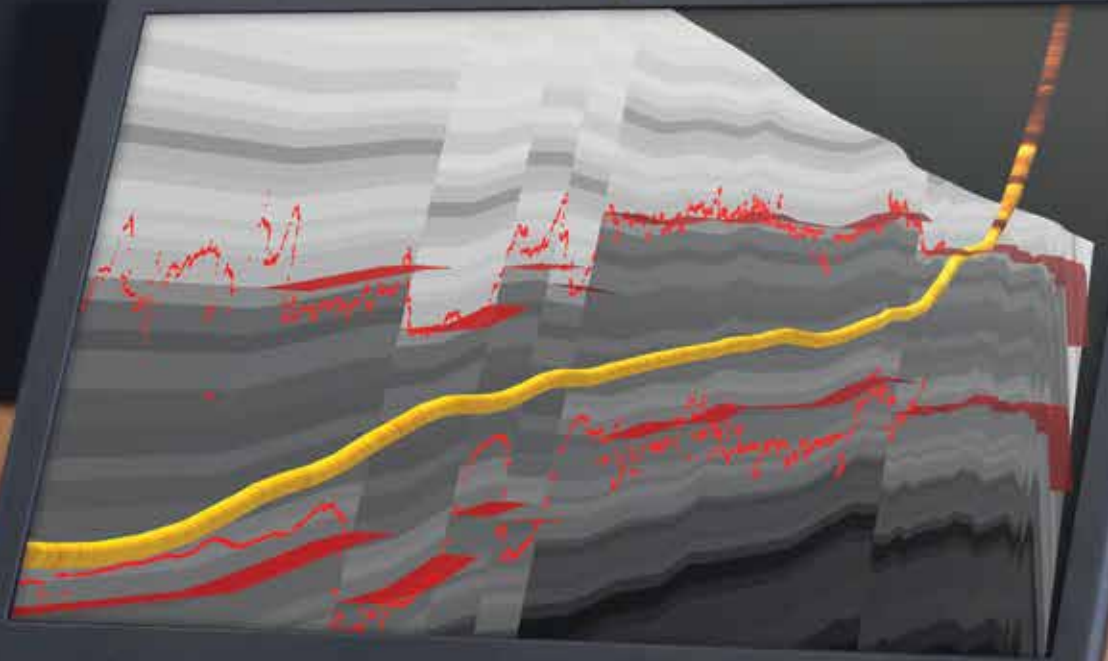


DRILLING SERVICES

InZone™

WELL-PLACEMENT SERVICE

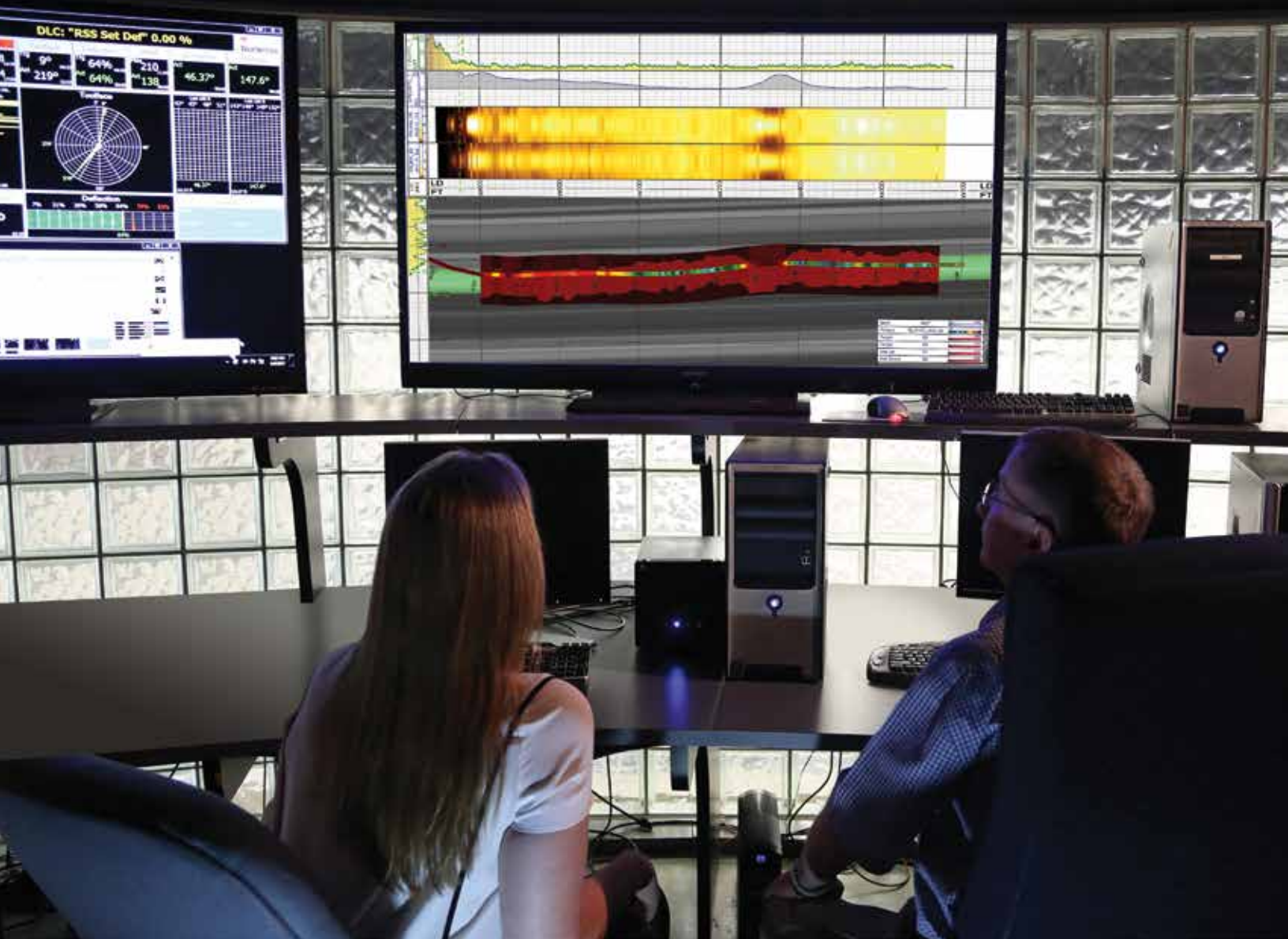
Exposing more of your reservoir
to production



Weatherford®

CHART YOUR COURSE TO MORE PAY

Drilling the sweet spot takes a team that can land the well and steer within pay zone boundaries, avoid water contacts, and regain position after crossing faults. As a leader in well-placement services, Weatherford has the right people and tools to stay in zone to open your reservoir for maximum production—even in your most challenging wells.



EXPERIENCE TO TAKE YOU BEYOND BASIC GEOSTEERING

Our well-placement experts can help you land and stay in the pay. Optimal well placement relies on real-time data and up-to-the-second correlations against an accurate reservoir model. To achieve their goal, well-placement teams rely primarily on logging-while-drilling (LWD) data, supplemented with surface logging data, including rate of penetration, gas chromatography, and advanced mineralogical analysis.

The basic LWD suite (typically gamma ray, resistivity, neutron and density) is generally used to land in reservoirs of little complexity. Although it is possible to geosteer using only gamma ray (GR) measurements, conventional (non-azimuthal) resistivity measurements could be recommended. This LWD data allows the geosteering team to update the structural model and revise drilling projections accordingly.

Resistivity measurements may not be sufficient for optimal geosteering. In reservoirs characterized by complex reservoir structure, thin layers, high-resistivity formations, or low-resistivity contrasts at critical boundaries, our experts may recommend borehole imaging to enhance well-placement precision.

LWD tools such as the HAGR™ high-temperature azimuthal gamma ray, AZD™ azimuthal density tool, SpectralWave®, CrossWave®, or UltraWave™ sensors provide borehole imaging capabilities, and can also be used to measure formation dip. The HAGR tool, with four-quadrant image acquisition, is the minimum requirement.

If resistivity measurements are not added to the service, we offer other options to meet your well-placement objectives, such as using an eight-sector GR measurement from the SpectralWave tool, or a density image, depending on formation lithology. The optimal imaging tool for each job is usually identified through the pre-well modeling process. Using QV software, Weatherford experts evaluate the imaging data and pick formation dips to update the geosteering models.



WELL-PLACEMENT WORKFLOW

Collaborate to Define Key Roles and Processes For the Success of Your Project

Weatherford well-placement specialists begin each job by preparing a geosteering model based on customer well data and drilling information. A feasibility study determines which tools will provide the best data for the project.

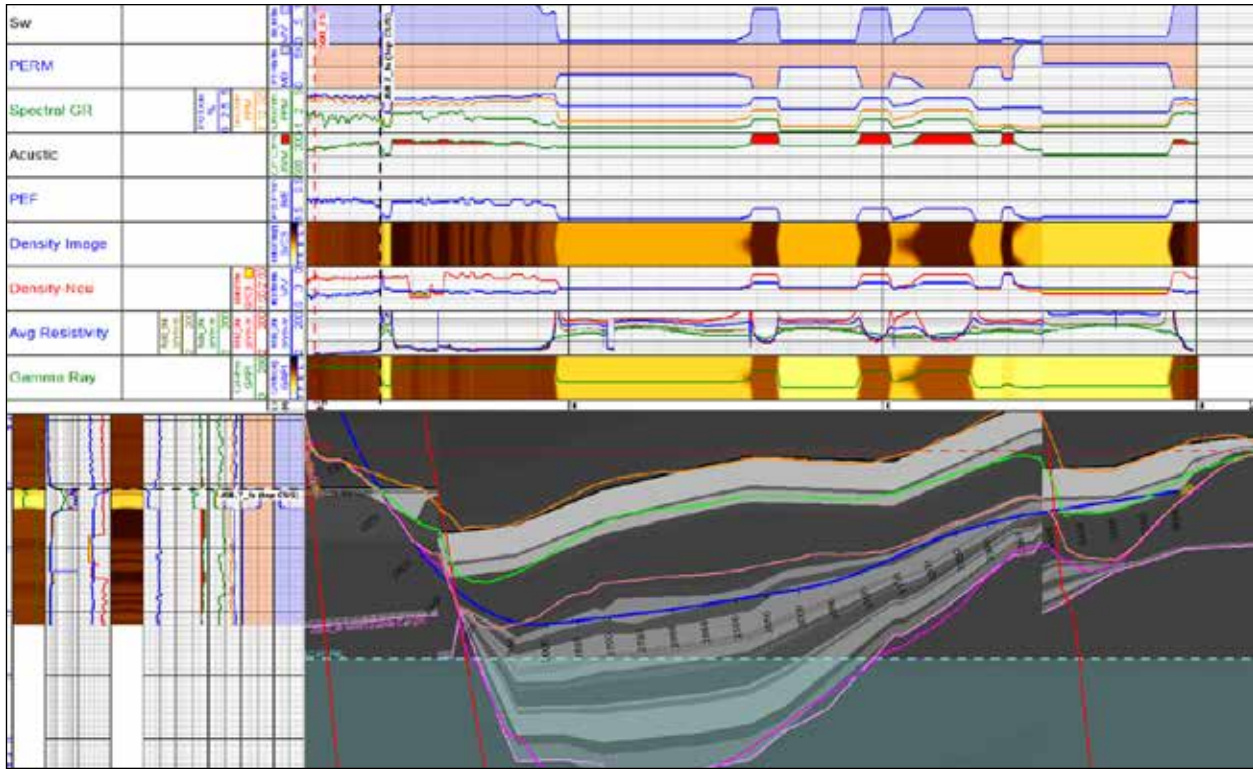
The model is presented to the customer for review during a pre-job meeting, and helps to fine-tune the drilling trajectory, based on specific drilling challenges, formation lithology, and structure. Communication protocols between the team and the customer are also established during this meeting.

While drilling, our well-placement specialists continually compare the geosteering model with real-time LWD data and various inversion parameters, then

update the model to reflect actual formation conditions encountered by the LWD tool. When correlations between the model and real-time LWD data indicate that the well has crossed a fault or encountered changes in dip or formation thickness, they notify the operator and make geosteering recommendations to regain optimal well position.

The geosteering specialists prepare a report prior to each shift change—or more frequently if required. After reaching TD, they deliver a comprehensive post-well report containing detailed descriptions of all geosteering recommendations, model correlation plots, and geosteering suggestions for future operations.





2D MODELING & SOFTWARE

Map the Course Ahead of Your Bit

The pre-well model serves as the main point of reference for the well-placement team. Using Weatherford proprietary QV software, our specialists incorporate geological cross-sections, structure maps, seismic sections, and data from offset wells, to create an earth model of the reservoir, overburden, and adjacent formations. In addition to stratigraphic and structural features, each layer of the model contains embedded information regarding petrophysical and geomechanical properties derived from offset well logs such as GR, resistivity, neutron/density, acoustic, and elemental data. The planned well trajectory is applied to the model, and expected responses of Weatherford LWD tools are calculated and integrated into the model.

Besides providing the basis for correlation with real-time LWD data, the pre-well model aids in:

- positioning the well plan within the expected geological model to verify wellbore trajectory, landing point, and lateral drainage volume to confirm expected reservoir exposure
- producing model data curves and images for evaluating geosteering challenges, potential uncertainties, and feasibility of the project
- defining which drilling and logging tools will be required for a successful geosteering operation
- evaluating different geosteering strategies for maximizing production

REAL-TIME STREAMING AND 3D VISUALIZATION

Track Your Well Trajectory Into The Sweet Spot

The 3D window enables drillers and geoscientists to visualize all data stored in the QV software database—including wellbore trajectories, interpreted surfaces, log curves, and operator-imported 3D surfaces. The link between 2D and 3D visualization is dynamically updated and connected by WITSML data streaming. This enables the geosteering team to instantaneously visualize all real-time data as it is received in the 3D windows and associated structure map.



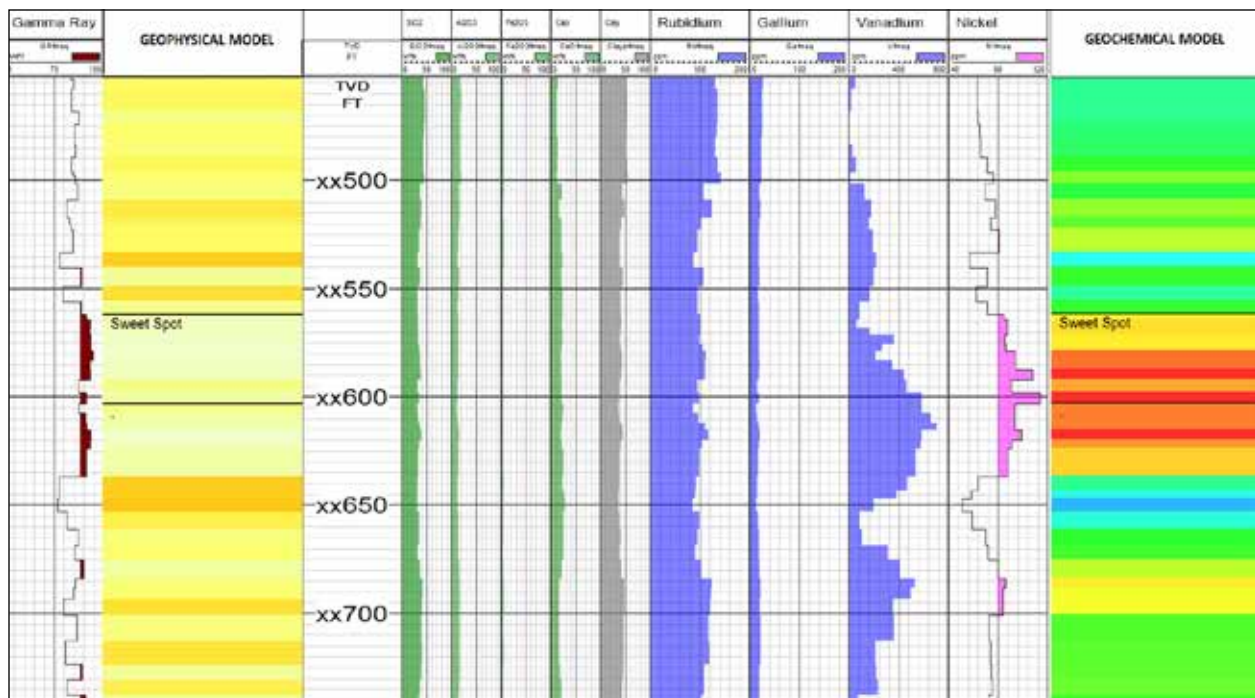


SPECTRALWAVE[®] TOOL + ROCKWISE[®] SERVICE

Stay In Zone with Spectral Gamma Ray Data and Elemental Analysis

Optimal well placement can be a challenge when operators rely solely on logging data. In horizontal wells, highly productive zones can be identified through X-ray fluorescence (XRF) elemental analysis. By correlating XRF data with azimuthal gamma ray logs, the geosteering team can accurately position the wellbore stratigraphically within the reservoir structure.

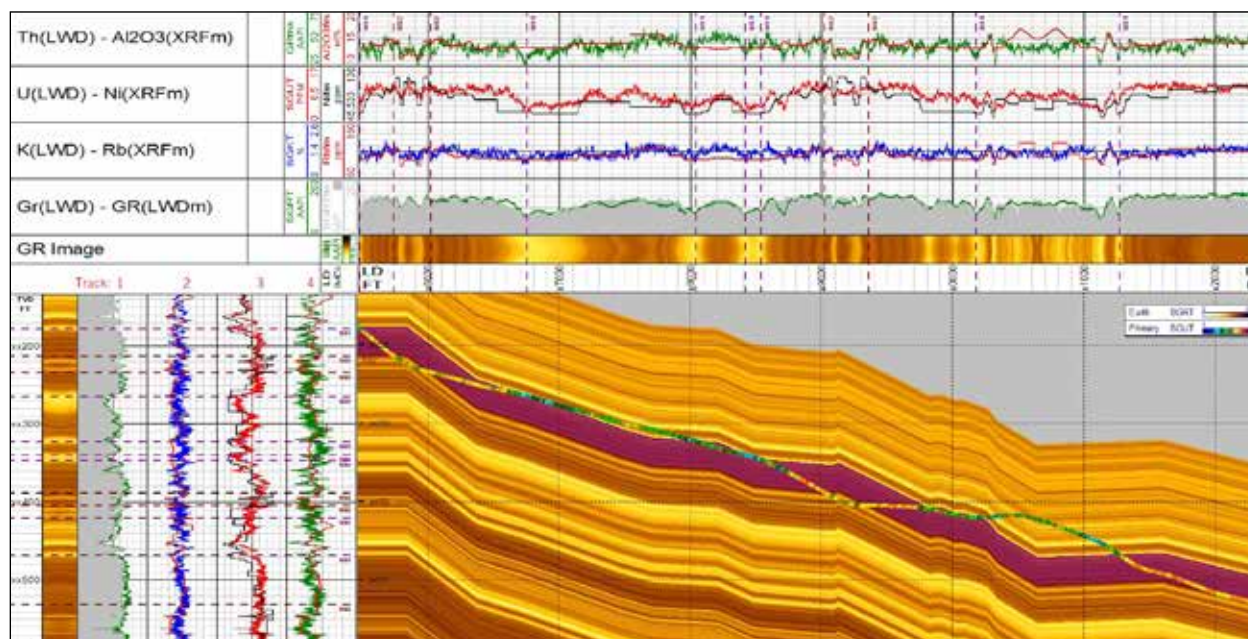
The SpectralWave gamma ray measurement provides a link between the geophysical and geochemical properties of a formation. The total measured gamma ray spectrum is resolved into the three most common sources of naturally occurring radiation in clastic formations: potassium (K), uranium (U) and thorium (Th). This data helps to determine the type of clay in the formation, and can be correlated with geochemical elemental data derived from XRF analysis of the cuttings.



BASIC GAMMA RAY (track 1) does not provide as much information as would be derived from XRF analysis. Here, the sweet spot is better defined by its vanadium and nickel content than by the gamma-ray count.

This log shows a bridged correlation between the spectral gamma ray content measured by the LWD tool, and elements within the cuttings measured by XRF. Track 1 shows the total gamma-ray count measured by the LWD tool. The blue and red curves in track 2 show a correlation between potassium (LWD tool) and rubidium content (XRF analysis). The third track shows the bridged correlation between uranium (LWD tool) and nickel (XRF analysis).

Within the geological curtain section, the nickel-enriched package is shaded in purple, and the operator sought to follow this zone. In this example, it is evident that when the well was drilled in the most hydrocarbon productive, nickel-enriched layer, the uranium measured by the spectral gamma ray LWD tool was also higher by about 10 ppm. In the lateral depth (LD) track, the well intersections within the target, verified by the enrichment in nickel, are plotted in purple, such that the net-to-gross value is 38%.



THE LOG ABOVE demonstrates how a combined classic geophysical model—based on gamma ray properties—and a geochemical mode—based on XRF cuttings analysis—can target discrete productive formation layers.

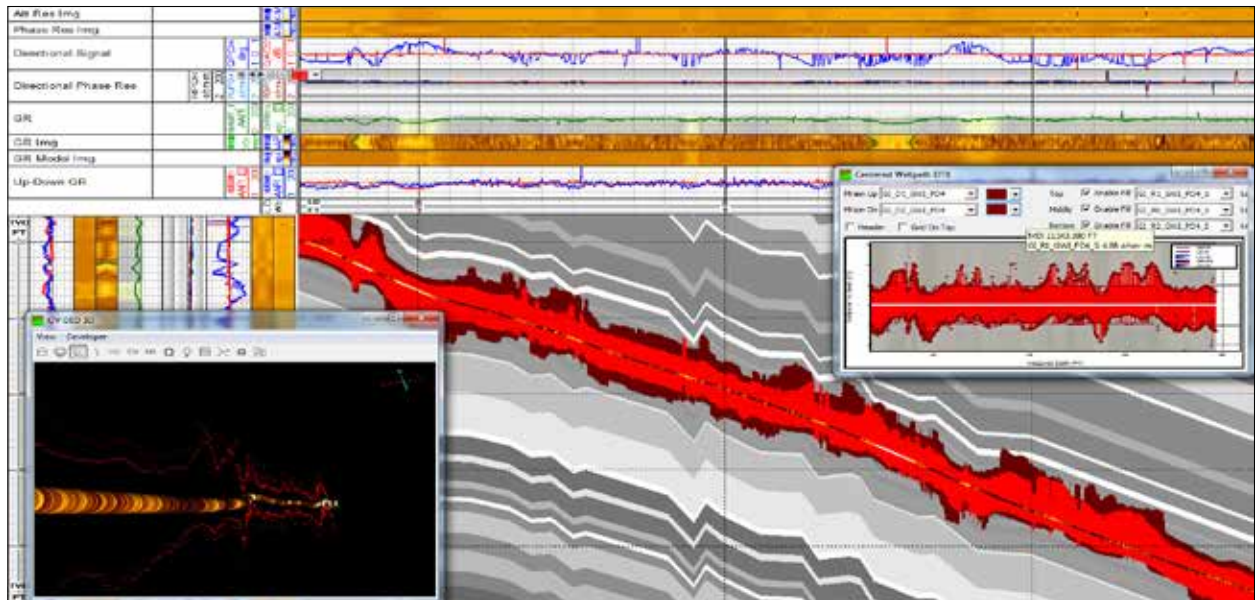
GUIDEWAVE® TOOL DTB, OWC

Find Your Distance to Bed Boundaries and Avoid Water Contacts Using Azimuthal Resistivity

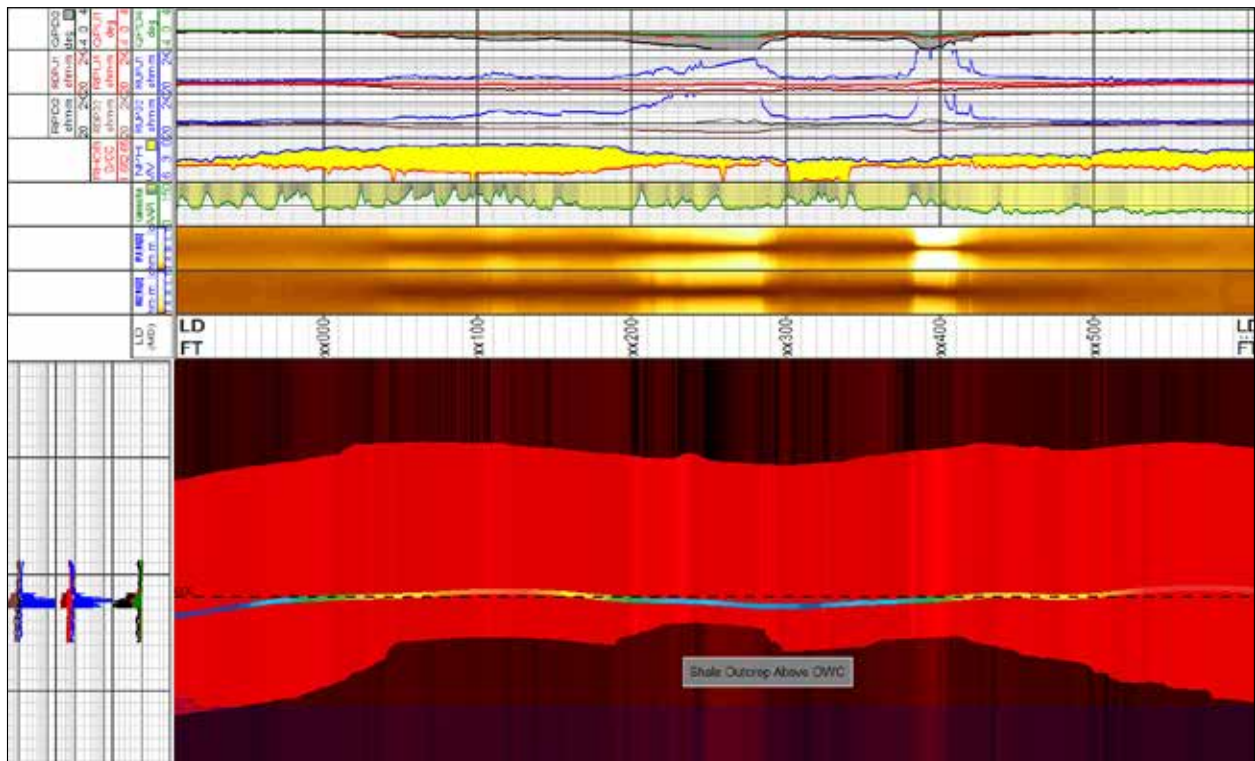
Azimuthal resistivity measurements are used for advanced well placement in clastic and carbonate reservoirs that exhibit a resistivity contrast between the pay zone and adjacent beds. We acquire the resistivity data using the GuideWave azimuthal tool. Our geosteering engineers use a sophisticated inversion algorithm developed by Weatherford to calculate the distance to formation boundaries (DTB) and direction. This technique is especially helpful for determining the distance and direction to an oil-water contact (OWC). Using geosteering to avoid the water zone while drilling, operators can delay the subsequent onset of coning during production.

In these challenging applications, the GuideWave tool uses additional 100-kHz azimuthal resistivity long-spaced measurements to detect boundaries at a radius of up to 35 ft (10.2m), and provides additional raw curves to correlate with the model. In addition to all basic services, Borehole imaging is usually included to optimize the structural control.





GUIDEWAVE MEASUREMENTS, in combination with other LWD measurements, can be used to identify intra-reservoir thin layers.



A TRIPLE COMBO LWD SUITE, with measurements from the GuideWave tool, was used to determine the oil/water contact while keeping the trajectory in the optimal zone.

GUIDEWAVE[®] TOOL + CROSSWAVE[®] SONIC TOOL

Combine Azimuthal
Resistivity and Sonic
Porosity Measurements
for Advanced Well
Placement

We acquire data from both our GuideWave azimuthal resistivity tool and CrossWave azimuthal sonic tool, and then correlate the measurements with the pre-well model.

Using GuideWave raw data, and a sophisticated inversion algorithm developed by Weatherford, we calculate the actual distance from formation bed boundaries and the direction to these detected boundaries.

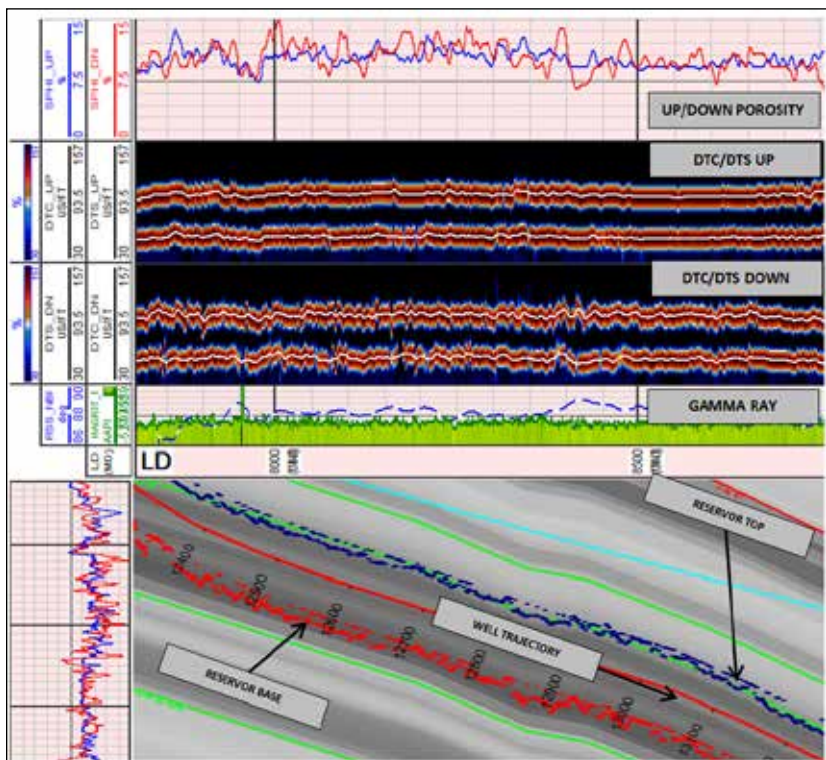
In addition to measuring porosity, the CrossWave tool records azimuthal waveforms and stores waveform data in 16 azimuthal sectors. The data from each of the 16 bins is processed to determine compressional slowness (DTC) and shear slowness (DTS) values from the coherence peaks. This results in 16 azimuthally oriented DTC and DTS log values. Our advanced algorithm for downhole data compression provides accurate azimuthal compression and shear acoustic information in real time to place the lateral in the optimal zone.



Azimuthal sonic measurements have other important applications beyond optimizing the well placement:

- Providing first-hand azimuthal-porosity evaluation
- Correlating seismic data with acoustic slowness and travel-time measurements
- Creating geomechanical models using compressional and shear data
- Improving capabilities to drill within pore-pressure windows and stabilizing the wellbore
- Optimizing completion-program effectiveness with enhanced formation-stress evaluation
- Correlating well position geophysically using high-resolution acoustic images while drilling

AN EXAMPLE OF ADVANCED WELL PLACEMENT using the Revolution[®] rotary steerable near-bit inclination and gamma ray, along with the deep-reading resistivity, and azimuthal acoustic measurements. DTB inversion was used to calculate reservoir bed boundaries.



CASE STUDIES

SPECTRALWAVE SENSOR
PLACED A 91° LATERAL WITHIN
PAY ZONE IN ONE RUN

MFR AND HAGR SENSORS
PLACED A 3,000-FT LATERAL
AND ACHIEVED 100% KPI

GUIDEWAVE SENSOR
PROVIDED PRECISE
OWC MAPPING

**GUIDEWAVE AND CROSSWAVE
LWD TOOLS** GEOSTEERED TO
MAINTAIN 100% PAY ZONE CONTACT

GUIDEWAVE TOOL HELPED
TO LAND MULTIPLE WELLS
WITH 9000-FT LATERALS IN
A NARROW PAY ZONE

WELL-PLACEMENT SERVICES
IMPROVED PRODUCTION WITH
ACCURATE BOUNDARY MAPPING
FOR AN OFFSHORE CAMPAIGN

GUIDEWAVE TOOL HELPED TO LAND
A WELL IN NARROW PAY ZONE AND
REVEALED AN ADDITIONAL 250 FT
OF OPTIMAL HYDROCARBON ZONE

WELL-PLACEMENT SERVICES
OPTIMIZED TRAJECTORY,
AVERAGED 99% NET-TO-GROSS
FOR FOUR HORIZONTAL WELLS IN
COMPLEX FLUVIAL SAND BAR



WELL-PLACEMENT SPECIALISTS

Make our experts a part
of your team

Working in-house or remotely, our well-placement specialists monitor the drilling process and advise your team throughout the course of your project.

With years of formal training and hands-on wellsite experience, the engineers and geoscientists in our well-placement crews have the background to take the watch, monitor and evaluate the structural and stratigraphic position of your wellbore, and maximize reservoir exposure.



EXPOSE MORE OF YOUR RESERVOIR.

Geosteering can open more of the reservoir to production. We provide the technology to help you stay in zone, and maximize production.

WEATHERFORD.COM/WELLPLACEMENT

CONNECT WITH WEATHERFORD



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