OGS**: $500-750MM/year in Shales
- **SHELL**: >$500MM/year in Shales
- **BP(123 GOM)**: $167.6MM 1985-97

*It is a huge capital loss*
Upshots of Wellbore Instability

• Lost circulation
• Stuck pipe
• Additional casing strings
• Side tracks
• Abandonment
Mud Weight Window

Pore pressure
Collapse Pressure
Fracture pressure

TOO LOW

DANGER

RISKY

SAFE

TOO HIGH

MUD WEIGHT

$p_p$

$s_h$
Parameters of Importance

- Earth stresses (vertical & horizontal)
- Pore pressure
- Fracture gradient
- Rock strength & failure criterion

All of these can be estimated from logs
Earth Stresses

These stresses are taken as principal stresses. This may not always be the case, however.
Earth Stresses

- Vertical stress can be estimated from density log
- Minimum horizontal stress can be estimated from MDT minifrac or equated to fracture gradient
- Maximum horizontal stress can be estimated either from minifrac or sonic scanner
- Direction of horizontal stresses can be firmed up either with a 4-arm caliper or sonic scanner
Near Well-bore Stresses

• Mud pressure may not exactly match the stress which the removed rock exerted
• This gives rise to stress imbalance or stress redistribution near wellbore wall
• The new stresses are:
  ✓ Hoop or tangential or circumferential stress
  ✓ Radial stress
  ✓ Axial stress
Stress Concentration Near Wellbore

Local stress field perturbed due to the borehole
Near Well-bore Stresses

In this model pore pressure and wellbore pressure are equal. Hoop stress reaches 7K psi in the direction of minimum horizontal stress.
Pore Pressure

• In permeable sections it can be measured directly with MDT

• In shale sections it is predicted on the basis of shale compaction theory
2. Extrapolate normal trend line

1. Establish “Normal” Trend Line in good “clean” shale

3. Determine the magnitude of the deviation

Porosity should decrease with depth in normally pressured shales
Pore Pressure Prediction

• Eaton’s sonic method:

\[ PP = OBG - (OBG - PP_N) \left( \frac{DT_N}{DT_O} \right)^x \]

• Eaton’s resistivity method:

\[ PP = OBG - (OBG - PP_N) \left( \frac{RO}{RN} \right)^x \]
Fracture Gradient

- Sets the higher side of safe mud weight window
- Can be approximated to minimum horizontal stress

\[
FG = PP + (OBG - PP) \left( \frac{\nu}{1-\nu} \right)
\]

Where \( \nu \) is the Poisson’s ratio
Stability Analysis

• The existing near wellbore stresses are compared with rock strength to predict failure

• If the stress field concentration around wellbore exceeds rock strength, yield may occur
Case studies
ANDW-1
Predrill Predictions

Fig. 10 PRE DRILL PRESSURE SUMMARY OF ANDW-1 (Source Executive Drilling Programme)
Well: ANDW-5
Kuth-9
Kuth-42
ANDW-1 (AND-1) - Breakout Analysis

Project Name: Andaman

4 Arm Caliper - Caliper 1
4 Arm Caliper - Caliper 2
4 Arm Caliper - Pad 1 Azimuth

- Elongation Analysis
- Key Seat
- Breakout
- Washout
- Breakout Azimuth
- Breakout Angle

4 Arm Caliper - Caliper 1 (in)

- Breakout Azimuth (deg)
Well: ANDW-1

Breakout azimuth from 4-arm caliper
Conclusions

• Mechanical Earth Models can be built for our fields with the help of logs to have a better control during drilling. This will result in reduced NPT.

• However the models have further scope of improvement if more data in terms of LOT, Minifrac, MDT, FMI (4-arm caliper) and laboratory report on rock strength, are added.