CASE STUDY

Balancing Risks at Salt-Exit: Deepwater Gulf of Mexico

The importance of pre-drill PPFG models and realtime WBS monitoring

CHALLENGE

Provide a pre-drill pore pressure and fracture gradient (PPFG) model for deeper wells with significant salt columns present. Develop an exit strategy from the salt into the underlying permeable formations where offset wells indicate there is a high risk of losses and potential to lose a complete section.

SOLUTION

Exit salt with a low mud weight (MW), ~2 ppg below the overburden (OB). In case of severe losses, utilize a contingency string above the base of the salt. Monitor the well in real-time to ensure wellbore stability is maintained and non-productive time (NPT) is minimized.

RESULTS

Real-time monitoring was undertaken to maintain wellbore stability while drilling and there were no losses when exiting from salt into the permeable formation. However, the planned low MW caused salt creep, which resulted in tight spots, reaming and stuck pipe events in the salt. MW was increased by ~0.7 ppg based on the recommendation of the real-time analyst after careful review of the pre-drill model and offset wells. This MW increase was still below the threshold of losses in offset wells and the remainder of the hole section was drilled with no further instability. The contingency string was not necessary and the well was drilled safely, ahead of planned AFE and with no NPT due to wellbore instability in the final hole section.

Background

The study area is located in the Gulf of Mexico in ~6000-7000’ of water. Pre-drill PPFG profiles were calculated based on the offset wells analysis in the area. PPFG models were predicted for supra and sub-salt sections only, as the salt lack pore space (PP=0) and it cannot support differential stress over time due to material creep. One of the offset wells experienced severe losses at the salt exit in the underlying permeable formation, eventually resulting in a sidetrack.

Pre-Drill PPFG Methodology

A user-defined method was used to compute the composite density profiles. An empirical density relationship based on water depth and estimated sediment density was used to calculate the supra-salt density profile due to lack of log coverage for offset and planned wells. A constant density was assumed in the salt section. For the sub-salt sections in the offset wells, the density profile was composed of calibrated pseudo-density curves and actual density logs, where available. For the planned well, the sub-salt pseudo-density was calculated using depth-corrected sonic logs from offset wells. The supra-salt, salt and sub-salt density profiles were composited to create the final density profile from ML to TD and was used to calculate the OB for each well. A normal compaction trend line analysis was performed and shale PP was calculated using Eaton’s method. Effective stress (EFS) was then calculated by subtracting PP from OB at the offset well (EFS = OB – PP). EFS was translated to the proposed well location using the EFS from offset wells corrected for stratigraphy and depth. Shale PP was calculated for the proposed well by subtracting EFS from OB. Sand PP was calculated by modeling the pressure data from offset wells using different fluids and gas gradients. No centroid and buoyancy effect was observed. FG for shale was calculated using the Mathews & Kelly approach with variable Ko (effective stress ratio) derived from offset well FIT/LOT/XLOT data and calibrated with drilling data from offset wells. Sand FG was computed using a distinct Ko calibrated to mini-frac data from offset wells. A most likely Mid PP Case with upper and lower limits was predicted along with the fracture gradient for both shale and sand.

Real-Time PPFG Methodology

While drilling, real-time pore pressure was interpreted using LWD logs and pre-drill PP model trend lines. Daily pore pressure plots were prepared including drilling events and presented in rig meetings. In the supra-salt section, the PP was approximately hydrostatic, with no evidence of overpressured sands. Salt was drilled with MW equal to 80–90% of OB to overcome salt creep and the sedimentary inclusions/sutures which were prognosed in the pre-drill geohazards analysis. However, near the base of salt, the MW was decreased to ~2 ppg below the OB as per plan, to minimize the risk of losses when drilling into the underlying permeable formation. This low MW caused salt creep, which resulted in tight spots, reaming and stuck pipe events. Though there was a legitimate concern that if the mud weight was too high at the salt exit, it could result in excessive losses in the permeable formation or even possibly in a lost section, the low MW was causing instability in the study well. The real-time analyst carefully reviewed the pre-drill model and offset wells and recommended a ~0.7 ppg MW increase. This MW increase was still below the threshold of losses in offset wells but allowed the remainder of the hole section to be drilled with no further instability and without utilizing the contingency string. The well was drilled safely, ahead of planned AFE and with no NPT due to wellbore instability in the final hole section.

Operator – Value Provided

Based on the pre-drill PPFG model, information and drilling events from offset wells, the drilling team was convinced to raise the mud weight by ~0.7 ppg to overcome the wellbore stability issues that occurred in the salt due to a MW that was too low. This higher MW was still below the threshold for losses based on offset wells and the hole section was monitored and drilled safely with no losses. The real-time PP was within lower and higher limits of the pre-drill model. The careful preparation based on the pre-drill PPFG model combined with the real-time monitoring and model updates resulted in saving a full contingent casing string and reduced NPT significantly, when compared to nearby offset wells, with a total savings of approximately **$8–10 MM**. If instability had been severe enough to necessitate a sidetrack, the potential savings is increased to approximately **$10–20 MM**.

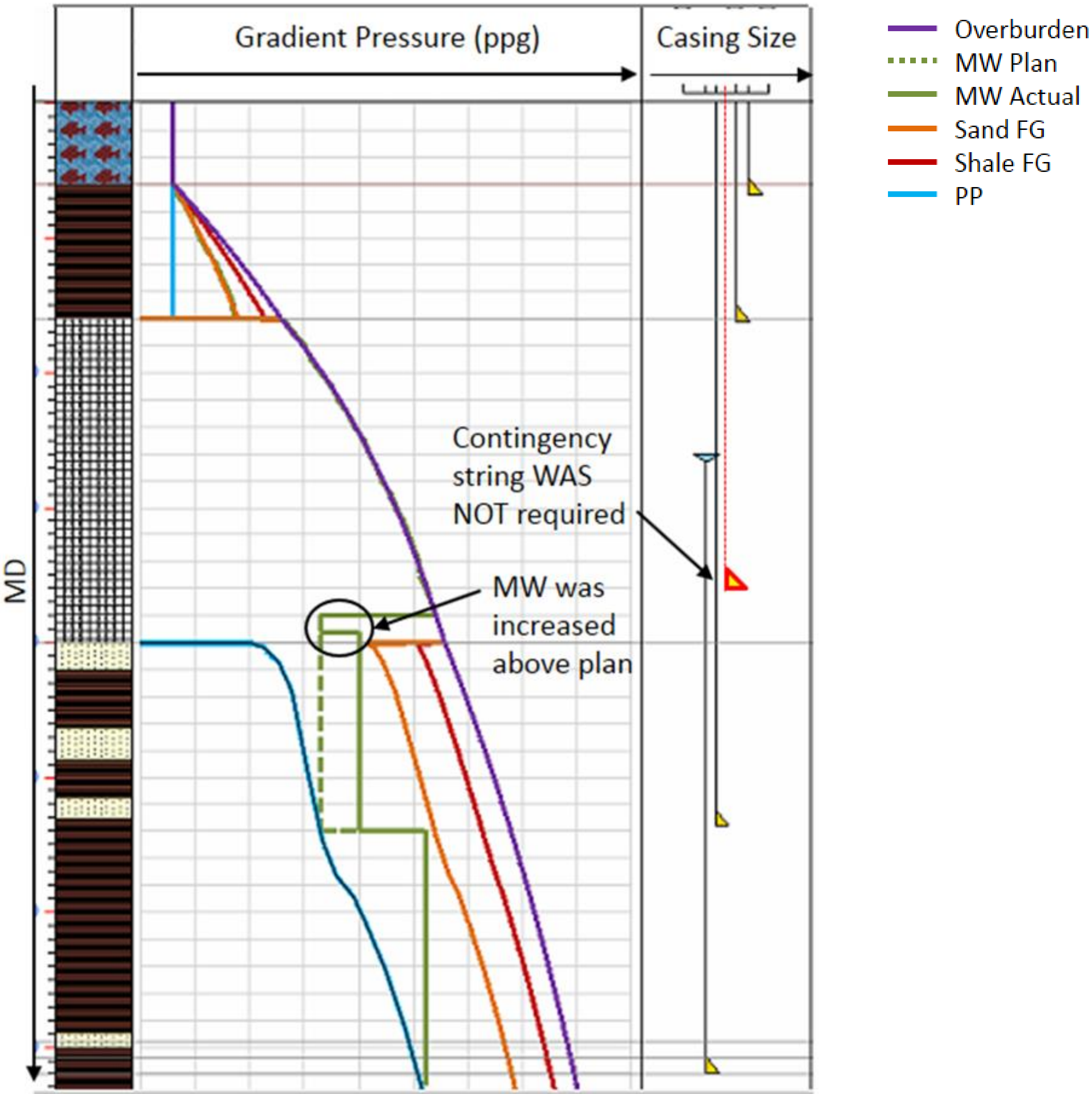

Figure 1: This plot shows the final real-time PPFG profile for a deepwater GOM well with a significant salt column and an underlying permeable formation. A low mud weight was planned to exit the salt due to the risk of severe losses, as observed in offset wells. However, the low MW caused salt creep resulting in tight spots, reaming & stuck pipe events in the salt. The real-time analyst reviewed the pre-drill model and offset wells and recommended a ~0.7 ppg MW increase. The hole section was monitored and drilled safely with no further instability.