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Revolutionising Drilling – Innovations in Fluids, Cementing, and Waste Management to Drive Well Performance and Champion Sustainability

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Minimizing Salt Creeping Through Geomechanics Application and Systematic Drilling Fluids Design In Ultra Deepwater Wells – Operator's First Experience in West Africa

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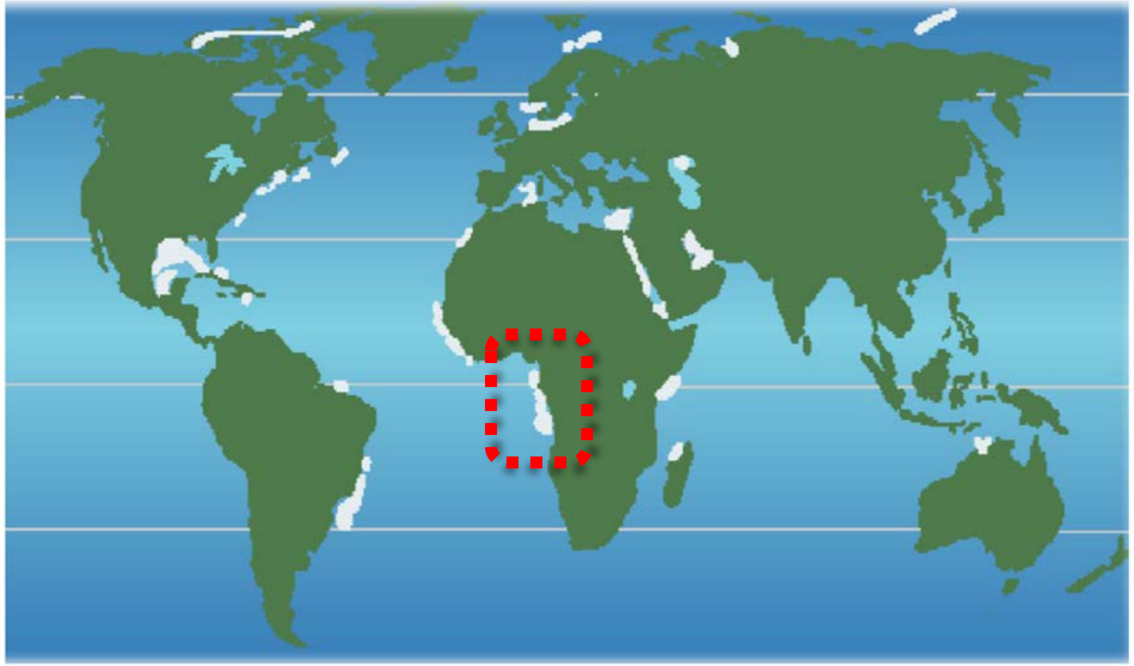
- ❑ Background & Challenges
- ❑ Well Information
- ❑ Salt Creep Modelling
- ❑ Key Properties of Drilling Fluids
- ❑ Identification of Salts
- ❑ Well Experience
- ❑ Summary & Conclusion

3 ultra deepwater wells were drilled in offshore West Africa drilling through salt formation

- ❑ Salt formation is normally an area of interest as it is a good sealing rock to cap hydrocarbon in pre-salt or sub-salt formation.
- ❑ Salt formation is unique due to its capability to flow plastically within the immediate vicinity of boreholes.
- ❑ The introduction of drilling fluid to replace the drilled borehole will require a proper analysis of density requirement to minimize salt plastic flow.
- ❑ Drilling through salt sections requires identification of the salt mineralogical composition, exposure time, stresses, drilling fluid density and temperature to minimize problems.



Salt Creeping

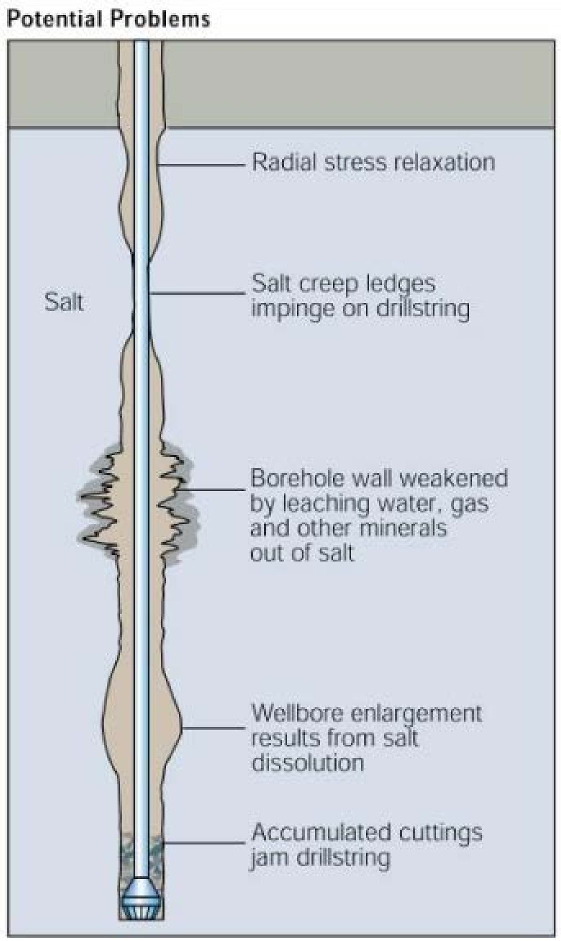
- ❑ This varies based on its content like magnesium, potassium (e.g. Carnallite and Sylvite) have the highest mobility rate while Halite (sodium chlorite) is less mobile.
- ❑ Stress difference between salt and borehole hydrostatic pressure

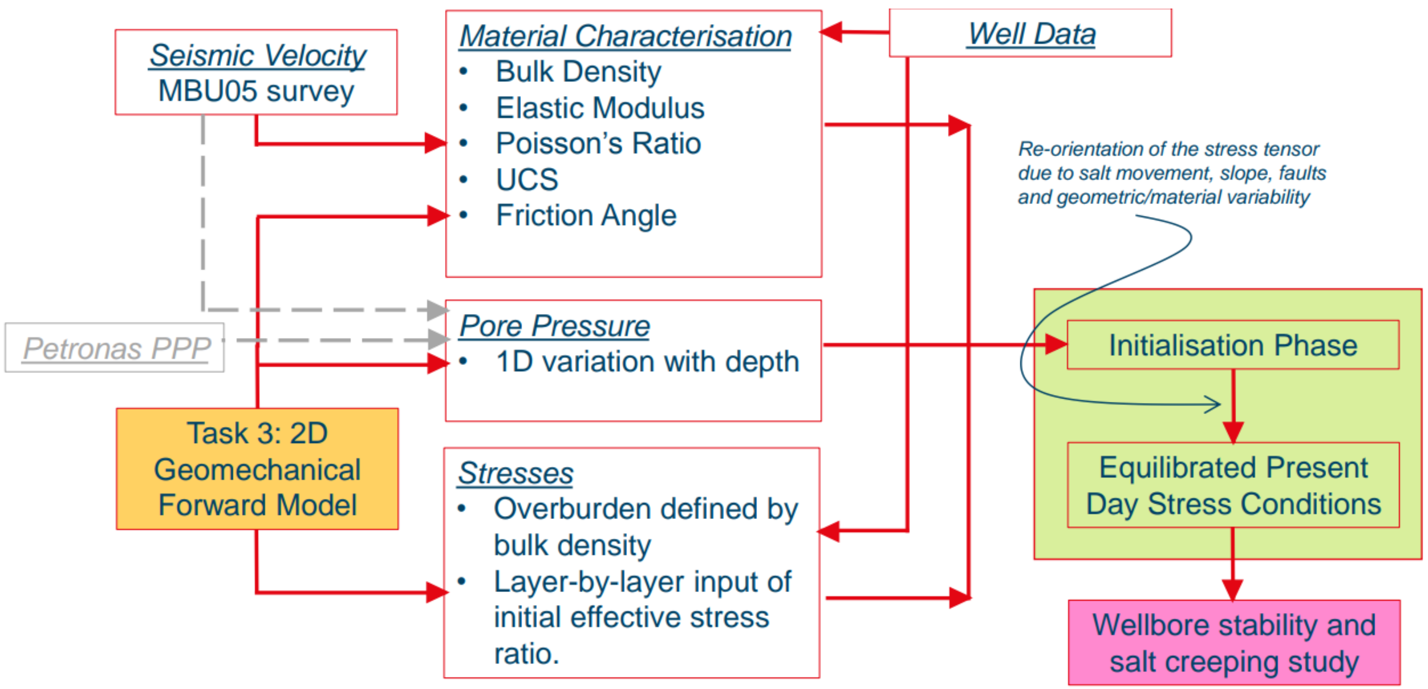
Salt Dissolution

- ❑ Salt can dissolve out of the formation and into the wellbore fluid if the drilling fluid is not designed properly.

Rubble Zone

- ❑ Possible presence of rubble zone which could lead to lost circulation.





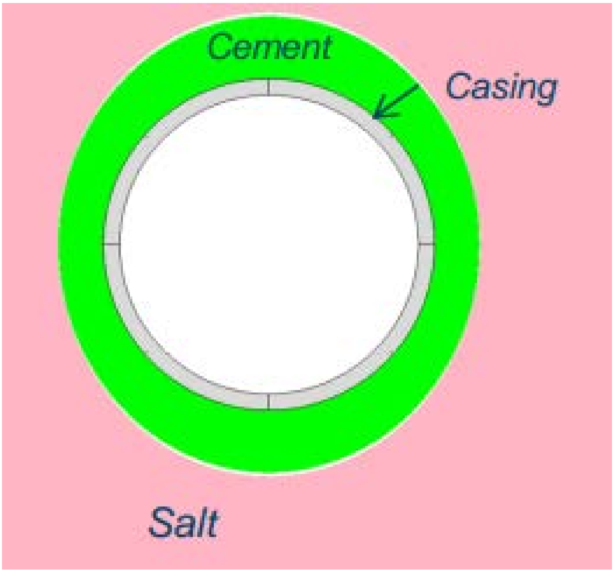
- To ascertain the current stress and pore pressure
- The higher the overburden, the higher the creep rate for a specific type of salt.
- Accurate Geomechanics study including salt creeping analysis to identify MW for critical closure
- Critical Closure : creep-driven hole radius reduction required for the salt to meet the pipe. Hole ID to Casing OD.

Summary of wells drilled by operator

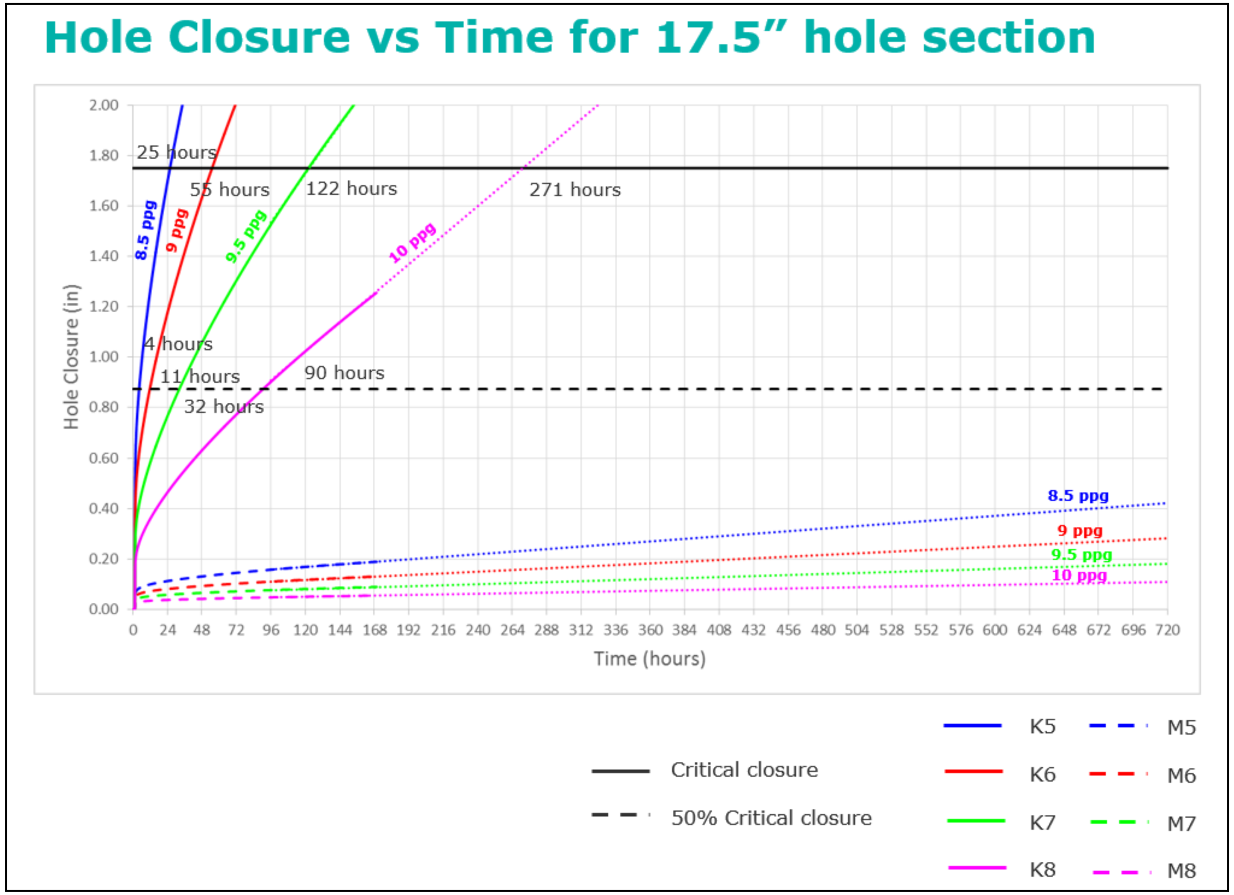
Well Name	Well A	Well B	Well C
Year Drilled	2017	2019	2021
Water Depth (m)	2904	2879	2104
Salt Thickness	56m	273m	495m
Salt Type	Dominantly Halite	Dominantly Halite with traces of Sylvite	Dominantly Halite with streaks Sylvite
Well Type / Trajectory	Wild Cat Exploration / Vertical	Exploration / Vertical	Wild Cat Exploration / Vertical
Well Distance (km)	0	8	56
Casing Scheme	36” conductor 28” surface 22” intermediate casing 18” intermediate liner 14” intermediate casing **12-1/4” open hole**	36” conductor 20” casing **14” casing** 9-7/8” liner	36” conductor 20” casing **14” casing** **12-1/4” open hole**

Key model parameters for the magnitude and rate of hole closure for duration from drilling until cementing.

1. **Mud weight -** exerts the most significant control on salt creep.
2. **Salt composition** – to identify the creeping rate either low, high or medium
3. **Temperature –** wellbore temperature affect the creeping rate
4. **Size of the open hole**



Casing Size: 14” casing / Critical Closure: 1.75”.

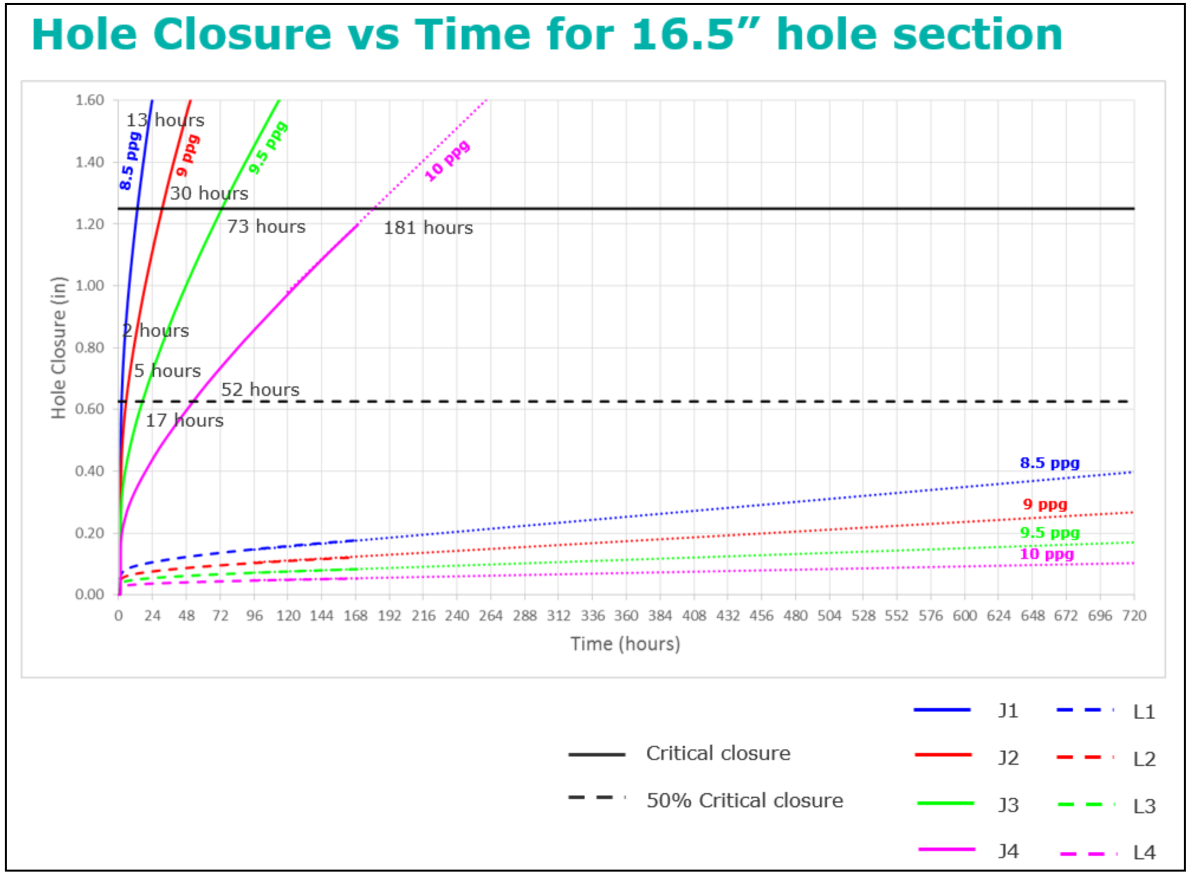


The simulations considered mud weights between 8.5 and 10 ppg and the two salt characterizations

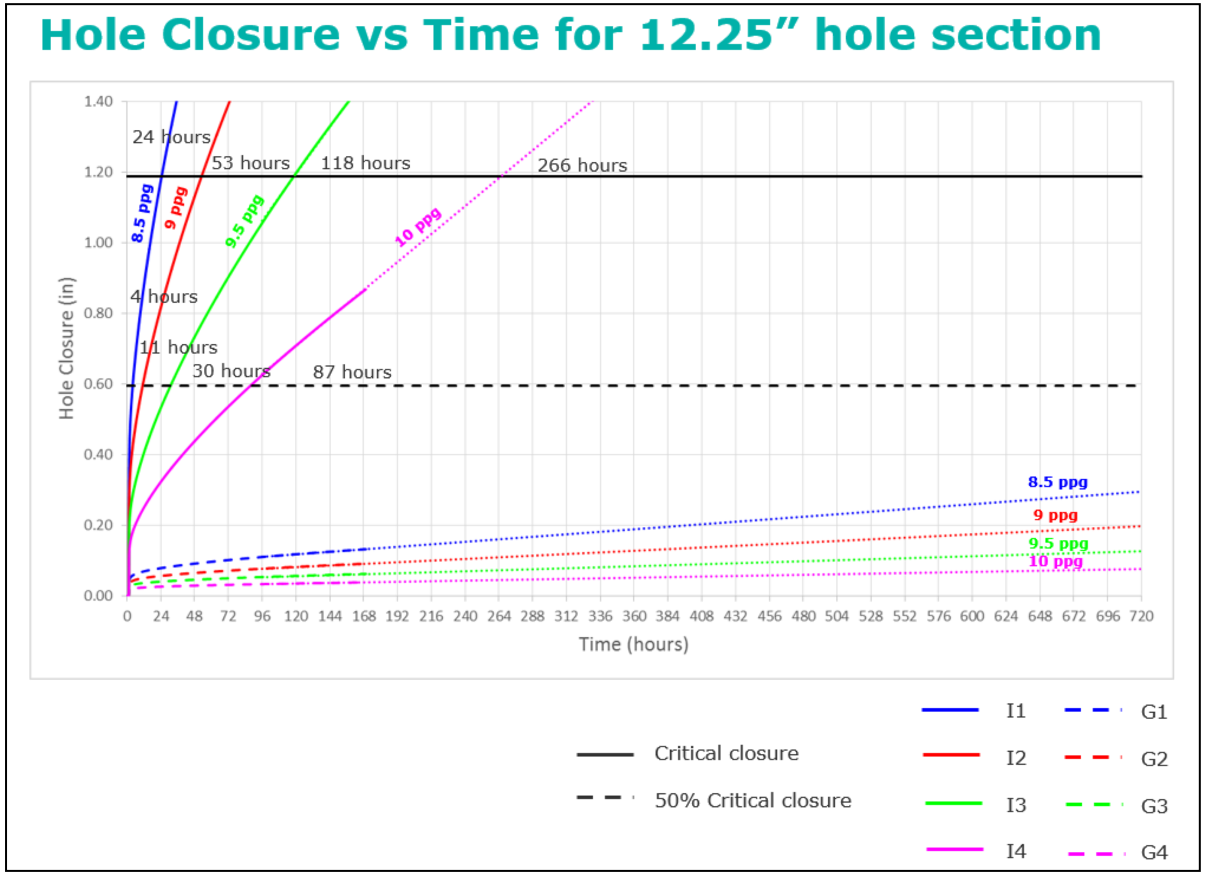
- ❑ Halite/ Anhydrite – low creep salt (dashed curves)
- ❑ Sylvite – high creep salt (solid curves)

The higher the density of the mud, the longer the time to reach to critical closure

Casing Size: 14" / Critical closure is 1.25".



Casing size: 9.875" casing / Critical closure:1.1875"



- ❑ Halite/ Anhydrite – low creep salt (dashed curves)
- ❑ Sylvite – high creep salt (solid curves)

- For the conservative approach, 50% of critical closure with 10.0 ppg mud weight for 12.25” with 9.875” casing is attained within 7 days
- The result emphasizes the role of mud weight selection in controlling the extent of creep.
- The initial hole size selected influences the time taken to reach the critical closure.

There are a few fundamental properties to address salt:

Density (Mud Weight)

- ❑ Critical to minimize the creeping rate based on salt creeping rate studies

Salinity

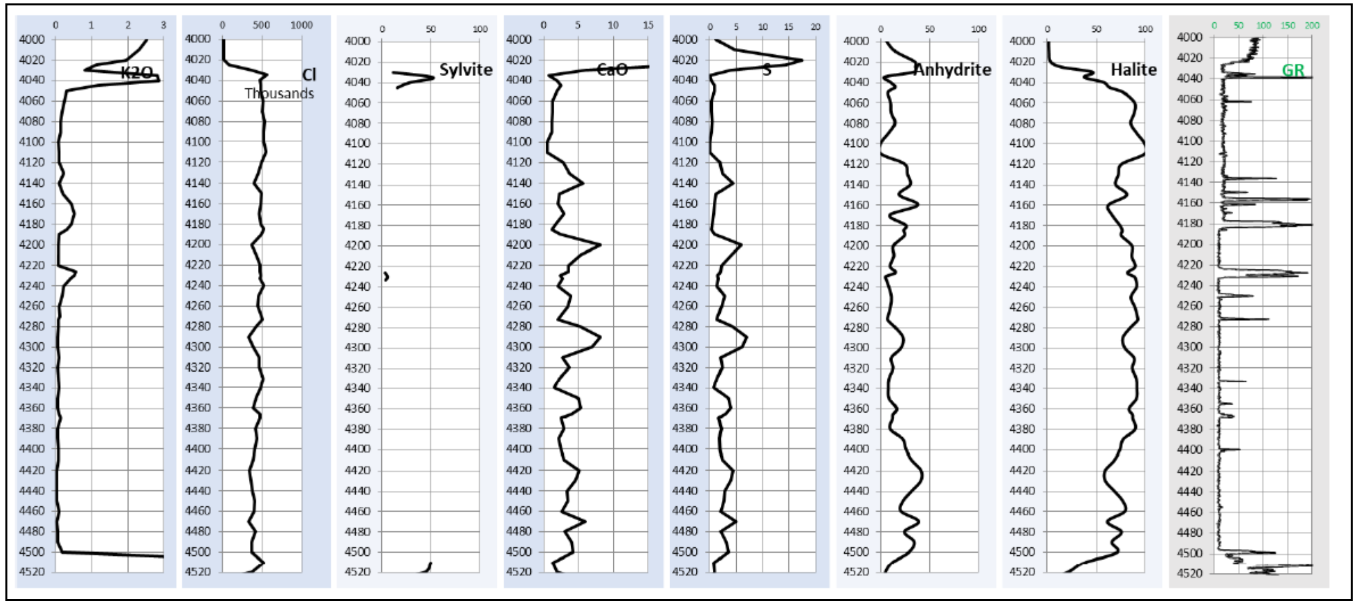
- ❑ The salinity of the drilling fluid is required to be at or near saturation to the salt being drilled to minimize salt dissolution and washout.

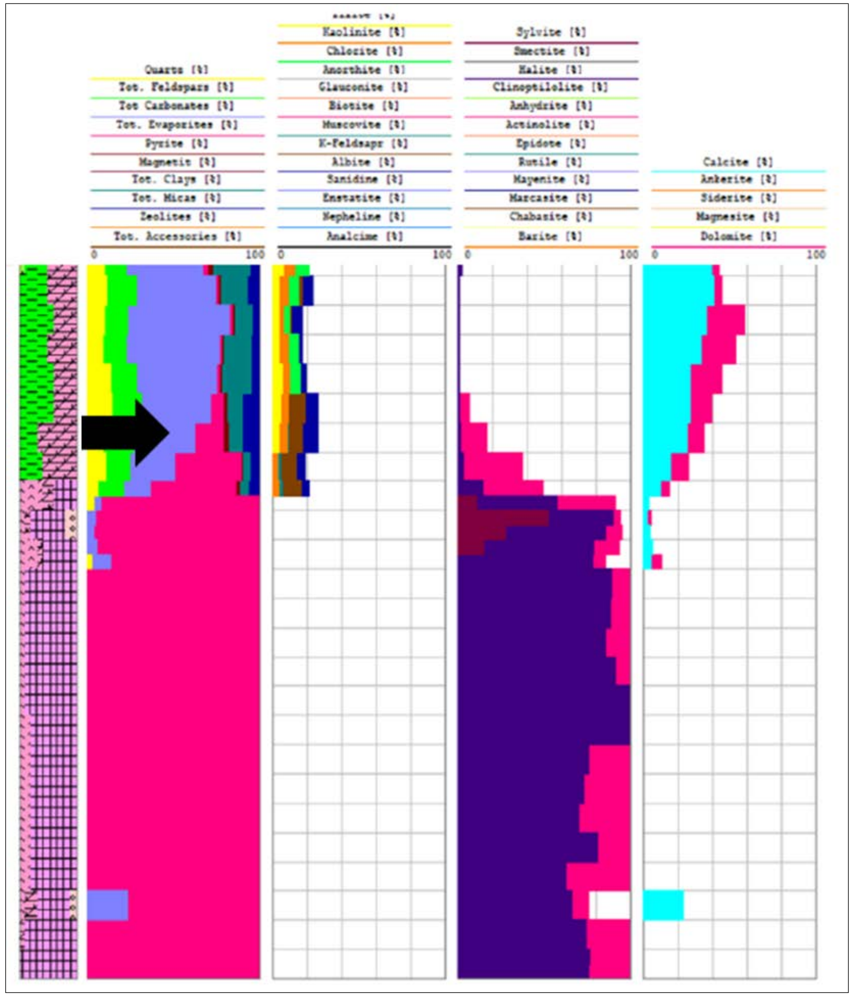
Bridging Agent/Lost Circulation material (LCM)

- ❑ As conservative approach, calcium carbonate of various sizes mixed with graphite is mixed for well A & B while for well C – higher performance bridging agent was used to further reduce risk of losses.

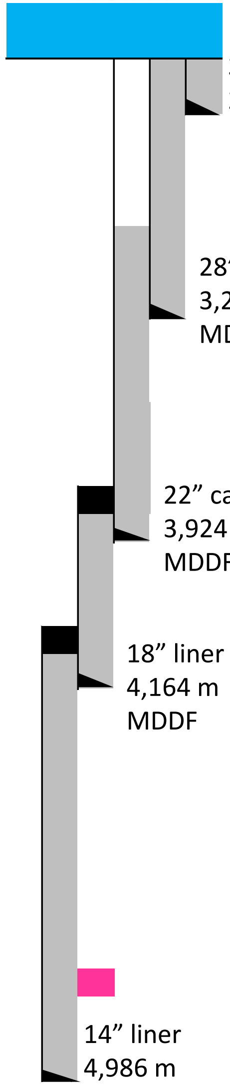
X-ray Diffraction (XRD) or X-ray Fluorescence (XRF) was utilized to detect the presence of various type of salt

- This was also due to similar physical appearance of Sylvite to Halite making it difficult to differentiate between the two minerals.
- The main important outcome of this is to ensure the actual type of salts being drilled will be reflected in the salt creeping model which will affect the well design.



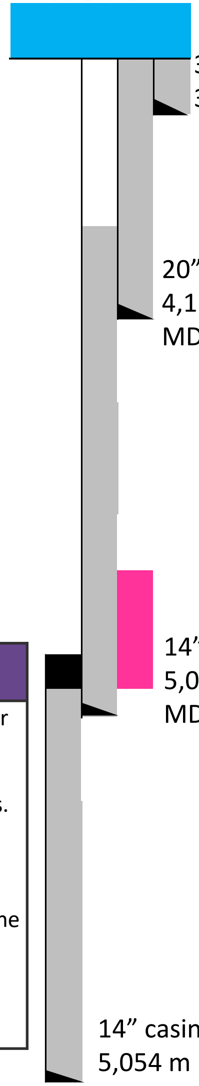


Well A



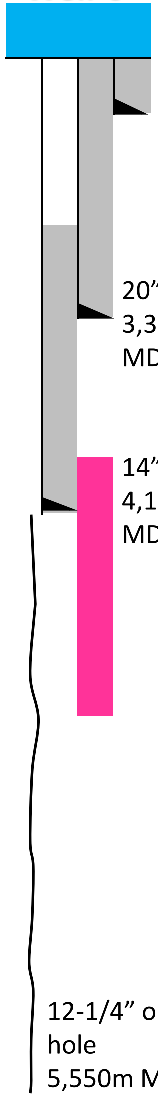
FLUIDS	EXPERIENCE
12.25 inch MW = 9.5-9.8 ppg PV = 29-37 Cps YP = 20-24 lb./100ft2 6 rpm = 15-16 HPHT FL <5ml ES < 550 v OWR: 70/30-75/25 CaCl2 WPS wt.%: 20-25	❑ The main salt layer consists of solely Halite, albeit with impurities in parts. ❑ Both cuttings and XRD technology show no fast-creeping salts in the salt interval.

Well B



FLUIDS	EXPERIENCE
12.25 inch MW = 9.0-10.0 ppg PV = 22-32 Cps YP = 19-30 lb./100ft2 6 rpm = 12-20 HPHT FL < 5ml ES < 650 v OWR: 65/35-68/32 CaCl2 WPS wt.%: 23-25%	❑ MW increased from 9.0 ppg to 9.7 ppg prior salt. ❑ Water Phase Salinity (WPS) increased from 23% to 25% for salt-saturation. ❑ ROP was controlled at 15m/h, and back reaming ❑ Incidents of drill string was stalled and freed by firing the jar. ❑ Mud weight up to 10.0 ppg. ❑ A wiper trip was conducted to the top of the salt zone and encountered only one tight spot. ❑ Reducing the ROP on the final 7m of each stand allows more time for bit and stabilizer contact with salt formation.

Well C



FLUIDS	EXPERIENCE
17.5 inch MW = 9.2-9.4 ppg PV = 22-28 Cps YP = 17 lb./100ft2 6 rpm = 11-16 HPHT FL <5ml ES < 550 v OWR: 73/27 CaCl2 WPS wt.%: 23-25%	❑ MW increased from 9.2 ppg to 9.4 ppg with with min 25% of water phase salinity. ❑ Cuttings Halite dominantly with some minor Anhydrite and Sylvite. ❑ Sylvite thickness varied from 0.7m to 4.0m of high GR (API) values due to the presence of K (Potassium) element and is confirmed by XRD & XRF analysis
12.25 inch MW = 10.0 ppg PV = 22-25 Cps YP = 20-23 lb./100ft2 6 rpm = 13-14 HPHT FL <4ml ES < 550 v OWR: 74/26 CaCl2 WPS wt.%: 25-27%	❑ MW increased to 10.0ppg ❑ The total salt consists of Halite with some Anhydrite and two identified intervals of Sylvite. The second Sylvite was at the base of salt. The thickness of Sylvite varied from 4.0 – 8.0m in this section.

- Higher mud weight will further suppress the creeping of the salt based on salt creep modelling
- Portable XRD and XRF for real-time salt identifications will give greater confidence in the accuracy of the salt prognosis and model simulation.
- No losses when exiting the salt, which shows that there was no presence of a rubble zone. However, precautionary measures are highly recommended for uncertainties.

We would like to thank PETRONAS for allowing the sharing of information during this SPE Workshop.

Q&A