SUBSURFACE ALLIANCE

DATA DRIVEN | SCIENCE BASED | FIT-FOR-PURPOSE

Make sure to check the boxes before you drill ahead:

- ☑ Mud Weight
- ☑ Fracture Gradient
- ☑ Pore Pressure
- ☑ *In situ* stress

We are multi-discipline subsurface specialists using a team-of-teams approach to efficiently solve problems that have a direct business impact in today's fast-paced and evolving energy industry.

We provide high quality subsurface solutions by bridging the gap between geoscience and engineering.

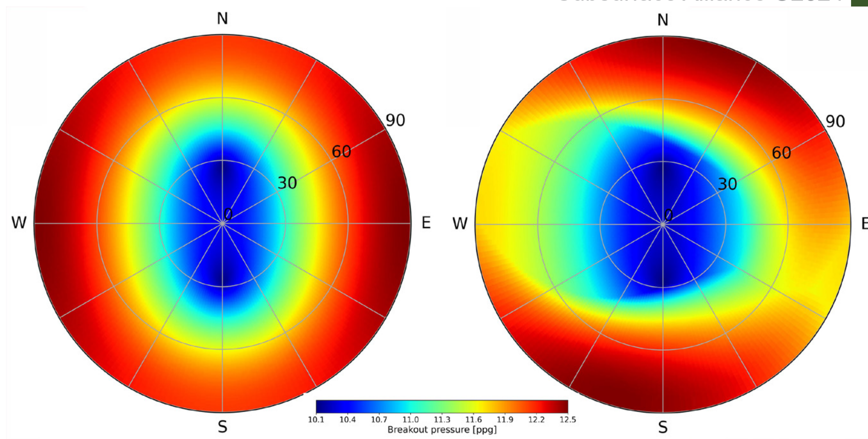
Drilling often comes with unexpected operational challenges such as kicks, losses, tight spots, or stuck pipe events that have a detrimental effect on safety and efficiency. Many of these hurdles can be addressed during well planning by taking geomechanics into consideration. We help you understand the in situ stress and mechanical properties of your reservoir and overburden rocks to mitigate geomechanical risks, minimize non-productive time (NPT) and ensure a safe drilling and completion program.

MAIN DRILLING RISKS

Well kicks are mainly the result of inaccurate abnormal pore pressure prediction and insufficient mud weight design to control it. Drilling a well with a mud pressure that is lower than the formation pore fluid pressure results in formation fluids to flow into the borehole, and uncontrolled kicks are a severe drilling risk that can result in a blowout.

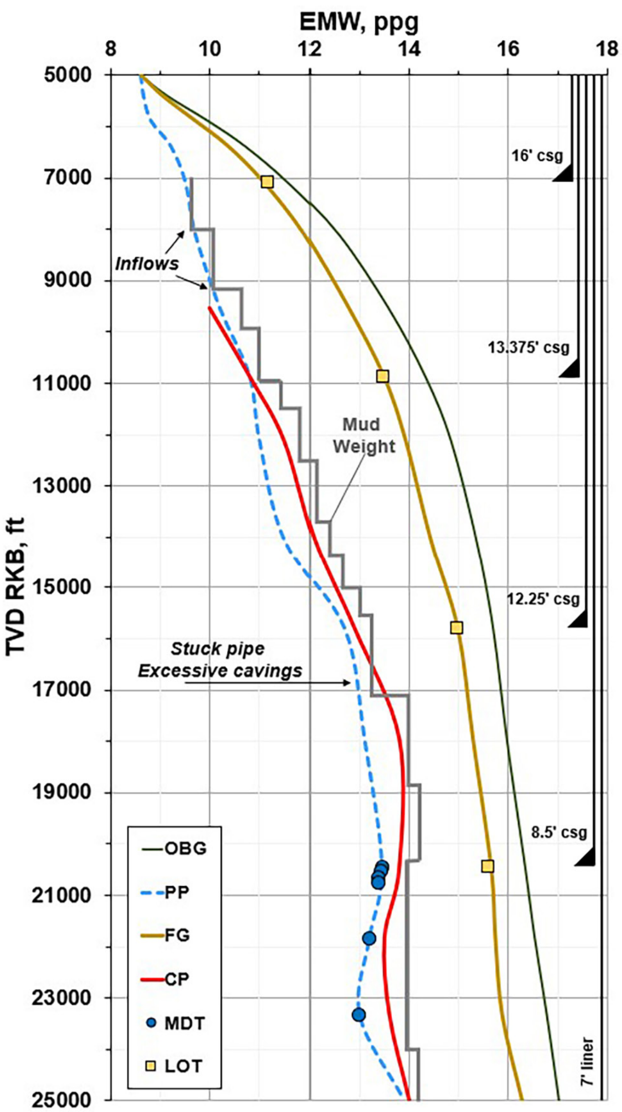
Lost circulation occurs when drilling fluids flow into the formation with no return to surface. Drilling induced lost circulation events are related to inadequate drilling practices that result from a bottom hole pressure that exceeds the fracture gradient. Excessive bottom hole pressures due to high mud weight, surge, improper hole cleaning or poor casing point selection, can lead to the development of drilling induced fractures and subsequent losses. Reactivation of faults while drilling also creates permeability pathways that can take large amounts of drilling fluid, resulting in total lost circulation. Curing losses increases NPT and well cost due to the use of costly lost circulation material.

Borehole collapse occurs when the borehole stresses exceed the compressive strength of the rock, due to insufficient mud weight, causing excessive shear failure. Most wellbore instability problems are found in shales, as they tend to be pore pressure sensitive and chemically reactive. Mechanical instability of shales is the result of low compressive strength or the presence of mechanical planes of weakness (e.g. bedding or natural fractures). Chemical instability results from an inbalanced between the mud and the formation salinities generating osmotic pressures that obliterates the overbalanced conditions. Borehole collapse is one of the major drivers of NPT and can cost millions of dollars per well.



Above, stereoplot showing required mud weights to keep a borehole stable for an isotropic (left) and anisotropic (i.e, planes of weakness, right) cases. To the right, an example of splintery cavings indicative of shear failure at the wellbore wall (from Zhang, and Yin, 2017 licecenced under CC BY 4.0).

GEOMECHANICS RISK MITIGATION



Fracture Gradient Prediction. We help you mitigate drilling induced losses by predicting changes in fracture gradient magnitude with depth and defining the maximum allowable bottom hole pressure to avoid fracturing the formation. We provide accurate predictions for scenarios of particularly low fracture gradient where there is a high risk of lost circulation. These scenarios include overpressured deepwater wells and well paths that intersect faults or depleted reservoirs.

Pore Pressure Prediction. We help you reduce the risk of well kicks and borehole collapse by constraining the pore fluid pressure profile for both the reservoir and overburden. We use drilling experience, seismic velocities and wireline data from offset wells to predict the most likely pore pressure scenario in new drill locations.

Wellbore Stability Modeling. We help you optimize your drilling program by using in situ stress and rock mechanical properties to design mud weight programs and keep the borehole stable. We support you in the most challenging wells by using our advanced tools for shale anisotropic failure and chemical instabilities. Such tools help our clients optimize wellbore trajectories to avoid wellbore failure and adjust mud chemistry to ensure wellbore stability.

Left: Key components of a wellbore stability analysis: overburden gradient (OBG), pore pressure gradiente (PP), fracture gradient (FG), collapse pressure (CP). Pore pressure measurements (MDT) and leak-off tests (LOT). Main drilling events occurred where the mud weight program was not optimized (too low).