HOW TO SUPPORT THE BOREHOLE INSTABILITY PROBLEMS AND OPTIMIZE THE DRILLING WELL IN REAL TIME

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Résumé - In petroleum industry, drilling exploration wells is still technically and economically challenging. The cost of well construction can exceed budget dramatically if drilling operations are plagued by wellbore-instability problems, excessive time and resources are needed to free stuck pipe, regain circulation, or clean the hole efficiently. In line with this statement, carbonate in Algeria revealed substantial difficulties when drilling. In addition to the consequent nonproductive time, wellbore quality and reservoir damages were the consequences of drilling these formations. Minimizing non-productive time is a complex task that requires thorough pre-spud planning to identify drilling risks and geological hazards and to develop contingency plans for handling those risks. To gain this knowledge and to implement it successfully requires a process for building a Mechanical Earth Model (MEM) and using it to provide timely information to decision makers. Based on the wellbore stability analysis, the mud weight for safe drilling can be planned founded on the mechanically stable mud weight window (from breakout/kick pressures to loss/breakdown pressures). Other essential concept for a wellbore stability study is a drill map which can guide drillers to drill a well quickly by using real time data, cost effectively by providing essential information such as mud weight window, drilling risks ahead as well as their identifications, detections, preventions and remedies.

Mots-clefs : borehole instability, losses, ovalization, geomechanics, S-E Constantine basin.

INTRODUCTION

Despite decades of industry attention, wellbore instability is responsible for many costly stuck pipe incidents. Stuck pipe is responsible for lost BHAs and considerable NPT spent freeing pipe, performing additional wiper trips and hole cleaning. In cases where wellbore stability problems are severe, the economics of developing a field can become challenging, for example the Oman and Abu Dhabi fields. In line with this statement, carbonate in North-Algeria revealed substantial difficulties when drilling, linked in general to wellbore instability. In addition to the consequent nonproductive time, wellbore quality and reservoir damages were the consequences of the drilling in these formations which affected primarily the reservoir characterization of the studied area.

Minimizing non-productive time associated with wellbore instability and unexpected pore pressure regimes reduces the risk of time and within budget. Minimizing non-productive time is a complex task that requires thorough pre-spud planning to identify drilling risks and geological hazards and to develop contingency plans for handling those risks.

These difficulties are accentuated by the lack of comprehension of the mechanical behavior of the drilled rocks. In order to address this deficiency, a geomechanical study of the field formations became obvious. This paper is devoted to highlight the using geomechanical modeling to understand the mechanical behavior of the crossed formations.

TEORY, DEFINITIONS AND MOTIVATION

Despite considerable effort from the drilling, subsurface and geomechanics communities, many oil wells continue to suffer from wellbore instability problems during drilling. Although instability is quite common, in the majority of cases a considerable amount of uncertainty exists around exactly where, when and why the instability occurred.

Unfortunately, it is almost axiomatic that logs will not be run in an unstable wellbore. Direct measurements of the borehole shape and condition which can be obtained from caliper and image logs are therefore rarely acquired in the wellbores where (from a geomechanics point of view) they would be most valuable. Modeling and cavings analysis alone can leave considerable uncertainty as to the location and to some extent the mechanism of failure. An exception to the axiom can be where LWD image data is acquired. It is still unlikely that LWD imaging tools would be run in a well where significant instability was expected. Understanding the geomechanics of well construction is becoming increasing important in order to drill technically and economically challenging wells on budget.

MECHANISMS OF WELLBORE INSTABILITY

Mechanism of mechanical wellbore instability can be grouped in two main classes :

1. Instability due to failure of intact rock (rock which is unbroken and isotropic in strength)
2. Instability due to failure of rock containing pre-existence planes of weakness (bedding planes, fractures, cleavage). Rock containing pre-existing weaknesses such as bedding or cleavage may be intact in the sense that it is unbroken.

Other mechanisms of instability where pre-existing weaknesses are present do not necessarily stabilize with time or with increased mud weight. Instability due to such mechanisms is therefore rarely calipered or imaged, making the exact location and mechanism of instability uncertain.

Consideration of wellbore instability due to pre-existing weaknesses in oil wells is for the most part relatively recent. Evidence of these mechanisms came from observations such as correlations of trouble time with wellbore trajectory and the existence of pre-existing fracture planes, bedding planes and cleavage in cavings.

Types of wellbore instability associated with pre-existing weaknesses can be grouped into two classes.

(A) Failure due to the existence of "impermeable" pre-existing weaknesses.

In the case where the pre-existing weakness are not preferentially permeable, increase in mud weight will tend to

further support the wellbore wall. An example of this type might be where a single set of bedding planes is intersected.

(B) Failure due to the existence of "preferentially permeable" planes of pre-existing weaknesses. Where the mud and filtrate preferentially enters pre-existing planes of weakness, increasing the mud weight does not add support to the wellbore wall and may increase instability.

Many Wellbore in the North of Algeria were abandoned, due to the instability problem encountered.

WHY BUILD AN EARTH MODEL

The Mechanical Earth Model is a numerical representation of the state of stress and rock mechanical properties for a specific stratigraphic section in a field or basin. The model is linked to geologic structure through the local stratigraphy and a 3D seismic cube.

Throughout the 1980s the practical theory of wellbore stability advanced slowly in step with the development of faster computers and better logging tools, such as sonic and imaging logs. At the same time geologists and engineers were gaining experience applying wellbore stability modeling techniques of various levels of complexity. The severity of the wellbore instability problems demonstrated that conventional approaches to solving wellbore stability problems simply did not work. It took a multi-company team of geoscientists and engineers almost one year to compile enough geomechanics information about the field to affect an improvement in the drilling performance. During the time when the model was being compiled wellbore stability was a continuing problem. This experience motivated the development of the mechanical earth model. Fortunately few fields in the world today have suffered wellbore stability problems as severe as those in the North of Algeria.

CONSTRUCTING THE MEM

Constructing the Mechanical Earth Model and using it to generate a wellbore stability forecast helps to reduce drilling risks.

1. The first step in the process is to build a mechanical earth model. The MEM represents all geological and rock mechanics information that currently exists in the field.
2. The second step uses information from the MEM to forecast wellbore stability along the planned well path. The stability forecast summarizes the expected drilling performance as a function of measured depth in the well.
3. The third step is to monitor the data while drilling and to test the model predictions for anomalies. Anomalies in the forecast indicate flaws in the data and or the MEM.
4. The anomalies are analyzed to determine the source(s) of error. If immediate action

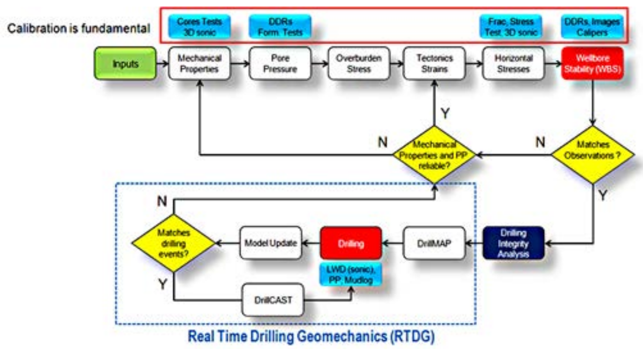
is required on the rig, it can be based on informed decisions.

5. The fifth step is to correct the MEM. Correcting the MEM may be done before remedial action is taken or it may be done off-line if the geology or stress changes drastically.

This process systematically captures potentially valuable information about the field earlier than would otherwise be possible. The wellbore stability forecast is revised, as required by revisions to the model, and the loop continues.

Implementing this process requires team work, excellent communications among staff on the planning team, at the rig site and between the rig site and the planning team. The benefits of implementing this process are fewer unexpected drilling events and accelerated learning about the field on real time.

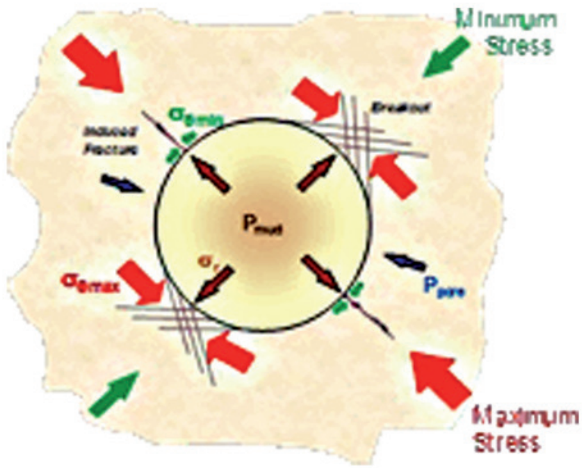
A simplified workflow of MEM construction is as follows.



WELLBORE STABILITY ANALYSIS

Principal stresses are redistributed around the wellbore to give a tangential or hoop stress while the pressure generated by the mud density is radial. A large stress imbalance induces a concentration of stress at 90° from the azimuth of the maximum stress. If the radial stress generated by the mud density is too low to counteract the maximum hoop stress the rock fails along shear planes leading to the appearance of breakouts and production of caving. The fall of cavings into the borehole increases greatly the risk of stuck pipe by off-packing.

On the contrary, induced fractures are tensile failure caused by a high radial stress generated by a high mud density. Large stress imbalances can also promote tensile failure at the same time of generating breakouts. The redistribution of the principal stresses around a wellbore and associated failures is as follows :



The wellbore stability analysis is based on a simulation of failures occurring at the wellbore. It is coupled with an analysis of drilling events, calliper logs and borehole images to determine the type of failure that occurred at wellbore during drilling. The stress magnitudes are then determined in the MEM in order to get the most reliable reproduction of failures observed.

CASE STUDY WELL ASU-1

The different sections of the well ASU-1 are ovalized along the marly intervals, mainly in the Turonian and Cenomanian where severe well damage is noticed. As noticed for the previous wells, total losses in shallow carbonates are present also in ASU-1, in the Maestrichian precisely. These losses have been reported even if the used mud weight density is 1.05 sg. This raises the question regarding the effect of karstification on mud losses.

Regarding rock failure, the model seems matching calliper data and drilling events like caving, back-reaming. ASU-1, have drilled with a mud density varying from 1.05 to 1.25 sg. Mud density in all the formations crossed by ASU-1 was low to prevent rock failure. Indeed, mud density should have been increased (~ 1.35 sg.) mainly in the sections 12.25 and 8.5in, in order to stabilize the wellbore by balancing the in-situ stresses. However a special care should be considered in karstified carbonates where the risk of mud losses is high.

Because the data in ASU-1 is limited at the depth 1927m-MD, the model couldn't reach the lower zone of Cenomanian where tool sticking, back-reaming and total losses have been reported while drilling. According to the other wells in the area, mud weight window in the zone of lower Cenomanian should be very narrow and should be drilled with a high attention.

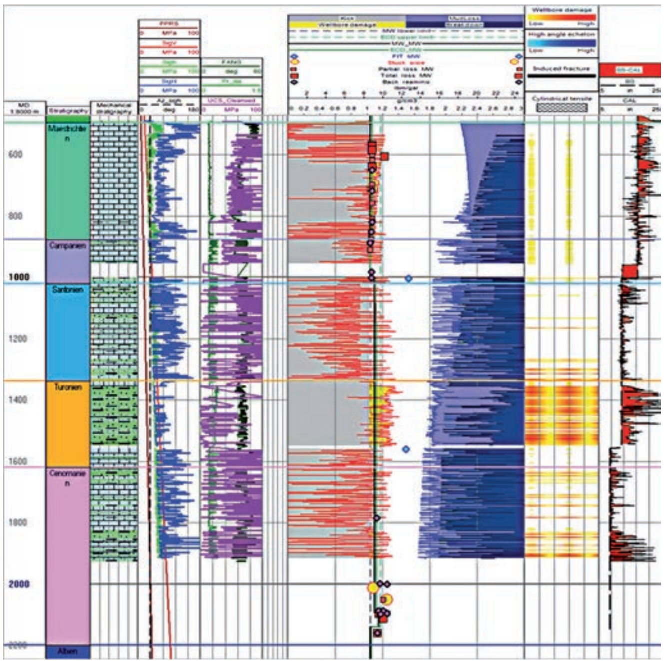


Figure 2 1D MEM and wellbore stability analysis of well A :

Track 1 : measured depth (m-MD);

Track 2 : Formation tops;

Track 3 : Mechanical stratigraphy: marls (green) and carbonates (blue);

Track 4 : Sigh and SigH: Minimum and maximum horizontal stresses (MPa); SigV: Overburden stress (MPa), PPRS: Formation pressure (MPa);

Track 5 : PR_sta: Poisson's ratio, UCS: Unconfined compressive strength (kPa), FANG: friction angle (deg),

Track 6 : Mud weight window, where the shear failure gradient (breakout) in red, the kick limit in grey the minimum mud loss gradient in blue, and the tensile failure gradient (formation breakdown pressure) in dark blue. The green line represents ECD and black line the mud weight used while drilling (g/cm^3). Drilling events are added in this track.

Track 7 : Computed (synthetic) image of rock failure (breakout);

Track 8 : CAL: Measured calliper (in) and bit size (BS)

CONCLUSION & RECOMMANDATIONS

The main conclusions according the using the MEM are :

a. The mechanical earth model concept has been defined.

b. Mechanical earth models can be built and refined while drilling exploration wells.

c. Mechanical earth models are valuable for reducing nonproductive time on high-risk drilling projects. When state of the art communication and data management techniques are implemented, information from the MEM can be delivered on short notice to support real-time decisions on the rig.

d. Mechanical earth models have greatest value to well construction and field development when they are integrated into a "plan-execute-evaluate and revise" process.

e. Geomechanics information developed early in the phases of field development is valuable for optimizing reservoir development for the life of the field.

The present study confirms the singularity of the studied carbonates compared to those studied, in the world and highlight the importance of laboratory tests before any study at well or field scale.

This approagh might be used for the exploration zones challenges (North and South of Algeria).

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