9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-379

# Importance of Collapse Gradient of Formation for Stable Well

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***Summary***

*Complication free drilling is a desirable objective of persons manning the rig. But this always is not the case. Stuck up of drill string, logging tools and mud loss constitute major borehole problems. More than 50% of total complications are due to the said problems during 2010-11 in ONGC assets and basins. Cumulative rig days lost on this count constitutes 57.71% of total rig days lost in complication.*

*Despite adopting latest technology in Drilling Engineering as well as in Mud Engineering, non productive down time has not been reduced to barest minimum.*

*What are the reasons behind this? Paper discusses in detail the missing link which may minimize NPT. That missing link is the lack of data on Collapse Gradient of formation. Hither to now, well bore are drilled based on Pore pressure data only. Pore pressure may give a safe well but not a stable well. Pore pressure gradient as well as Collapse pressure gradient predicts the minimum mud weight needed for safe as well as stable well.*

*Concept of Collapse Gradient was floated in different assets and basins of ONGC to solicit views on it. Case history of Patan area of Mehsana asset was taken for bringing the point home. The field has shown past history of well bore instability in spite of increasing level of chemical inhibition. Stability in well could be achieved by increasing mud weight . They were convinced of the concept.*

*A collaborative study has been taken up with CEWELL, one of the Institute of ONGC to determine Collapse pressure from logs (DSI). Approach was finalized to validate the modeling from software available in ONGC by determining collapse pressure and mud weight window from DSI logs and then matching it with case history of the selected well.*

*This is for the first time in ONGC that data on Collapse pressure will be generated utilizing existing facility in ONGC which will definitely give idea for having stable as well as safe well and help in cutting down undesirable NPT.*

## Introduction

While drilling an oil well cutting is lifted through circulation of drilling fluid and discarded at the surface. Material in the form of cutting is discarded but stresses associated with cuttings, when placed in situ, are transferred around wellbore wall. These are called tangential stress or Hoop stress, which if not nullified destabilizes the wellbore. Radial stress provided by the mud weight is a means to nullify hoop stress. If radial stress is less than hoop stress, wellbore fails under compression (Compressive failure). If radial stress is more than hoop stress wellbore fails under tension (Tensile failure).

Wellbore instability may occur in any formation (sand, clay coal, shale) but instability generally implies problems associated with shales as it constitutes major part in drilling. Not only mud weight but also Mud type and design also play a major role. Mitigation of shale problems has led to development of high performance water base fluids based on rock-fluid interaction principles. Different high performance water base mud system used in ONGC viz KCl-PHPA, KCl-PHPA-Polyol, Amine-PHPA-Polyol, LTMO mud coupled with advanced drilling technology have resulted into substantial improvement in shale stabilization. But it still fails to reduce non productive time to barest minimum. Stuck up of drill string, logging tools

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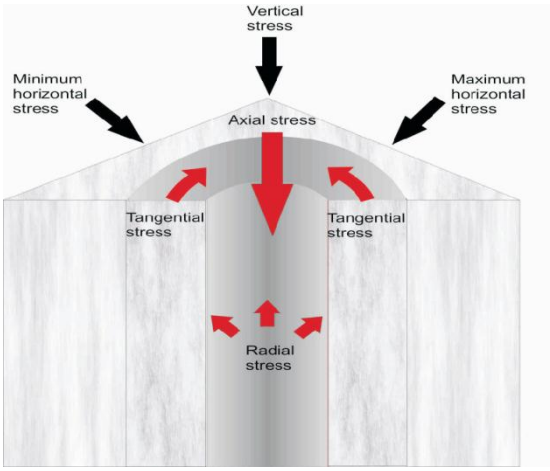



and mud loss constitute major borehole problems. More than 50% of total complications are due to the said problems during 2010-11 in ONGC assets and basins. Cumulative rig days lost on this count constitutes 57.71% of total rig days lost in complication. What are the reasons behind this is a major issue of concern for Drilling as well as Mud Engineers.

### The Missing Link

For the last so many years selection of mud weight was based on Formation pressure (Pore pressure) given In GTO. It escaped the notice that pore pressure is actually meant to control influx of fluid (water/oil/gas) into the well. It is meant for drilling a safe well avoiding kick/blow out. It has nothing to do with wellbore stability. So the selection criteria of mud weight has changed. It now becomes imperative to understand it.

### Mud weight Selection

Selection of mud weight for pressure control requires knowledge of not only pore pressure gradient and Fracture gradient but also of Collapse gradient of formation, 'The missing link'. Satisfying collapse needs of formation gives a **stable well**

### Pore Pressure Gradient

It is the density of pore fluid per foot of depth and is expressed as equivalent mud weight, ppg or psi/ ft. It is determined from density logs, or from VSP data. Mud weight is increased to confine pore pressure and therefore kick and subsequent blow out.
Mud weight > Pore pressure gradient = Controlled
Mud weight < Pore pressure gradient = Kick is taken

### Collapse Gradient

It is the collapse resistance of the borehole per foot of depth and is expressed as equivalent mud weight, ppg or psi/ ft.
Mud weight > Collapse gradient = Borehole wall supported
Mud weight < Collapse gradient = Borehole wall collapses
Borehole instability can lead to

- Borehole collapse
- Trapped tools
- Most logging operations affected
- Reduce casing support
- Blocked offholes

### Fracture Gradient

It is the fracture resistance of the borehole per foot of depth. It is determined by performing a leak off test on the borehole. Mud is slowly pumped into the open borehole and measuring the pressure increase. When the increase becomes non linear, the borehole has started to fail. This indicates fracture pressure at that point. Fracture gradient is expressed in equivalent mud weight, ppg or psi/ ft.
Mud weight < Fracture gradient = Safe borehole
Mud weight > Fracture gradient = Fractured borehole
Fractured boreholes can lead to

- Underground blowout
- Lost circulation

Collapse and Fracture gradients depend on formation rock properties, in-situ stresses, pore pressure and well bore trajectory.

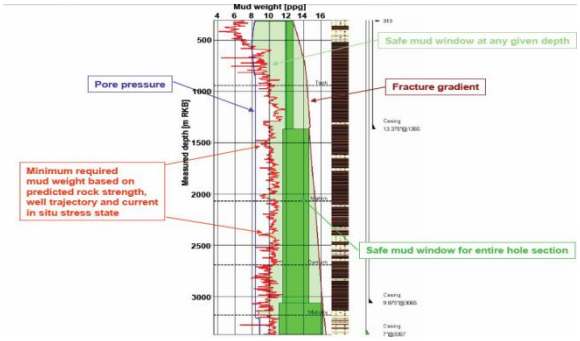
### Mud weight window

The boundary between Collapse pressure/ Pore pressure and Fracture pressure is called the mud weight window. It should be in excess of former and lesser than the latter. Collapse pressure/Pore pressure constitute low bound side of mud weight window whereas Fracture pressure constitutes upper bound side of mud weight window. There are several approaches for optimizing mud weight while drilling. One approach that attempts to optimize mud weight

such that hoop stress is zero, is the median line principle proposed by Aadnoy. This principle suggests that mud weight should be half way between the pore pressure and the fracture gradient to bring the hoop stress to zero.

There may be a temptation to keep mud weight as low as possible in order to maximize penetration rate. Unfortunately this often leads to hole enlargement and lost time due to tight hole problems. The median line approach sacrifices penetration rate early on in the well but makes for it by minimizing hole problems.

**This how the concept of Collapse pressure gradient of formation came into notice for drilling 'Safe well'. The Collapse pressure gradient is not given in GTO.**




## Case Study

Case study of Patan area of Mehsana asset was taken for bringing the point home. The field has shown past history of wellbore instability in spit of increasing level of chemical inhibition. Stability in well could be achieved by increasing the mud weight. (Table-1)

Wellbore instability can occur as a result of:

- Chemical effects,
- Mechanical effects, or
- Combination of both.

***Chemical effects*** are related to electrochemical interactions between mud and formation being drilled. The problems may result due to • Inappropriate mud type being used or • Inadequate inhibition being given to mud system.

***Mechanical effects***, In simple terms, are usually related to: Inadequate mud weight *(too high or too low and* Inappropriate drilling practices (*rate of penetration, vibration effects, torque and drag, poor practices, and frequency of trips*).

## Chemical Effects; Mud Design Perspective

Based on CST and Dispersibility studies, following fluids were found to be best suitable for providing optimal inhibition and mitigating shale problems in respect of 'Chemical effect perspective' for the shales of the Patan area of Mehsana asset.

- KCl-K-Lignite-Sulphonated Asphalt fluid
- KCl-PHPA-Polyol fluid
- Amine(Choline Chloride)-PHPA fluid

## Mechanical Effects; Mud Weight Perspective

As per GTO, mud weight need was 1.26 but well was drilled with a weight of 1.68. In case of #WPAA it was 1.57-1.76 against 1.20-1.26 as per GTO. Same pattern was observed in #WPAB.

Why is it so? Mud system tackles the hydration stresses generated due to swelling of shales. If inhibition level is not proper mud weight has to be increased for stability and vice versa. In #KAAF, shale section was opened with MW~1.25 with KCl~12%. But lot of problems were faced. Mud weight was raised to 1.50 with no substantial improvement. Ultimately well could be drilled with a mud weight of 1.68 coupled with dose of KCl~15% and Polyol~5%.

It can be inferred that system inhibition takes care of hydrational stresses and mud weight takes care of in situ stresses of rock. Merely using advanced mud system will not drill the well with reduced mud weight. Point is to emphasise that never ever one can lower the mud weight below Collapse gradient even if most inhibited oil base mud system is used. Pore pressure given in GTO was sufficient to check influx of fluid (safe well). But increased mud weight in case study was needed to check the collapse of formation (stable well).

## Determination of Collapse pressure

The concept of Collapse gradient was floated in different assets and basins of ONGC to solicit views on it. With the

help of case study, they were convinced with the concept of Collapse gradient of the formation for stable well.
A collaborative study has been taken up with CEWELL, one of the Institute of ONGC and IDT to determine Collapse pressure from logs (DSI). Approach was finalized to validate the modeling from software available in ONGC by determining collapse pressure and mud weight window from DSI logs and then matching it with case history of the selected well. The study is under final stages of completion.

## Conclusions

Data on collapse gradient of formation is needed for drilling stable well

Collapse pressure along with Pore pressure may be considered for selecting lower bound mud weight and must be displayed in GTO.

Collapse pressure can be determined from DSI logs.

A collaborative study with CEWELL, Baroda is under final stages of completion.

This is for the first time in ONGC that data on Collapse pressure will be generated utilizing existing facility in ONGC which will definitely give idea for having stable as well as safe well and help in cutting down undesirable NPT.

## References

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Estimation of Near-Wellbore Alteration and Formation Stress Parameters From Borehole Sonic Data, SPE Paper no 95841-PA by Bikash Sinha et al; 2008

Physicochemical stabilization of shale, SPE paper no 37263 by Eric van Oort.

Table-I Wells of Mehsana asset

| Sl No | Well | MW as per GTO | MW actual |
|---|---|---|---|
| 1 | KAAF (Exp) TD: 2600 m | 1.26 | 1.68 |
| 2 | WPAA (Exp) TD:2400 m | 1.20-1.26 | 1.57-1.76 |
| 3 | WPAB (Exp) TD:2600 m | 1.26-1.28 | 1.58-1.75 |