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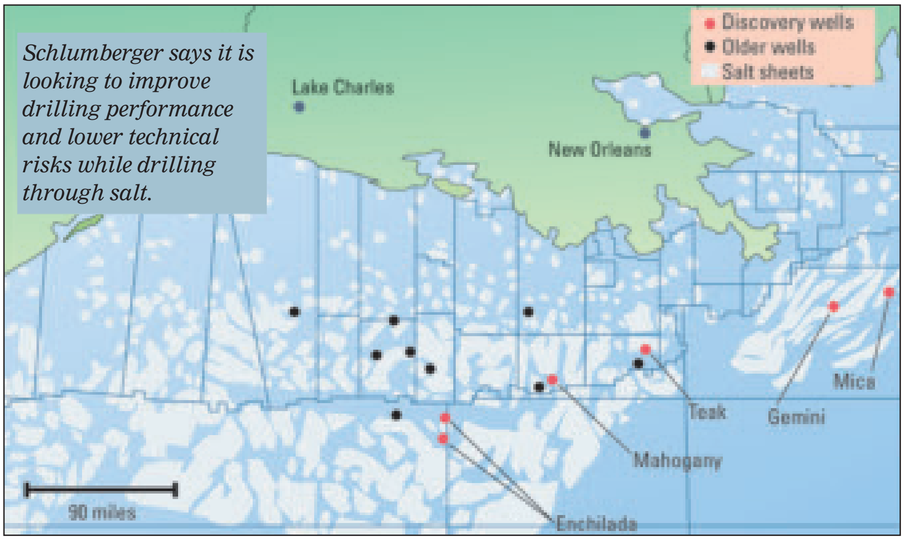


Schlumberger says it is looking to improve drilling performance and lower technical risks while drilling through salt.

GRPAPHICS COURTESY SCHLUMBERGER

Drilling through salt

In less than two decades, salt has morphed from foe to friend. Once viewed as difficult to drill, salt has shown it can offer certain benefits. Even so, drilling to reach a sub-salt prospect still holds some challenges, as **Jennifer Pallanich** reports.

Since the first Gulf of Mexico subsalt discovery in 1990, the industry has worked to ease the drill bit's path through the salt thought to overlie huge quantities of hydrocarbons.

The Gulf of Mexico hosts 'cold salt,' or salt which is low in temperature and mobility and high in purity. Where the salt has mobilized, its impermeable nature means it can serve as a hydrocarbon trap. As attractive as the potential payoff is, getting there can still be difficult.

'Salt drilling is technically challenging,' says Riaz Israel, Schlumberger senior drilling engineer, calling it 'unforgiving' to drill through. For starters, it's hard to drill quickly through the salt. Second, drilling directionally through salt is difficult. Third, don't forget the rubble zone and tar, which often exists below.

The oil industry has found ways to decrease the challenges and increase the ROP for drilling through salt, via drilling technologies like rotary steerable systems (RSS), improvements to PDC bits and reamers and real-time monitoring and decision making.

Israel, who estimates Schlumberger has been involved in drilling nearly half a million feet of salt in the past six years, says companies working in the Gulf have come to understand the resident salt structures fairly well.

Which is a good thing.

'It's usually a considerable amount of salt that we drill in the deepwater area,' says Marco Aburto, Schlumberger drilling engineer, noting that the longer the salt section, the more it affects drilling performance.

The industry should expect to see more drilling through salt, particularly in the tertiary play. The challenge lies not just in drilling through salt, but adding a directional component, needed once an operator begins developing the offshore subsalt fields.

'Nowadays in the Gulf of Mexico deepwater, we almost inevitably have to drill through salt,' Israel says. Salt thicknesses vary but can be greater than 15,000ft in some wells. 'We've drilled a lot of salt in the Gulf of Mexico, but we have a lot more salt to drill.'

Drilling directionally through salt has many of the same planning elements as for other offshore wells, including working from a reduced number of site locations or platforms and avoiding wellbore collision. Drilling through salt can take time, of course. 'In the past, to improve ROP in the Gulf of Mexico's cold salt areas, a slower drilling speed steerable motor with a higher weight on bit was used; however, this generally proved inefficient. Unfortunately, the aggressive bent housing caused twist-offs,' Aburto says. 'If we want to cut days from the drilling curve in deepwater wells, we need to optimize performance before the base of the salt.'

Preparing a successful directional well plan through salt means meeting three criteria, according to Israel. The first is planning the directional trajectory, the second is determining the angle to drill through and exit the salt, and the third is managing drilling shock and vibration. When it comes to planning the trajectory, Israel says, it's important to consider the salt's natural tendency to walk. Exiting the salt, through the rubble zone, may lead to wellbore stability problems if the angle is too high, Israel notes. The exit strategy must be solid, he says, and should not introduce unnecessary stuck pipe or geomechanical risks. Finally, he says, real time drilling mechanics measurements are required for managing shock and vibration.

'You can find self tripping out of holes to replace damaged or broken downhole tools if you can't manage your shock and vibration in real time while drilling,' Israel says.

The trick comes in deciding where to start the directional aspect of the well – either in the salt or above the salt. Making that decision depends on the optimal trajectory required to intersect the target, achievable doglegs, the need to avoid colliding with other wells, the increased level of vibrations in salt, and geomechanical issues like salt creep and hole quality.

Israel says it is important to have a contingency option available in case a problem arises with the original well plan. In one example, he says, an original well plan for drilling through 6000ft of salt required a lot of slide drilling to keep the

'Our experience shows that rotary steerable is definitely the way to go in drilling through the salt.'
Riaz Israel, Schlumberger

well on path. 'Avoid slide drilling in salt if at all possible,' he advises, calling it costly and slow in addition to creating other issues.

The refined well plan turned that well into a directional well in the salt with an 11° inclination.

In a second case study, Israel says, the driller drilled 11,000ft in one run before casing was set. The well plan, which was followed, was to kick off in the salt and drill directionally with an RSS and underream in the salt.

'Our experience shows that rotary steerable is definitely the way to go in drilling through the salt,' Israel says. RSS, introduced in the Gulf of Mexico in 2000, can provide better hole quality, Israel says, especially when combined with the use of improved bits and underreamers.

Aburto says it's important to transfer the maximum amount of energy to the bit while drilling instead of having that energy dissipated through shock and vibration in the drillstring. Drilling through salt, however, with its high coefficient of friction, means it's easy to lose energy to the wellbore wall while drilling.

'It is a perfect environment for stick and slip issues,' Aburto says, noting this can damage the BHA and/or the drillstring. Because stick and slip issues are more prevalent when drilling through salt, 'we have downhole sensors that can measure the stick and slip issues,' Aburto says, adding that Schlumberger also uses procedures to mitigate and prevent those very issues.

Rig selection also factors into success, Aburto notes. The rig needs to manage the increased torque and hydraulic demands and hoisting requirements when drilling salt. 'Most of the rigs in use in the Gulf of Mexico to drill these deepwater wells need to be rated to drill to depths of 35,000ft,' Aburto says. This means, he says, the rig must meet the derrick capacity requirements to handle the weight of the long drilling and casing strings; the power and torque capacity to allow for more WOB on the PDC bit needed to generate higher ROPs; pump capacity to pump to deeper depths; and a typical standpipe pressure capacity of at least 7500psi.

While the salt in the Gulf of Mexico is generally understood, 'all salt bodies are slightly different,' Aburto says. The drilling plan must take into account salt, geomechanics, directional capability, gauge versus overgauge hole, shock and vibrations, type of drilling fluid, mud weight for enhanced drilling speeds and duration, connections and back-reaming as well as rig capacities, Aburto says.

Salt doesn't always stay put.

'If salt is exposed to high temperatures, the mobility of the salt is increased, and that may make it more difficult to drill,' Aburto says. The mud program or drilling with an expandable reamer can address salt mobility issues, he adds. The optimal placing of casing strings above, within, and below the salt, is one of the keys to successfully drilling these wells, he says.

Just as important is deciding whether to start the directional section of the well above or in the salt is determining the exit strategy, Israel says. While the industry may have figured out how to deal with salt, drilling through salt can sometimes mean meeting up with its frequent companion, tar, which cannot be identified from predrill seismic images.

'Tar is a huge problem in the Gulf of Mexico for some operators,' Israel says. 'No one really has a foolproof solution. If you can avoid tar, that's probably your best bet.'

Exiting salt and avoiding the 'rubble zone,' where the risk for getting stuck increases, often comes down to local experience, Israel says.

The rubble zone often has unpredictable pore pressure and fracture gradients, which can result in lost circulation or other problems.

Not without technology

The key ingredient on the road to drilling performance improvement is technology, including tuning of existing technology, Aburto says. Some of the technology that has paved the way to success in the Gulf includes real-time measurements, PDC bit technology, and RSS. Of course, the rig has to be able to meet the demands laid down by these technologies, as well.

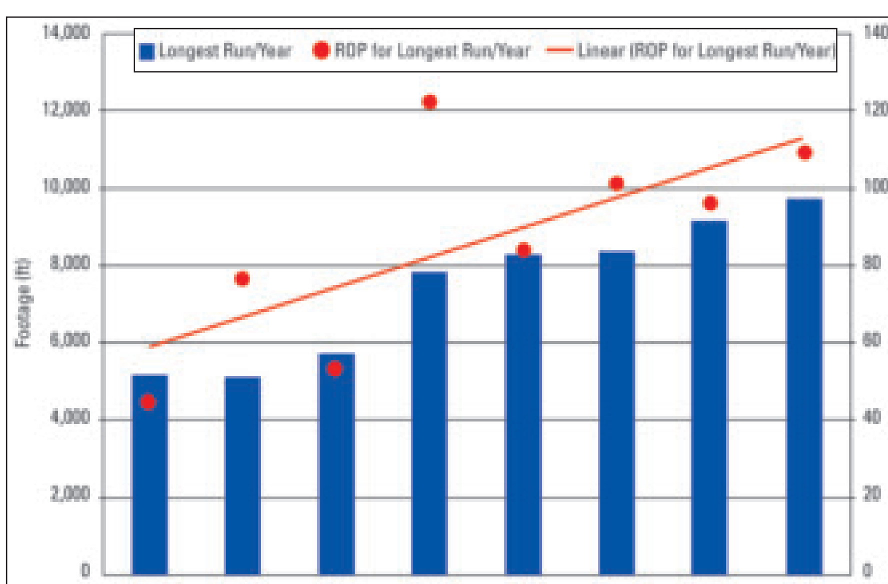
Following RSS, the next most important tool in drilling through salt is real-time monitoring and management of the drilling parameters, Israel says.

'That's been a critical component in letting us drill some of the salt formations in one bit run,' Israel says. Part of that real time monitoring comes in the form of LWD. 'It really adds value to the process' because each person can focus on their own area of expertise, Israel adds.

One case study involves a bit run in 6000ft of water, drilling $18^{1}/_{4}$in by 20in holes through 1500-2000ft of salt.

'While drilling through salt, we encountered shock and vibration. This is not uncommon with large holes and underreamers,' Israel says. While it's not possible to eliminate shock and vibration, he adds, it's possible to adjust in real time to reduce the level, which can prevent a trip for damaged tools.

That real-time shock and vibration data can be sent via the MWD tool, and a dedicated engineer can interpret the information and recommend a method to



Drilling longer and faster philosophy has allowed double the salt footage and ROP within eight years of drilling it in the Gulf of Mexico.

> ‘If we want to cut days from the drilling curve in deepwater wells, we need to optimize performance before the base of the salt.’
> **Marco Aburto**, Schlumberger

reduce shock and vibration. With expensive deepwater operations, ‘real time decisions are critical, and to make those real time decisions, we need to have real time data,’ Aburto says.

The other main component is the drilling action.

‘We have all the pieces of the BHA that we need to drill to these depths. We just need to synchronize them so they work together, enabling us to drill longer and faster salt sections,’ Aburto says. That work is in progress. ‘We are analyzing the performance of different components and looking for the best combination.’

For instance, Aburto says, some bits can drill well by themselves but adding a reamer to the scenario generates different results.

The type of PDC bit cutting action associated with salt drilling creates a lot of torque, which in turn creates shock, vibration, and stick and slip issues.

‘These (issues) can reduce life of the BHA, so stability is a critical point for these bits,’ Aburto says.

When the goal is to keep the BHA in the hole as long as possible, it’s important to have a stable bit that performs well. PDC is ‘the bit of choice for salt,’ according to Israel, and these bits are stable and less likely to generate high shock and vibration levels.

The RSS has been instrumental in moving past slide drilling with mud motors, which has been one method of correcting well trajectory in salt as well as other formations, Aburto says.

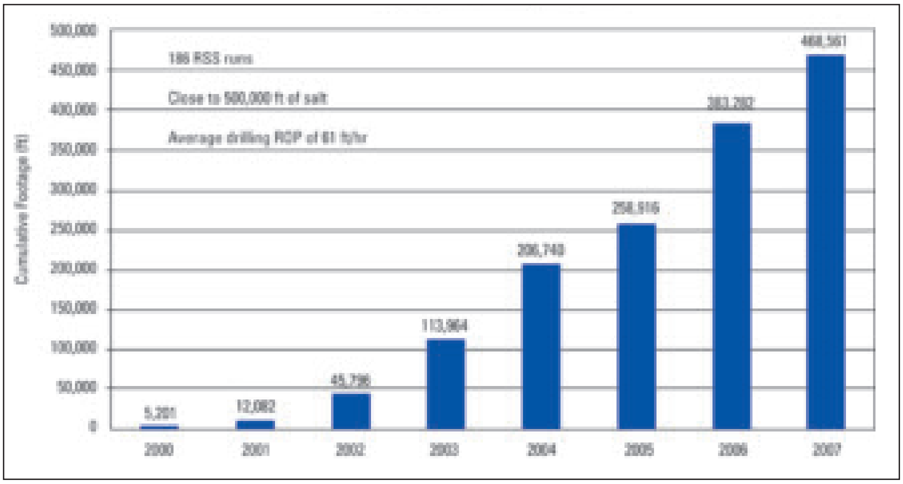
‘Rotary steerable systems have proven to be the right technology to drill through salt in the Gulf of Mexico,’ Aburto says. ‘Now we have the tools, but we are always looking at ways to improve the performance further.’

Before the introduction of RSS, Aburto says, it was common to use bicenter devices or an additional trip to enlarge a hole at rates of roughly 70ft/h. Further, he adds, slide drilling with a steerable motor was reduced by 20% to 40% the rotary ROP.

Using the RSS, Aburto says, yields a better quality and cleaner hole and means there’s no need to slide. Without the need to slide, he adds, it’s possible to use expandable reamers to drill and enlarge the hole at the same time.

Israel notes that in a riserless application when salt is encountered just below the mudline, large hole rotary steerable systems can provide an advantage, especially if about a third of the total section of footage is salt. Using RSS in the riserless section can help maintain the ROP at a suitable rate, which can prevent certain logistical problems like running out of brine, he adds. Additionally, the rotary steerable systems offer tighter control with doglegs and inclinations, Israel says.

‘Most of the operators understand the benefit of rotary steerable systems in the salt. There’s really no debate’ that the preferred way to drill salt is through this technology, Israel says. **OE**



From 2000 to 2007, there have been 186 Schlumberger push-the-bit RSS salt runs in the Gulf of Mexico, reaching close to half million feet of salt drilled.