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Mitigating deepwater and subsea formation evaluation and drilling challenges

Formation evaluation and drilling pose challenges on land. Offshore conditions are more complex, with HPHT stresses placed on equipment, due to deepwater and formation conditions. In the Gulf of Mexico, salt formations present added complexity, requiring specialized formation evaluation and drilling solutions to maximize and protect assets and drill smooth wellbores.

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Deepwater and subsea formation evaluation and drilling in the Gulf of Mexico are critical to energy production in the United States. The U.S. Department of the Interior estimates that 97% of all U.S. Outer Continental Shelf oil and gas production is from the Gulf1. But that doesn't mean exploration and extraction aren't without their challenges. In offshore operations, where the challenges are abundant, operators grapple with the intricacies of evaluation and drilling through unpredictable salt formations amidst unhospitable deepwater conditions.

Drilling offshore is complex, and operators are under constant pressure to increase production and maximize the value of their assets through greater efficiency. Operators need the ability to predict salt formation geology with accuracy, anticipate inclusions or sutures, and avoid mechanical challenges. Precise steering and accurate well placement are facilitated by extensive data points and are further enhanced with software-assisted predictions and modeling.

Why salt formations create complexity. From a deepwater perspective, seismic images are not always accurate. The location of the formation is not always clear, and it is not always easy to use interpreted salt geometry to determine whether inclusions, sutures, or unexpected lithologies, such as shale or tar, exist inside the salt body. In the salt body, operators can run into difficulties just to get to the base of the salt formation.

Without high-resolution imaging, they could mistake that there is a single salt base, but instead have multiple bases. The dip angle is often underestimated in salt formations. These faults do not always appear on seismic imaging, and as a result, operators, who are unable to anticipate the characteristics of the formation, will drill blind.

In the Gulf of Mexico, Halliburton worked with a customer to create a directional drilling profile with a vertical, kickoff, tangent, and return to vertical. The entire process had to be completed in salt. Because of salt's homogenous profile, it is tough to drill in the base case, because it moves and flows; it can pinch off a drill's string. Unexpected lithology may lead to stuck pipe and excessive torque and vibration, and other mechanical challenges. As sutures and inclusions are introduced, the environment changes often and requires detailed plans and precise execution for success.

Monitor downhole measurements–while drilling. To overcome the challenges of subsalt formations, one method is to execute a sophisticated plan that drills and enlarges the wellbore at the same time, using an underreamer. This allows the operator to deploy a contingency casing string, if needed. However, without a smooth trajectory, the operator cannot run structural casing with success. Drilling in salt formations requires solutions to potential challenges while the bottomhole assembly (BHA) is in operation at the top end of its technical capabilities.

Tools that measure downhole weight, torque and vibration are all required to monitor BHA behavior, as operators go deep into subsalt formations. This allows operators to compare what is seen at the surface to actual conditions at the bit, which is almost never the same.

The importance of having the right tools cannot be overstated. Halliburton prioritizes execution excellence, but not at the expense of the well or the equipment, as this could cause even more issues with damaged or lost equipment. A common challenge in salt formations is the risk of a tool twist-off that leads to drilling equipment being lost in the hole. Appropriate equipment is required to drill faster while avoiding anomalies that could grind operations to a halt.

Complex BHAs provide real-time steering decisions. Deepwater operations require complex BHAs that include multiple sensors and capabilities. Multiple cutting structures, gamma, resistivity, density, porosity, sonic, formation pressure test/sample capabilities, drilling dynamics systems, and onboard diagnostic sensors all come together to capture more data and enable better steering decisions.

When intelligent systems to monitor and control BHAs are added, operators can implement automated steering for directional drilling assemblies in subsea conditions. Intelligent bit technology allows operators to map the downhole bit motion and any drilling dysfunctions that may arise. The technology gathers data closer to the actual cutter element. The data are then used to better understand the application and improve performance.

Software algorithms anticipate issues. Automated drilling software, when combined with downhole steerable systems, uses physics-based models and machine learning to provide a projected well path, avoid collisions, manage vibrations and pressure parameters, and control steering.

This software uses a digital twin to simulate drilling conditions and adjusts performance to help lower the uncertainties inherent in deepwater and subsea drilling. Integrated models utilize real-time data gathered from the BHA to predict the well path and execute steering commands.

Fig. 1. Halliburton's iCruise® Intelligent Rotary Steerable System set a new global record of 8,515 ft drilled in a single run.

Model-based, fully automated steering relies on wellbore propagation models that incorporate trajectory, mechanical properties, and bit/formation interaction.

In addition, automated drilling software includes an algorithm to recognize the type of vibration that could cause damage to downhole tools or the wellbore. It uses downhole and surface vibration measurements to calculate and recommend optimal drilling parameters. This allows for quick mitigation of any issues that may be caused by vibrations and helps reduce well time and maximize efficiency, even in offshore applications.

Navigating difficult geosteering situations. For Halliburton's Gulf of Mexico customer, an extensive offset well study was conducted first to identify key hazards and opportunities for improvement. A combination of specialized drilling tools, engineering software, and optimization services were used to drill deeper, with a higher ROP.

Because salt formations present a significant challenge in geosteering applications, the proprietary iCruise® Intelligent Rotary Steerable System (RSS) proved ideal for the operation, Fig. 1. This tool's fully rotating, push-the-bit design includes high mechanical specifications for these types of operations.

The RSS provides operators with a reliable system capable of precise directional control, fast drilling, and automated control. Its sensors were designed for reliable operations in extreme temperature, pressure and vibration situations. Two-way communication between the surface and downhole is accomplished via a downlink that transmits data by either pressure pulse or electromagnetic telemetry.

Halliburton customized the optimum BHA and iCruise RSS hydraulics with the proprietary DrillingXpert™ engineering software suite to support maximum drilling parameters, minimize vibrations that could damage tooling or the borehole, and deliver precise trajectory control across the entire hole section.

Halliburton also employed the proprietary DrillDOC® Optimization Service to provide real-time measurements of weight, torque, bending moment, and 3-axis vibration within the BHA. This data gave the operator the needed confidence to apply maximum drilling parameters and deliver superior drilling performance.

In other instances, Halliburton deploys large density tools to gather downhole data. With logging while drilling (LWD) azimuthal density, consistent dip and dip azimuth can provide reliable representations of structural dip.

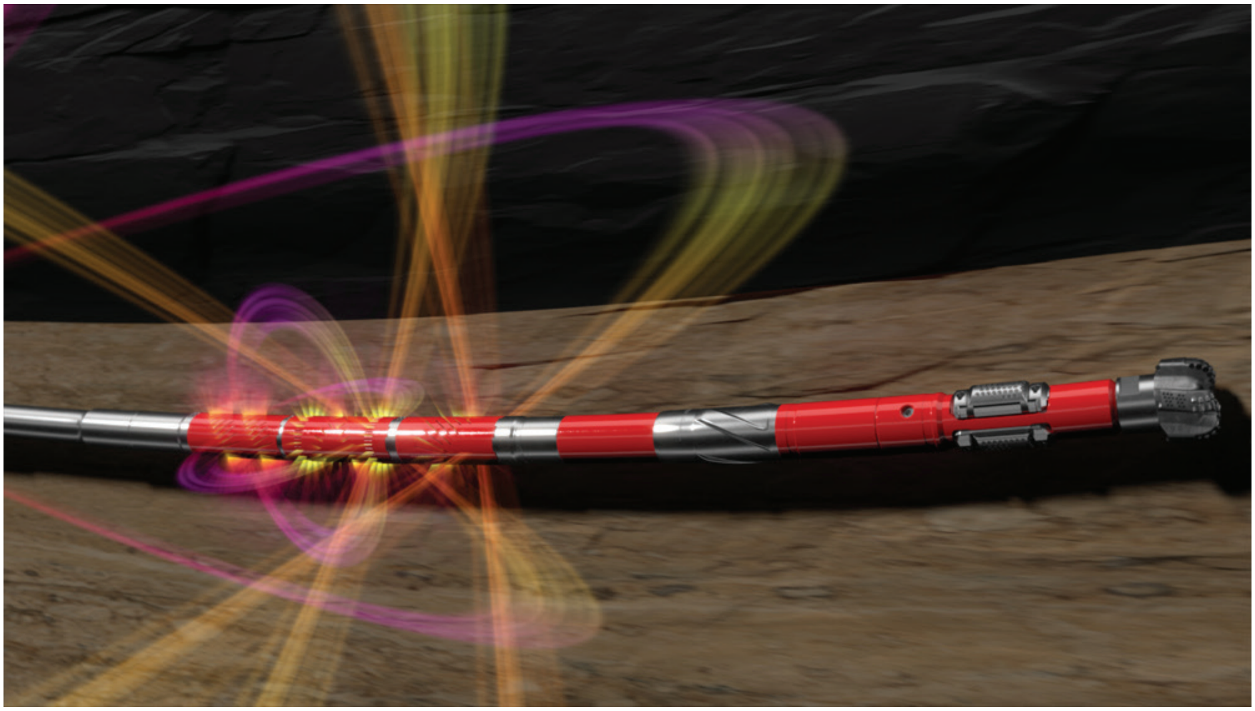

Fig. 2. EarthStar® 3D Ultra-Deep Resistivity Service helps operators address geological and reservoir challenges in deepwater formations.

LWD technologies, because of their drill-pipe conveyance, require no additional rig time for logging, reduce the risk of a stuck tool, and offer real-time capabilities to gather and interpret data. The information from large tool sizes can be used to help reduce geological uncertainty.

Large capacity tools for formation evaluation. The 9.5-in. azimuthal LWD tool provides consistent data and repeatable performance from well to well. It is ideal for operators, who require bulk density, structural dip analysis, and borehole caliper measurements in large boreholes in the Gulf of Mexico. By gathering real-time measurements in deepwater boreholes, operators can reduce well costs.

This tool can be used in boreholes larger than 14.5-in. as well. In 16.5-in. boreholes, operators have been able to acquire structural dip information below salt sections without running expensive wireline operations. The tool captures data in real time as drilling progresses, while the borehole is in its best condition, and provides borehole imaging for early geosteering decisions and formation dip information.

Operators have used this tool to identify shallow hydrocarbon deposits in 17.5-in. boreholes and to determine the formation dip and reservoir structure immediately below large salt intervals below 16.5-in. boreholes.

Addressing deepwater challenges with real-time, ultra-deep resistivity. Ultra-Deep Azimuthal Resistivity (UDAR) technology, such as the proprietary EarthStar,® integrated with a geosteering service, is another way operators can address geological and reservoir challenges in deepwater formations, **Fig. 2.** The technology helps optimal well placement with 1D and 3D modeling, as drilling progresses.

In one instance, UDAR geomapping was used while drilling to identify the top of the reservoir and to land the well with success. The service was then used during drilling in that section to stay in the zone and map reservoir thickness, which provided the operator with an optimized completion interval and detailed understanding of the well.

The use of LWD-provided representative formation pressures further enhanced the reservoir understanding and complemented geomapping from the UDAR technology. This service has the potential to reduce geological uncertainty while drilling in complex deepwater formations.

Fig. 3. Integrated models utilize real-time data gathered from the BHA to predict the well path and execute steering commands.

In addition to geosteering in clean sand play facies and changes in bed thickness, UDAR technologies can help operators avoid drilling out of zone. An accurate model of the geological environment is produced with the inversion of raw UDAR data. More advanced 3D inversion capabilities provide even greater insight and accuracy.

Record depth for deepwater Gulf of Mexico. Halliburton's Gulf of Mexico customer set a new record for the deepwater field to achieve the most footage and fastest ROP on bottom. The combination of tooling allowed the customer to achieve a section length 21% longer and increase ROP by 20%, compared to other offset well performance, **Fig. 3.**

While drilling, the ROP in the salt formation reached instantaneous values of up to 245 ft per hour in a section riddled with dominant inclusions. High performance was delivered, while low vibration levels were maintained at the same time. The 9.5-in. iCruise RSS set a new global record of 8,515 ft drilled in a single run.

Automated drilling was also employed, using iCruise vertical and CruiseControl™ downhole automated steering modes to drill a smooth trajectory with excellent dogleg severity (DLS) control. The average DLS during the vertical was 0.07°/100 ft., leading to a successful structural casing run without any tight spots.

Because of the results that the customer obtained with this precision-engineered, offshore appraisal well, the opportunity arose to plan and execute longer intermediate hole sections. This helped the operator save time and money on contingency scenarios and minimize the project footprint.

As operators continue to plumb the depths of the Gulf of Mexico, the mastery of salt formations and effective and efficient drilling will remain critical. Complex BHAs enable thorough data collection, while software algorithms anticipate problems and provide direction.

The ability to navigate difficult geosteering situations and ultradeep resistivity mapping will all prove invaluable to increase ROP and decrease costs. Tools that operate in larger boreholes enable real-time evaluation and modeling, and that leads to greater success in deepwater and subsea drilling applications. **WO**

REFERENCES

1. Oil and Gas - Gulf of Mexico | Bureau of Ocean Energy Management (boem.gov)

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