ID-P304

Delivering Optimal Mud weight Window for Safe and Efficient Drilling Through Wire-line Data

R.N.Chakravorty, Gopala Rao and Ravinder Kumar

HLS ASIA LIMITED, C – 2, Sector – 57, Noida – 201 301 (U.P), India

Presenting author, E- mail: rk.bhardwaj@hlsasia.com

Abstract

Borehole failures are an increasing concern in oil / gas drilling business. This is partly because of new drilling capabilities e.g. horizontal and multilateral wells, which has become a routine now, and partly due to unique geological environments and array of difficult reservoirs, e.g. unconsolidated or poorly consolidated sediments, shales of different kinds, complex reservoir geometries, naturally fractured reservoirs, over pressured zone, and high temperature regimes. The goal of this paper is to demonstrate an easy procedure for evaluating optimal mud weight window, which is vital for successful and near gauge drilling through stability studies employing wire-line data. The study was done in wells of Cambay basin by noticing changes in formation strengths when mud weight is successively increased, from a lower end i.e. when the stress becomes too compressive, to higher mud weight end i.e. when the well bore becomes too tensile. Stability studies, in addition, delivers sand prediction assessment, and pin point zones having early fracture tendencies as the mud weight is increased. The study is advantages in framing good strategy in field development, so that— formation, borehole and surface equipment can be saved from damages, and reduces number of wells lost due to sand and early water production.

Introduction

Borehole stability technology is an effective method of finding desired mud weight. Experience has shown that by getting drilling fluid weight right first, gives greater flexibility to optimize the mud system to meet all objectives at least cost. Stability technology though strictly desires composite impact on formation resulting due to variety of reasons, operating on Earth, e.g. mechanical, porous, chemical and thermal. But on practical consideration, mechanical phenomenon is given the maximum credence. This is because mechanical phenomenon appears most dominant, relatively easy to estimate, and to an extent well understood.

The constitutive behavior of sound propagation and its relation to mechanical properties of the formation has opened up wire-line logs utilities to work out effects on mechanical properties, over a range of stresses that would operate at different mud weights.

Mechanical properties of the formations are derived from longitudinal and shear slowness, in conjunction with formation density values. These are wire-line derived parameters. These elastic properties (often referred as Geo-mechanical properties) are empirically proportional to absolute values, when measured on core / cutting in the laboratory, and/or in the field employing engineering measurements.

Formation Stress Direction

Knowledge of stress direction is an important input to Drillers. A borehole drilled in the direction of least principal stress, will generate fracture perpendicular to the direction of well bore. And wells drilled in the direction of maximum principal stress, fractures will be encountered in the direction of the well bore.

A borehole, by and large, assumes a cylindrical shape in which the two horizontal stresses acts like tangential stress around the borehole, and radial stress acting at the borehole wall. The irregular borehole shape could be due to breakout, dilation and washout, creeping, fracturing and caving. These are illustrated in figure – 1.

Borehole breakout Analysis

Mathematical computation has shown that the highest stress concentration is created in the direction of minimum horizontal stress. The borehole wall that intersects the minimum stress will be the first to break out and cave in. Hence the detection of breakout becomes important, which allows fixing stress orientation without any calculation. XRMI (Extended Range Micro Imaging Tool) have been found very effective in identifying break-out and fractures. The break out and fracture orientation is depicted in XRMI** response in figure – 2 through 5.

Sanding and fracturing

Stability studies besides optimum mud weight provide inferences on sanding and fracturing tendencies at different mud weights. Mohr Circle criterion is one of the most effective methods to work out sanding and fracturing yield of the formation. It requires two inputs, one, initial shear strength, to be plotted in the Y axis, and two, effective radial and tangential stress values to be plotted in the X axis. Y axis represents shear strength, and X axis represents compression in the positive side, and tension in the negative side. Using this criteria sanding and the fracturing tendencies at different mud weights have been worked out in the under mentioned case studies. Mohr circle and various failures are displayed in figure – 6.

Case Study

To determine the optimal mud weight value, to prevent the well from sanding, fracturing, borehole collapse and blowout conditions, in a stack of heterogeneous formation, the borehole stability analysis was performed through modeling using different mud weight values, in wells located in Tarapur block of Cambay basin using a lower end mud weight value of 10.5 lbs/gal, and towards the higher end, the mud weight value is stretched to 20 lbs/gal and 22 lbs/gal, till the fractures are initiated.

Observation

At the lower mud weight end of 10.5 lbs/gal, sanding becomes prominent everywhere, as indicated by yellow colour in figure – 7 (third track), and fracturing tendency is absent. The mud weight line, in this case, is outside the stability zone (indicated by green colour, which is enveloped by minimum shear pressure value PCMINO, and maximum shear pressure value PCMAXO) and is positioned pretty close to pore pressure line. This is a case of unstable borehole condition, and the borehole is expected to collapse.

The stability model with mud weight of 20 lbs/gal displays total absence of sanding tendency, and placement of mud weight line towards the higher end of the stability area, close to PCMAXO, especially in the shallower portion. A close examination reveals slight fracturing tendency at around XX90m, wherein mud weight value exceeds maximum shear pressure value represented by PCMAXO. This is displayed in figure – 8 in red colour. A further increase of mud weight value to 22 lbs/gal shows a substantial increase in fracture height to 150m. This is displayed against interval XX70 to XX20m in figure – 9. This is an indication of leak of pressure value.

The appropriate mud weight for drilling therefore should be around 11 lbs/gal, and for initiating fractures, mud weight value should be raised to 20 lbs/gal. Mud weight window, is therefore 11 lbs/gal > mud weight < 20lbs/gal. The well was successfully drilled using mud weight value of 11.75 lbs/gal.

Conclusions

XRMI response has clearly depicted break-out zones, which is oriented in E-W direction, representing minimum horizontal stress direction. Fractures are also displayed in the imagery, dipping in southerly direction, which is the direction of maximum horizontal stress. Displayed breakout and fractures are at right angles to each other, as is expected.

At 10.5 lbs/gal mud weight value, the model shows unstable borehole condition, wherein lot of sanding is indicated, and mud weight line is placed outside the stability region. The minimum mud weight value therefore has to be around 11 lbs/gal. The well was successfully drilled using 11.75 lbs/gal mud weight, which validates the conclusion drawn from stability model.

At 22 lbs/gal mud weight value, the model shows a major fracture tendency in the shallower section. The fracture height in this case is around 150m, and is confined against interval XX70 to XX20 indicated by red colour. The first initiation of fracture, however, is displayed at XX90m, when a mud weight of 20 lbs/gal is used in the stability model. The fracturing tendency in this case is confined to a small interval only. The highest end of mud weight value to initiate leak of is therefore 20 lbs/gal.

Acknowledgement

We thank the management of GSPC for the permission to write this paper, and make extensive use of their data. We also thank management of HLS Asia for the NCC facilities to undertake this experiment and draw the conclusions.

References

1. Serge, A. and Axel Kaselow, 2005, Porosity and elastic anisotropy of rocks under tectonic stress and pore pressure changes. Geophysics, Volume 70, Issue 5, pp. N27-N38.

2. Zhao Jian-tao, Cui Xiao-feng and Xie Fu-ren, 2002, Preliminary analysis on the tectonic stress level in the source region of Tangshan earthquake.

3. Lin Tang and Pinya Luo, 1998, The effect of thermal stress on wellbore stability. SPE 39505.

4. Begelow, E.L.,1995, Practical Analysis of Formation Strength Properties in both Consolidated and Unconsolidated Reservoirs., SPWLA, 36 Annual Logging Symposium.

5. Esmersoy, C., Kane, M., Boyd, A., Denoo, S., 1995, Fracture and Stress Evaluation Using Dipole-Shear Anisotropy Logs., SPWLA, 36 Annual Logging Symposium.

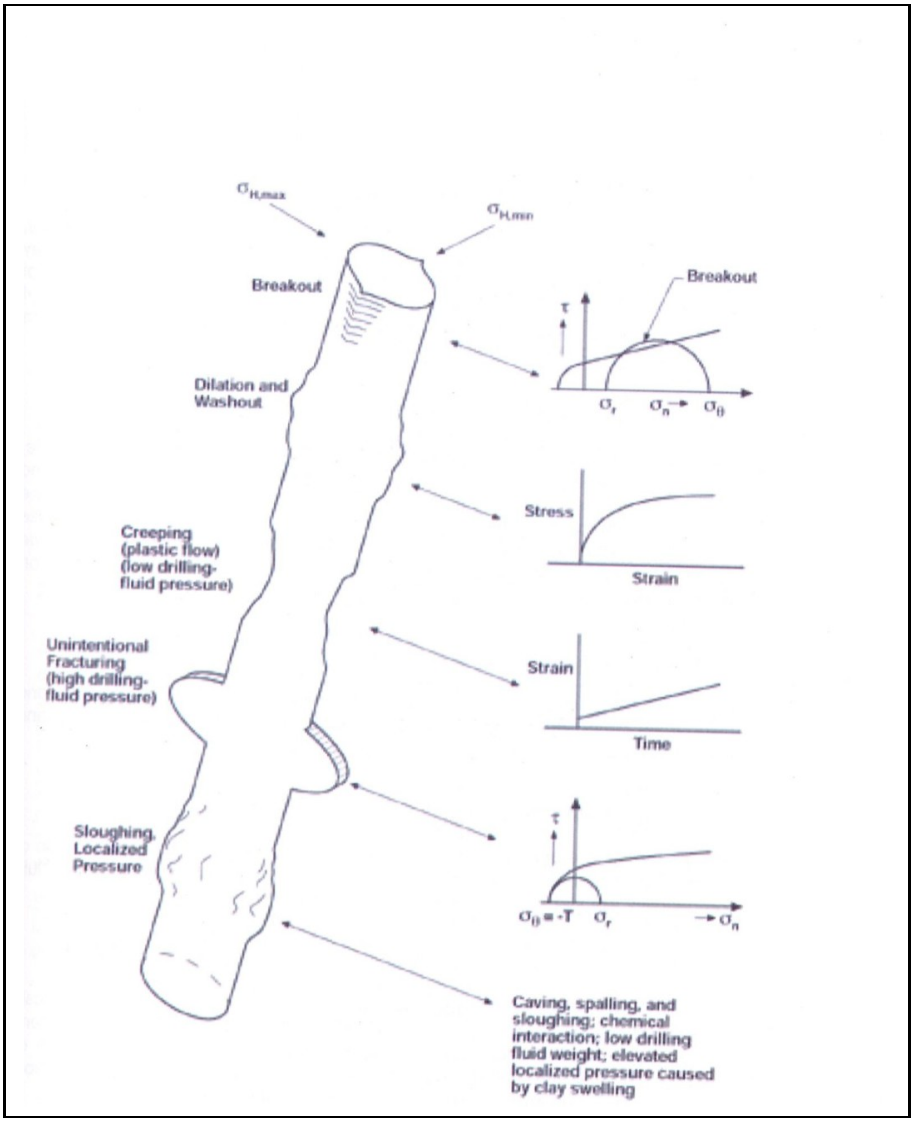

Figure- 1 Possible wellbore instability problem during drilling.

Figure-2 Break out represented by conductive anomalies in opposite pads confined in East-West direction

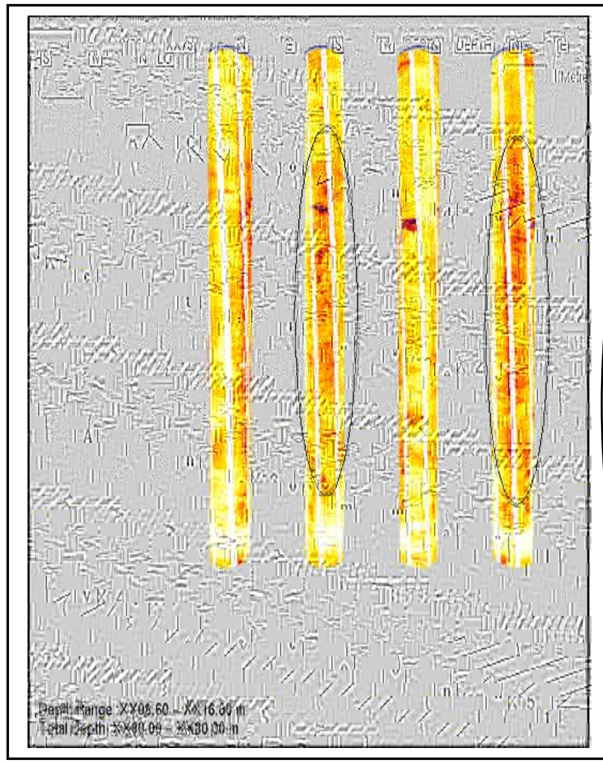

Figure-3 Break out in 3D view

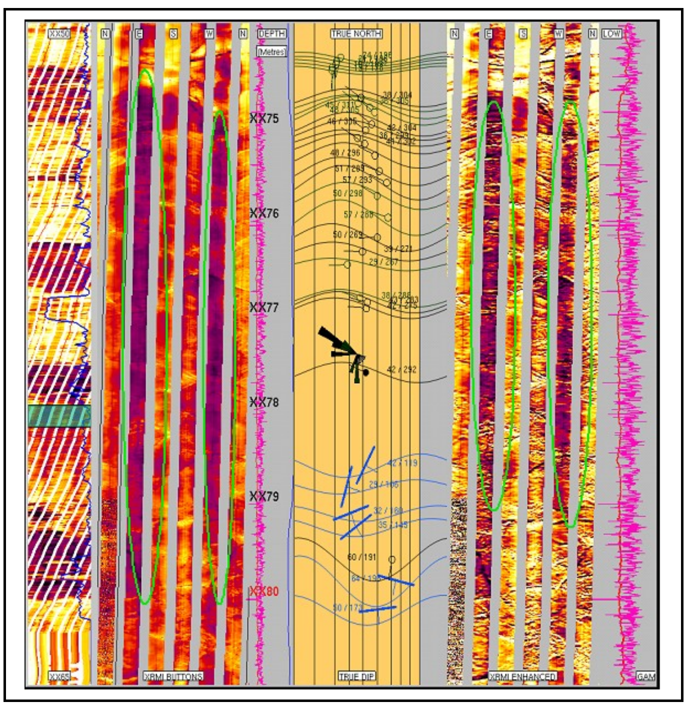

Figure- 4 Break out shows in pad East-West Direction.

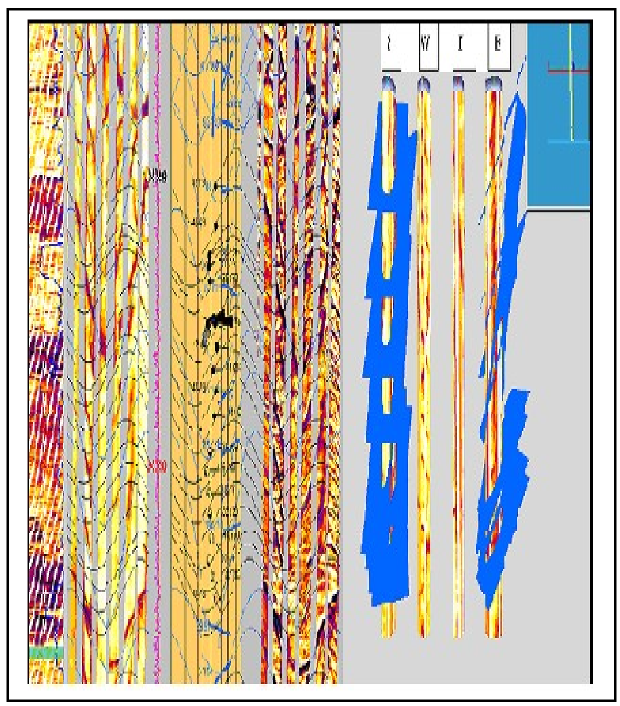

Figure- 5 Fracture plane oriented in South direction. Fault plane represented by blue colour in 3-D view.

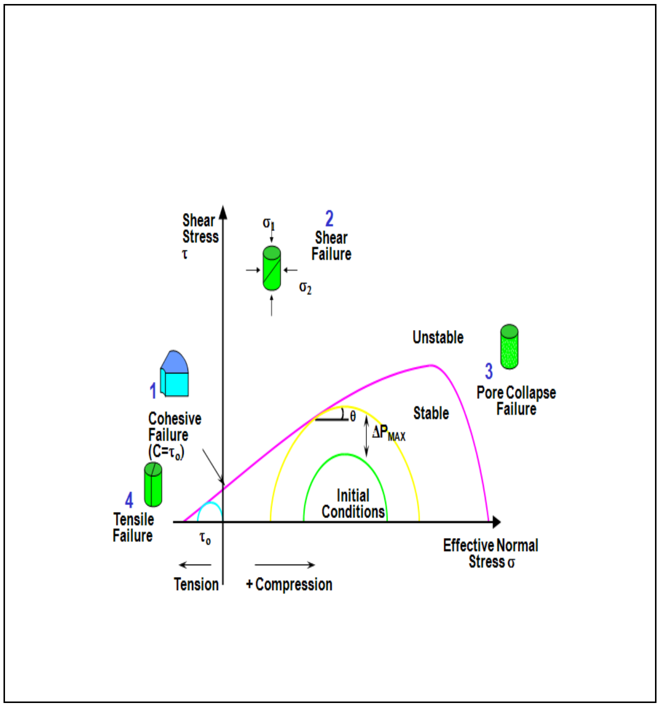

Figure- 6 Mohr circle and various failures.

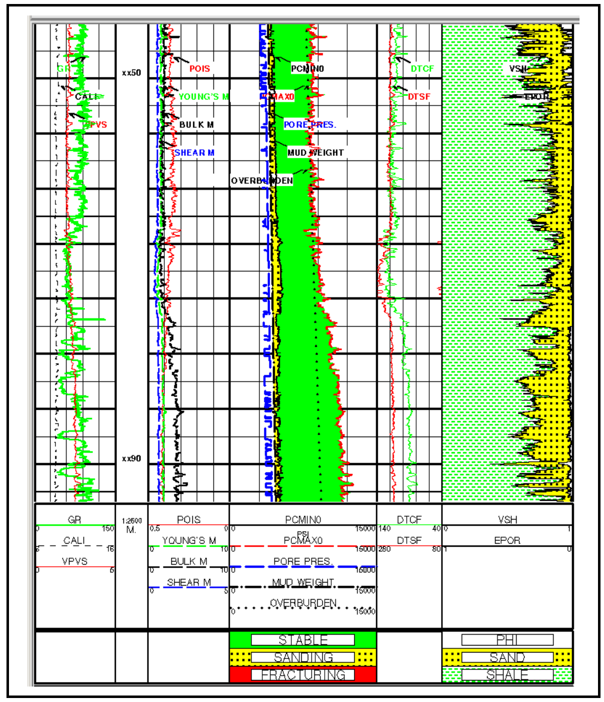

Figure- 7

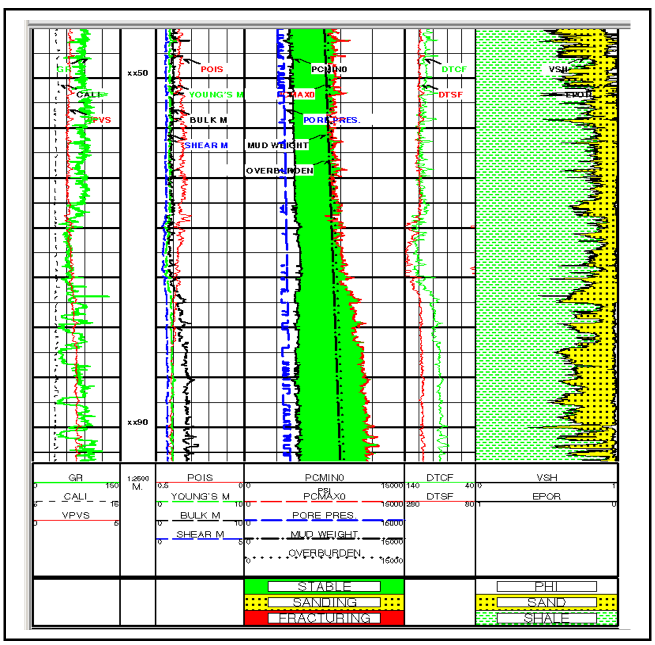

Figure- 8

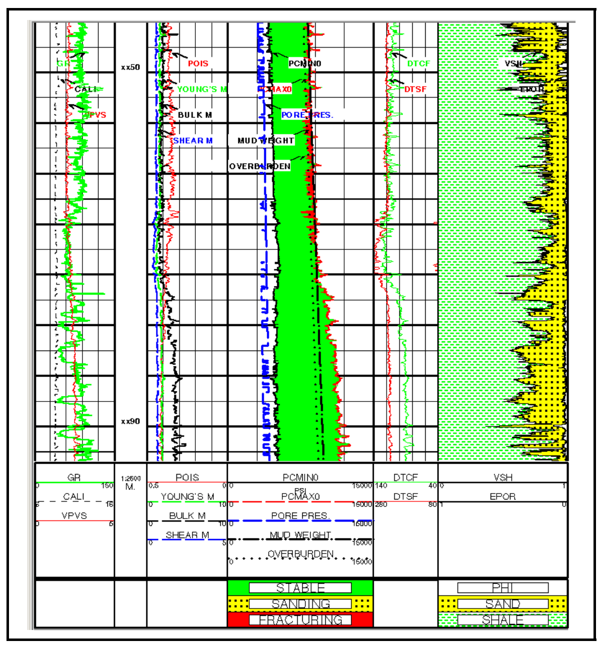

Figure- 9