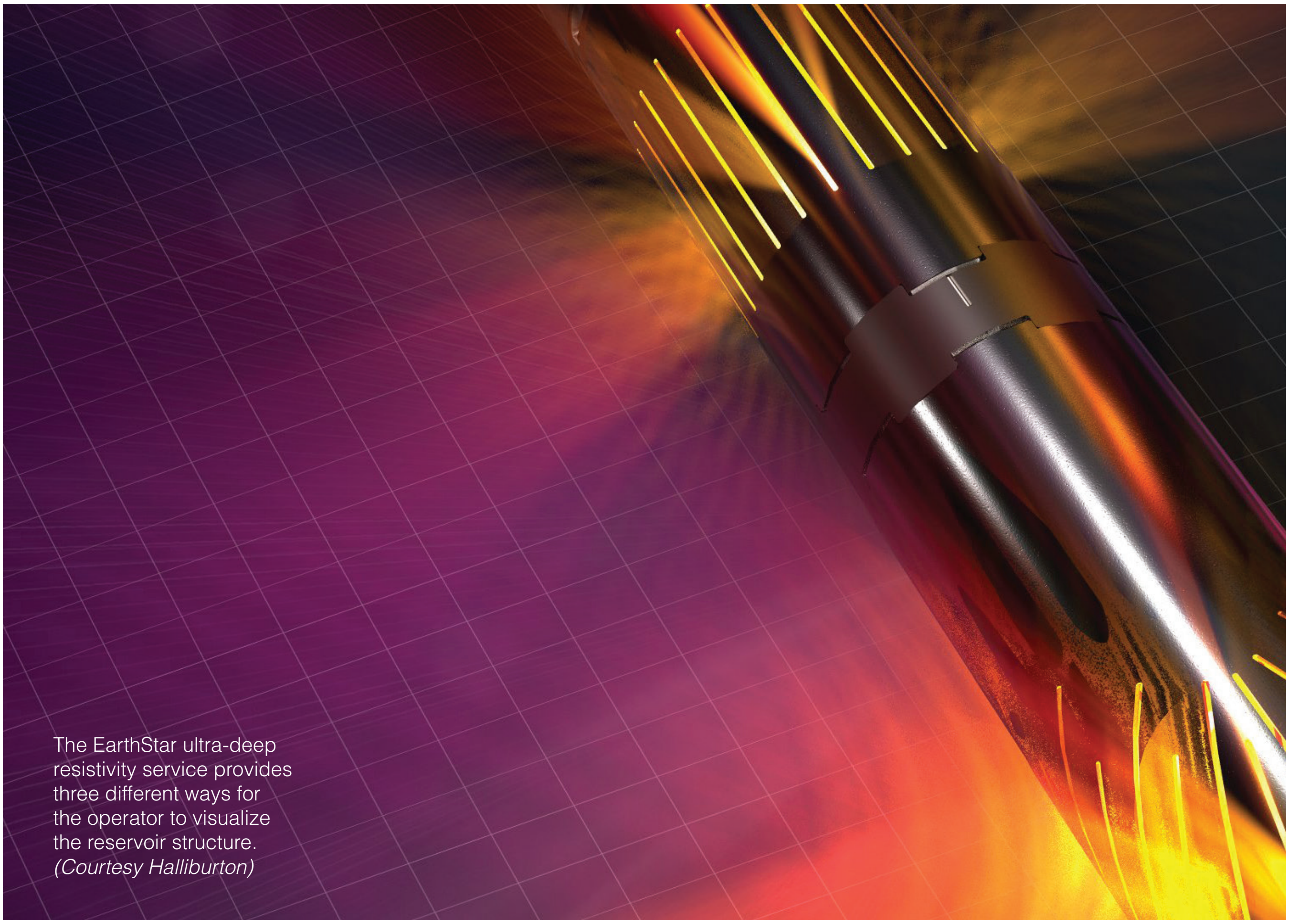
Offshore



The EarthStar ultra-deep resistivity service provides three different ways for the operator to visualize the reservoir structure. *(Courtesy Halliburton)*

New ultra-deep resistivity service identifies bypassed oil in mature North Sea field

Increases pay zone by 50% in water-flooded reservoir

TIM PARKER, *HALLIBURTON SPERRY DRILLING*

IN COSTLY OFFSHORE ENVIRONMENTS, E&P operators strive to lower their cost per foot and maximize their return from every well drilled. A key factor in achieving this goal is accurately placing each production well to maximize exposure to the most productive reservoir zones, while minimizing the number of wells required to drain the field. For new developments, the main obstacle to optimal well placement is uncertainty in the reservoir position and structure because of the inherent limitations of surface seismic data. In mature fields, the reservoir position and structure are generally well-known; however, the position of fluids may be uncertain because of movement caused by production or water flooding. Such fluid movement is difficult to predict and leads to well-placement challenges.

Conventional resistivity-based geosteering tools are sensitive to bed boundaries up to 18 ft (5 m) from the borehole. This range is sometimes insufficient to detect important structural features in time to make appropriate steering decisions. This can result in undesired exits from a reservoir target zone, suboptimal positioning of the well in a target zone, or failure to hit a target zone altogether.

Halliburton has introduced the EarthStar ultra-deep resistivity service, a logging-while-drilling (LWD) technology that helps operators map reservoir and fluid boundaries around the wellbore in real time. The system uses electromagnetic wave-propagation technology to detect and illuminate boundaries between zones with differing resistivity. In the right geological conditions, the service is proven to be capable of mapping fluid and reservoir boundaries up to 225 ft (69 m) from the wellbore, more than double the depth of detection of the previous industry standard.

The new service incorporates the proprietary RoxC real-time geosteering software, which processes the data using a customized inversion process, and displays the results graphically in a clear format that can be compared directly with other types of subsurface visualization, such as seismic data or existing 3D models. It also includes various quality-control functions useful for interpreting the results. The company's geosteering geologists use the software before, during, and after the job to provide the operator with pre-well models of the system's expected performance, real-time displays of the interpreted reservoir structure while drilling, and detailed post-well analysis of data from the tool's memory.

The EarthStar service provides three different ways for the operator to visualize the reservoir structure:

- A curtain-plot display, based on a 1D inversion, showing a cross-sectional view of the reservoir along the well path, illustrating the positions of fluid and formation boundaries above and below the well.
- Azimuthal resistivity images, providing a 360-degree view of resistivity variations around the wellbore, allowing operators to make left-right, as well as up-down steering decisions. The images are independent from the measurements used in the 1D inversion.
- A full 3D inversion, giving a realistic 3D view of the structure and fluid positions in all directions around the wellbore.

These visualization methods provide an unprecedented insight into the reservoir structure, allowing operators to maximize asset value via three applications: geostopping, geosteering, and geomapping. Geostopping means stopping the drilling assembly just above a target boundary. For example, the top of a reservoir. This allows operators to set casing and isolate the upper parts of the structure before entering the reservoir. A similar approach allows production wellbores to be landed accurately in the reservoir without the need for a preliminary pilot hole, helping to reduce well time. Geosteering means to adjust the well trajectory based on real-time measurements from LWD sensors, identifying the most productive parts of the reservoir, and placing the well accurately within them. Geomapping refers to visualization of the large-scale structure surrounding the wellbore and the identification of reservoir boundaries and fluid positions. This helps the operator to enhance its understanding of the reservoir and to evaluate potential reserves for future development.

The service has been deployed in several offshore environments. For example, in a mature field in the North Sea, an operator was seeking to intersect remaining lobes of oil within a partially produced reservoir. The reservoir had been producing via water injection for many years. Uneven flooding had resulted in many areas of bypassed hydrocarbon deposits, which were distributed in ways that were hard to predict. This made the placement of new wells, intended to exploit the remaining reserves, very challenging. The operator sought to improve the reliability with which residual reserves could be identified and accessed, in order to reduce development costs and maximize recovery from the field.

Halliburton recommended the new ultra-deep resistivity service to detect and map the location of remaining oil reserves, helping the operator place production wellbores optimally within them and maximize the length of wellbore exposed to the productive zone. In one well, it successfully mapped a large oil-bearing zone. The real-time LWD data indicated that after drilling about 1,000 ft (305 m) measured depth (MD) in the oil zone, the well drilled into a zone of injected water that continued for more than 400 ft (122 m) MD. At this point, the operator had to decide either to continue drilling, or to stop drilling and complete the well.

The real-time visualization of the EarthStar data indicated that the drillstring was moving toward a second oil lobe approximately 50 ft (15 m) true vertical depth (TVD) below the well. None of the other sensors in the LWD string indicated anything other than water, but based on the real-time data, the geosteering team recommended that the operator continue drilling to target the second oil zone. Through precise geosteering, the well successfully intersected the second zone and remained within it for approximately 500 ft (152 m).

By landing in the second sweet spot, the operator was able to increase the overall productive length of the well by approximately 50%, dramatically increasing potential production and the value of the mature asset. The distinct geomapping capability of the service led to the discovery of additional pay and without it, the additional reserves would have very likely remained untapped.