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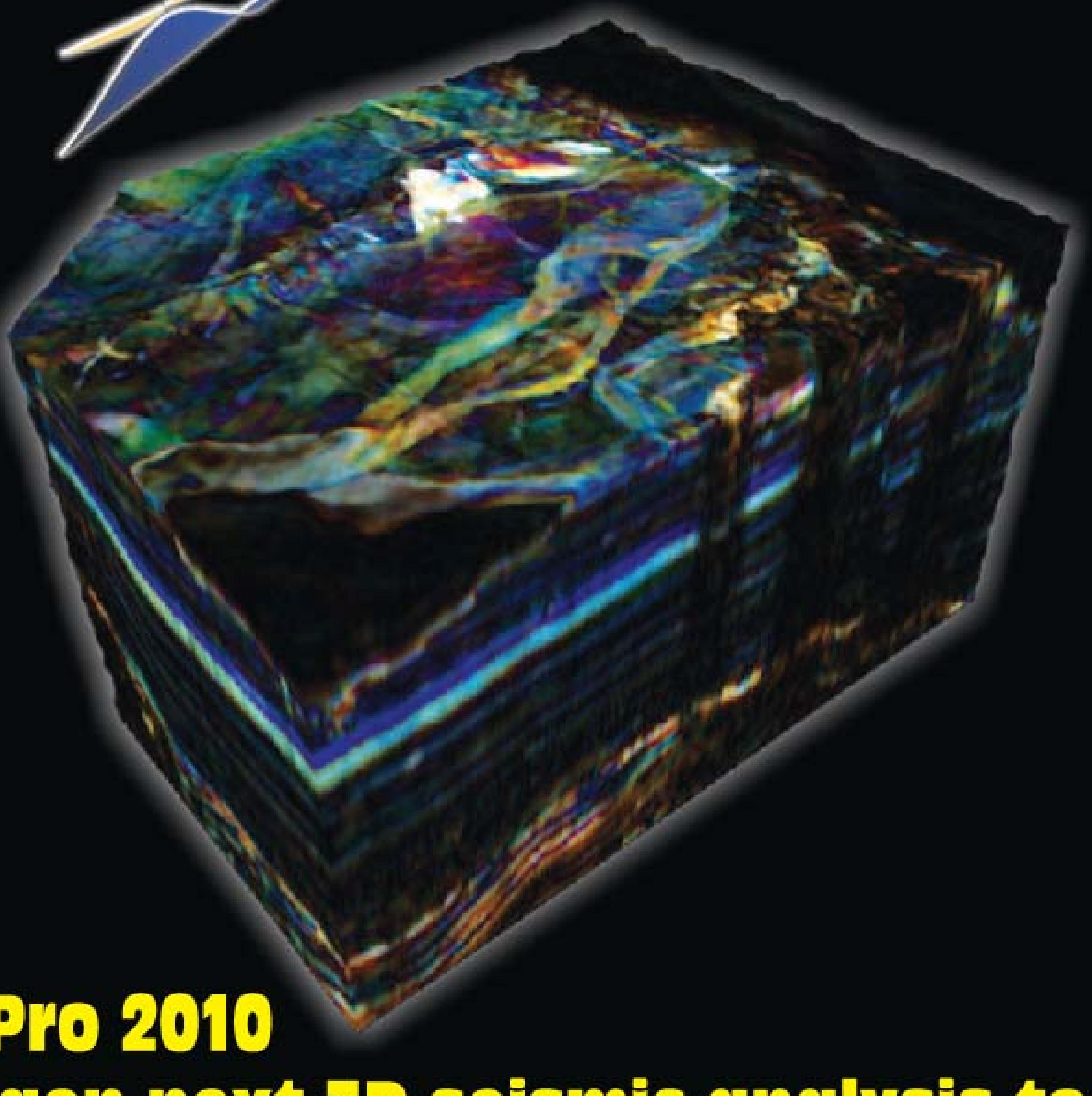

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Updating the Reservoir Model while Drilling - A new Geosteering methodology

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This article examines the growing relationship between geoscience, drilling and reservoir modelling. It looks at how, through the latest version of reservoir modelling solution, Roxar RMS 2010 and new geosteering methodology, reservoir engineers are able to better integrate real-time drilling data within their reservoir model so that the model can be updated closer to the time of drilling.

The Growth of Well Planning and Drilling

The last few years have seen 3D reservoir modelling become the standard platform for the mapping, understanding and predicting of the behaviour of oil & gas reservoirs.

Reservoir models provide the information E&P companies need when developing their assets. They provide models for scenario generation, a spatially accurate analysis of the field, tools to explore reservoir management possibilities, and a repository to store and interrogate information.

One key component of reservoir modelling today and traditionally one of the most expensive elements of the E&P process is well planning and drilling. In an era of complex wells and a need for greater efficiencies in drilling operations, effective well planning and accurate wellbore placement is a vital tool in reducing uncertainties.

With the increasing demand for more efficient drilling operations, the oil & gas industry is searching for new ways of utilizing all available data while drilling. The integration of real-time drilling information with data from offset wells and the reservoir model has therefore become of primary importance in reservoir modelling operations.

This article will examine this growing relationship between geoscience, drilling and reservoir modelling. It will look at how, through the latest version of our reservoir modelling solution, Roxar RMS 2010 and our new geosteering methodology, reservoir engineers are able to better integrate real-time drilling data within their reservoir model so that the model can be updated closer to the time of drilling.

In order to achieve this, however, it is first necessary to look at well correlation and well planning and how it links in to the new geosteering methodology.

Well Correlation - A Smooth Start to the Modelling Workflow

Well Correlation and the ability to correlate horizons and zones between wells provides a crucial start to the reservoir modelling workflow and plays a key role in helping operators make the best possible use of well data.

The new Roxar RMS 2010 release comes with a brand new well correlation system and interface, which makes picking and tracking the geology simpler, faster and more adaptable.

Templates can be well-specific, picks and interpretations can be tracked across multiple wells, and horizons and fault picks can be inserted and interactively adjusted. Hundreds of wells can now be displayed in the same correlation view.

In the new well correlation module, the log data, structural framework, and reservoir data can all be co-visualized together. The reservoir engineer can set up templates to view the well data with flexible colouring and patterning of the stratigraphy, with the user able to flatten the stratigraphy on one or more horizon or between any number of horizons.

Flattening the stratigraphy helps to catch subtle changes in the sequence, as does comparing log responses in different wells using ghost curves which can help find correlation points between wells or within the same wells. The user can click on the ghost icon and select an area into a track. These ghosts can then be moved across wells, or be resized and mirrored to deal with changes in the geology or well path orientation.

Effective well correlation plays a crucial role in the Roxar geosteering methodology, allowing the user to check the correlation of the new well data, trigger a model update, use the deviated well session while monitoring the well, and continue to monitor and adjust the well path during drilling.

And the same goes for target picking and well planning, which allows for the quick design of targets and well paths and the use of seismic attribute parameters, horizons, faults, fluid contacts and simulation results, when designing targets and creating new well paths.

This leads to interactive target planning based on seismic, structural framework, geological or simulation models with a drillable trajectory automatically generated based on customisable drilling constraints.

Well pick functionalities include the ability to calculate intersections using a network-based or horizon model and specific horizon picks can be moved between pick sets.

Analyzing the Proximity between the Bit and Objects in the Model

The growth in WITSML (Wellsite Information Transfer Standard Markup Language) has played a key role in allowing live well data – generated from the well correlation and well planning tools – to be visualized and interpreted whilst drilling as part of the Roxar geosteering workflow.

Take the Bottom Hole Assembly (BHA) data, as illustrated in figure 1. Each of the physical property measured by the MWD (Measurements While Drilling) and LWD (Logging While Drilling) tools can be defined onto the BHA by its distance from the bit.

The BHA specifications can be automatically subscribed via the WITSML receiver and the information used to position each of the logging tools behind the bit. Each physical property recorded by the MWD/LWD tools can be characterized by a measurement point defined as an offset from bottom.

The bit, MWD/LWD tools and the measurement sensors can then be co-visualized with the 3D geological model. For the geologist, this provides an understanding of how far behind the bit the logs are recorded and with the knowledge of the BHA program, logging tools can be visualized and combined with other well data.

The Roxar Geosteering Methodology

The Roxar Geosteering methodology within Roxar RMS 2010 is used to optimize horizontal wellbore placement into the reservoir and is also a means of integrating real-time data into the geological model. It is used to monitor the proximity between the bit or sensors behind the bit and objects in the model, with alarms triggered when approaching or exiting the proximity of objects. These objects can include horizons, contacts, faults, targets, well trajectories, grids and volume properties, and log properties.

Distance calculation can be performed in a number of specific directions, including the shortest distance, the measure depth distance (along the trajectory), the Up / Down distance, the Left / Right distance, the North / South distance, and the East / West distance.

In Figure 2, for example, the Left / Right distance from MWD measurement point to fault B05 and the Measure Depth (MD) distance from Bit to fault B05 following the planned ahead trajectory are calculated.

An alarm methodology – based on the distances between objects and on the differences between property values – has also been developed to help the geologist's decision making. As part of the rules, there are two thresholds to separate the three warnings of green, yellow and red with the threshold definition based on the object uncertainty. These are automatically applied after an update of the real-time data or an update of the model.

Figure 3 defines how the alarms should be triggered with rules depending on the type of object in the model.

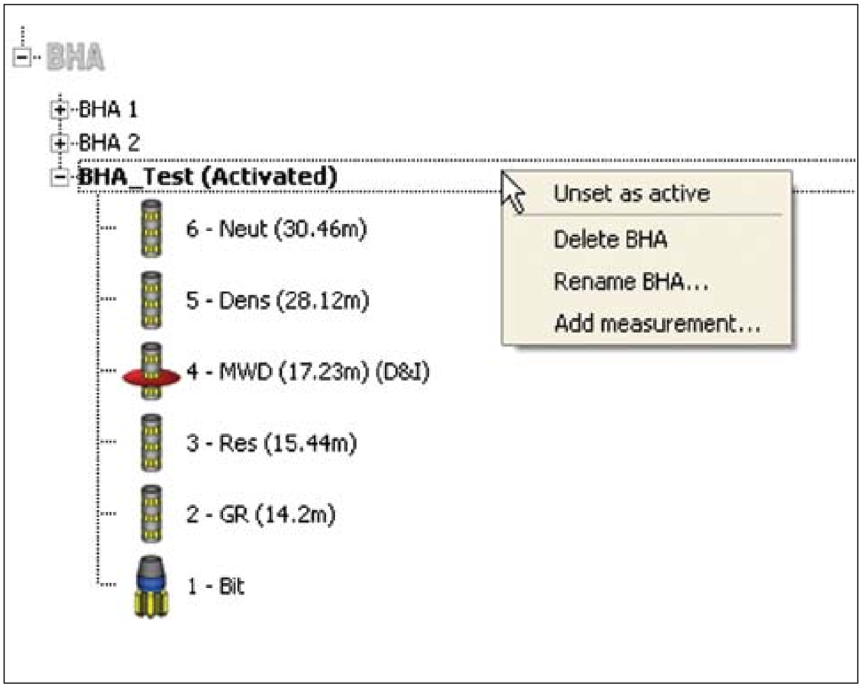

Figure 1

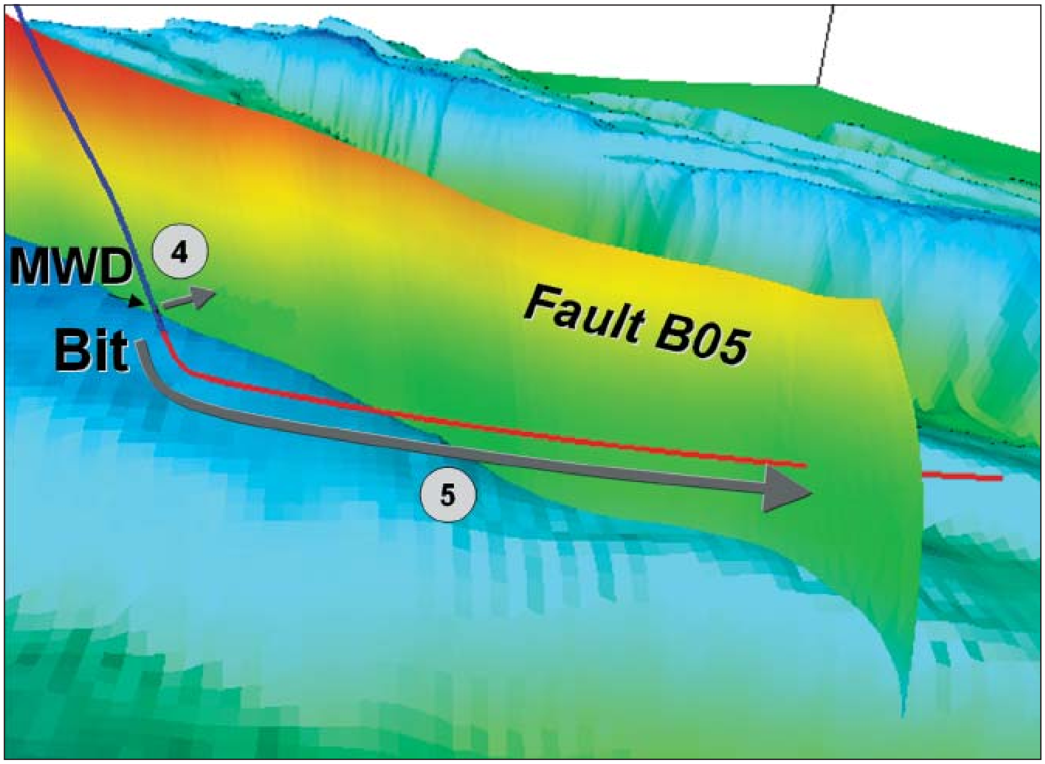

Figure 2

Warnings are activated when the monitored object (the well) crosses the vicinity of the targeted object (Cross-It), when the monitored object leaves the vicinity of the targeted object (Stay Within), and when the monitored object does not stay above (Stay Above) or does not stay below (Stay Below) the targeted object.

Distances between the objects of the bottom hole assembly and geological objects can be calculated and the MWD/LWD information can be monitored against the geological model to predict future trends of the data based on the project-ahead trajectory.

The geosteering diagnosis can consist of 'While Drilling Monitoring', where the operator evaluates the status of the rules at the current location of the bit or the sensor behind the bit; 'While Drilling Prediction', where the operator applies the rules along the project ahead trajectory at regular intervals and displays the MD of the two next changes of status; or where the diagnosis

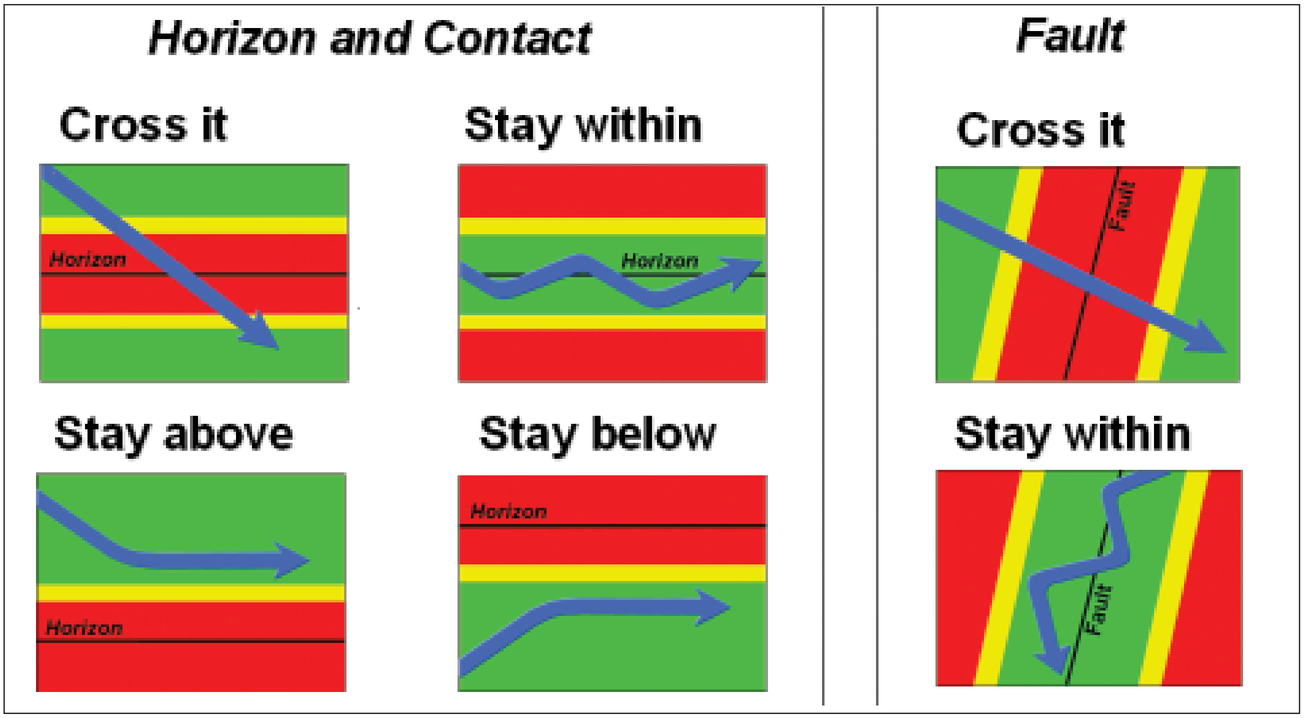

Figure 3

	TopC MD from Bit
Category	Horizons
Monitoring	
Monitored Object	Bit
Monitored Object MD [m]	2201.78
Monitored Object TVD [m]	1532.28
Monitored Object Property	-
Targeted Object Type	Horizon & Contact
Targeted Object Name	TopC
Targeted Object Scanning	Measured Depth
Targeted Object Property	-
Targeted Object Distance [m]	99.41 After
Analysis	
Rule method	Cross it
Prediction	
MD from Monitored Object [m]	2.00
MD from Monitored Object [m]	102.00

Figure 4

	B05 LeftRight from
Category	Faults
Monitoring	
Monitored Object	Survey
Monitored Object MD [m]	2170.7
Monitored Object TVD [m]	1519.7
Monitored Object Property	-
Targeted Object Type	Fault
Targeted Object Name	B05_001
Targeted Object Scanning	Left / Right
Targeted Object Property	-
Targeted Object Distance [m]	257.85 Left
Analysis	
Rule method	Cross it
Prediction	
MD from Monitored Object [m]	1933.0
MD from Monitored Object [m]	1951.0

Figure 5

applies automatically after an update.

Some Examples...

Below are some Geosteering examples, based on the methodology described in the previous section.

Figure 4 monitors the MD scanning from the Bit to TopC. While drilling monitoring finds the Bit 99.41m MD after TopC. The rule is Cross it and the red warning is triggered. The while drilling prediction is that the yellow warning will be triggered in 2m MD and the green warning will be triggered in 102m MD.

In figure 5, the Left/Right distance from the survey measurement to the fault B05 is being monitored with a Cross-it rule. B05 is 257.85m on the left side of the survey tool, initiating a green warning. The 'while drilling' prediction triggered a yellow warning at 1933m MD and a red warning in 1951m MD.

And multiple rules can also be defined and monitored for the same drilling session.

Updating the Model

Roxar RMS 2010 and the Roxar geosteering diagnosis come with a number of model updating features.

For example, there are a number of specific functionalities to constrain the update of the model locally around the well trajectory. These include well pick editing, synthetic vertical wells along the section, and isochore thicknesses and/or structural dip preservation.

Log forward modelling can also be used to understand the stratigraphic position within the model, quantify the editing process, and validate the model. RMS 2010 proposes a functionality called Log from Offset well allowing the calculation of a modelled log based on its stratigraphic position within the model and the correlation with surrounding existing wells. Figure 6, for example illustrates the modelling of the Gamma-ray log (in red) and its comparison with the real-time gamma-ray (in black).

Updates of the structural model can be performed along the horizontal well, on the drilled section and on the planned section ahead. Functionalities are provided in order to locally update the model using different options. For example the model can be updated while preserving the structural dipping, which allow a change in

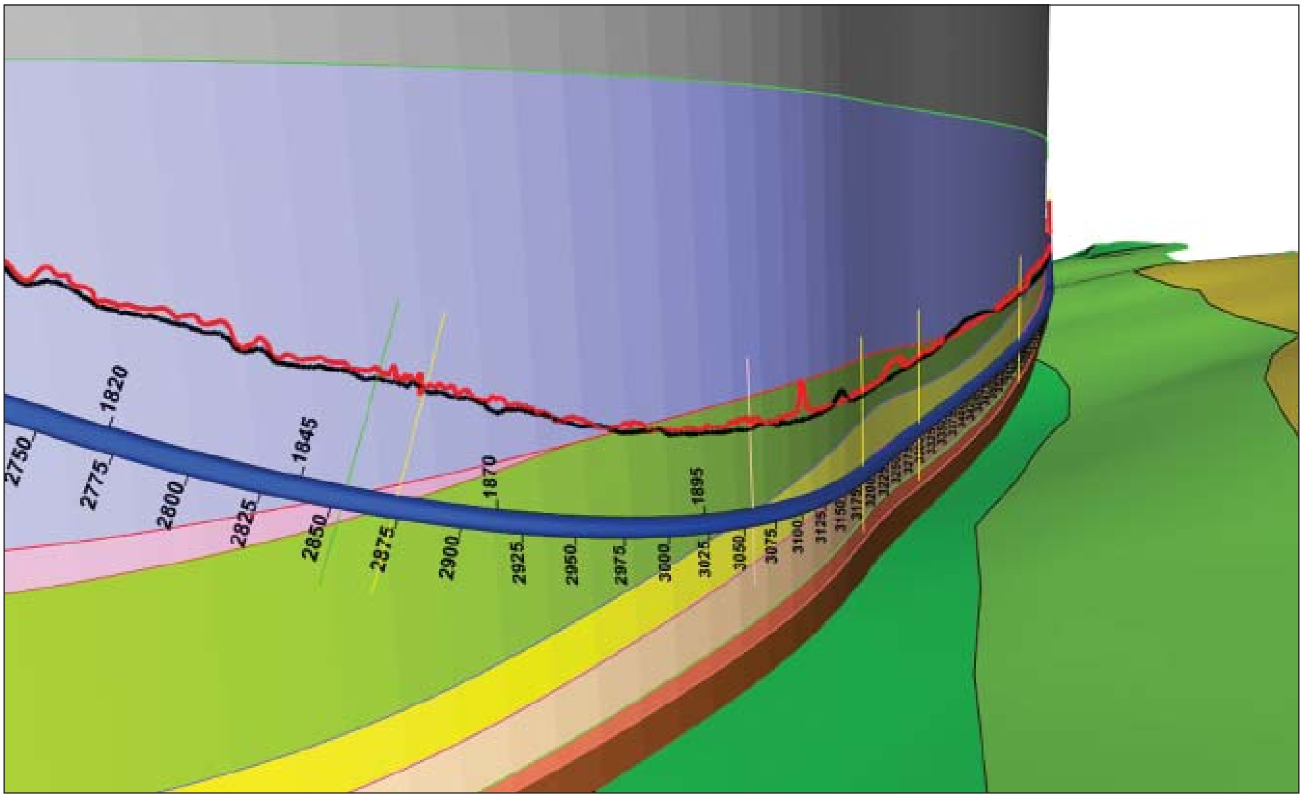

Figure 6

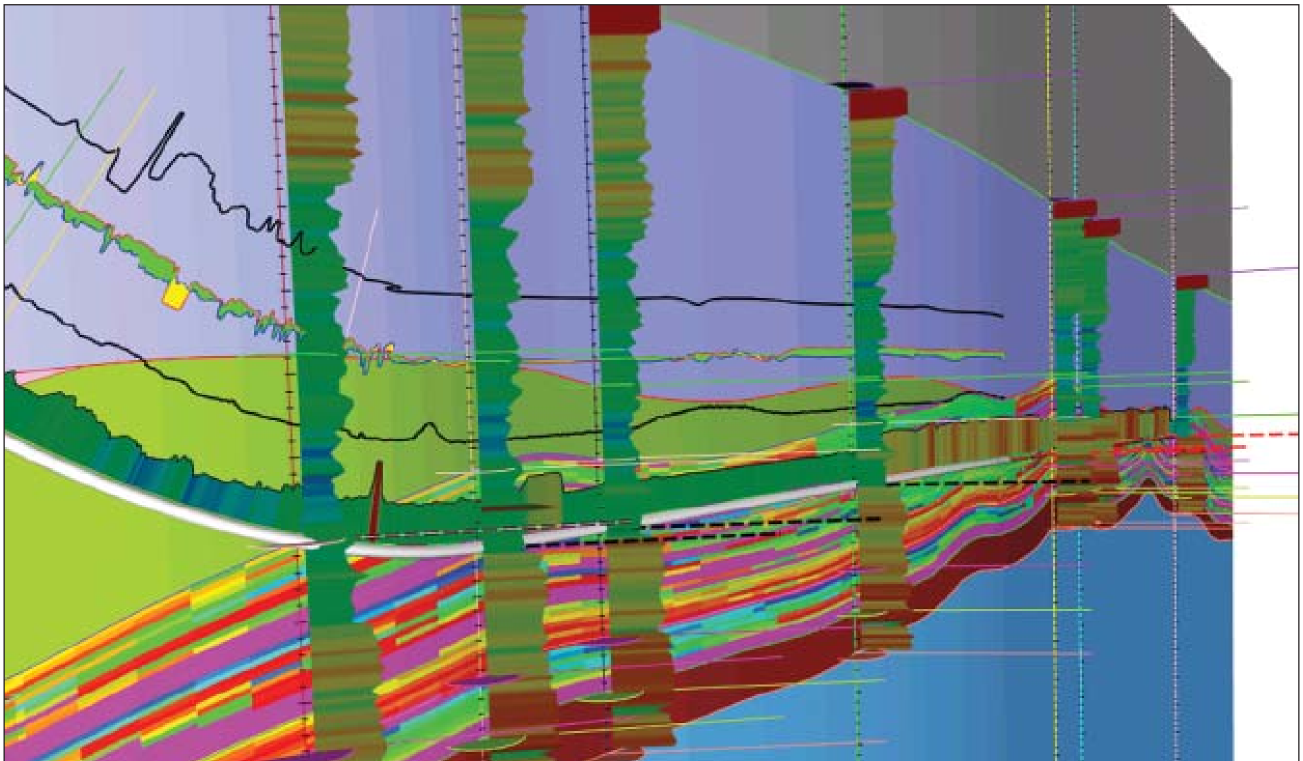

Figure 7

isochore thickness, and while preserving the isochore thickness of the formations, allowing a change in structural dip.

Control points can be inserted along the well where specific editing can be done. Options are available to define how to propagate the editing along the section and log the intervals above and below the current location.

Figure 7 illustrates the representation of vertical wells generated at control point locations along the horizontal well. The vertical wells are very useful in extending the editing vertically to several intervals and horizontally to the entire section defined by the drilled and planned ahead trajectories

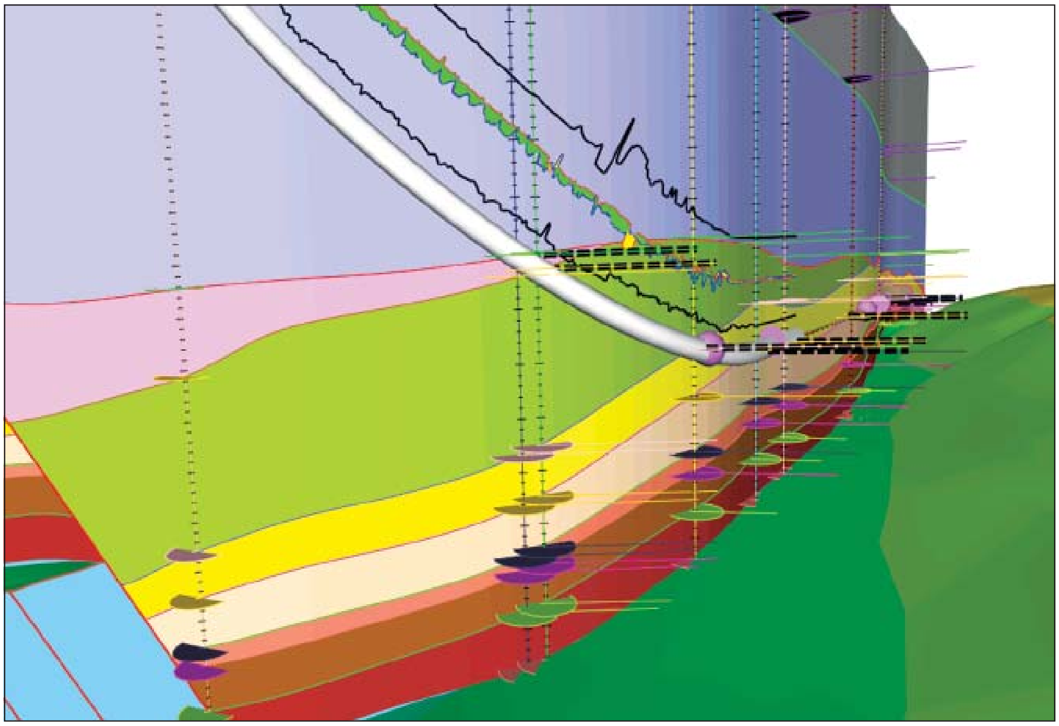

Figure 8 A

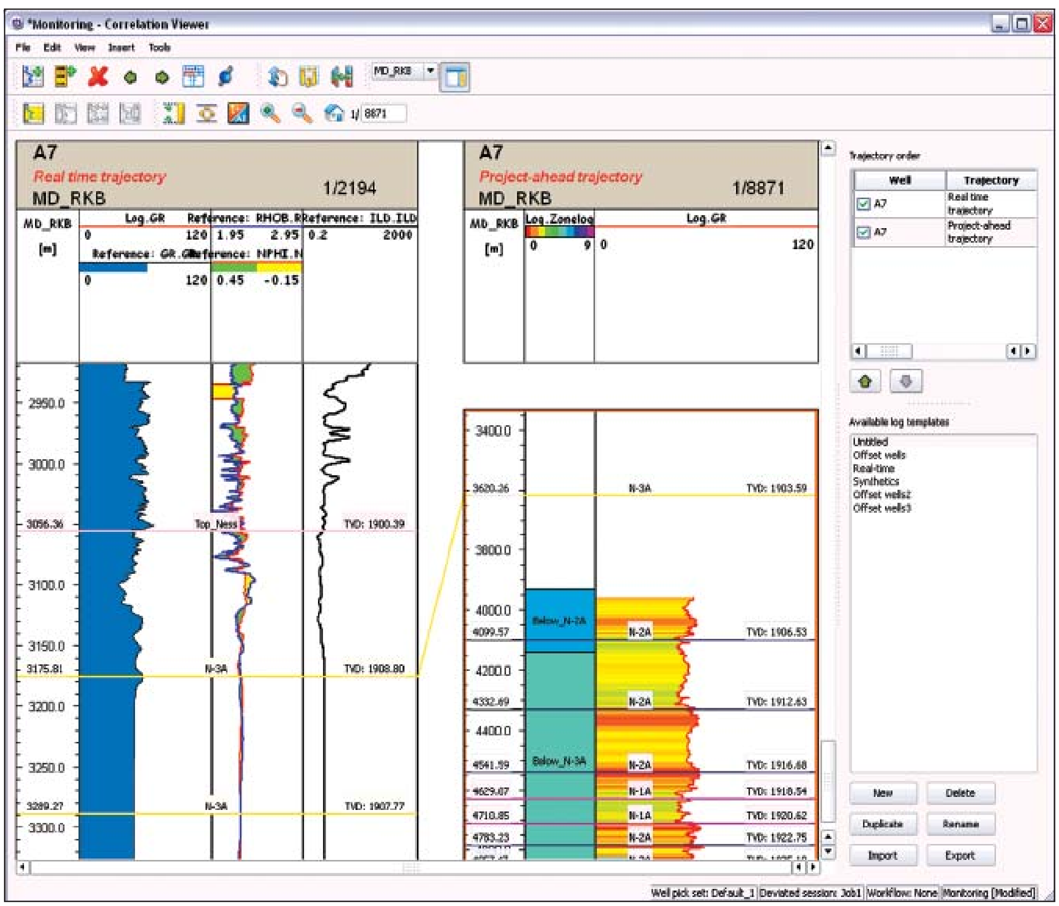

Figure 8 B

Landing the Well & Navigating the Reservoir

Figure 8 provides a geosteering example of landing a well where the targeted well is composed of real-time and project ahead trajectories. The ed-

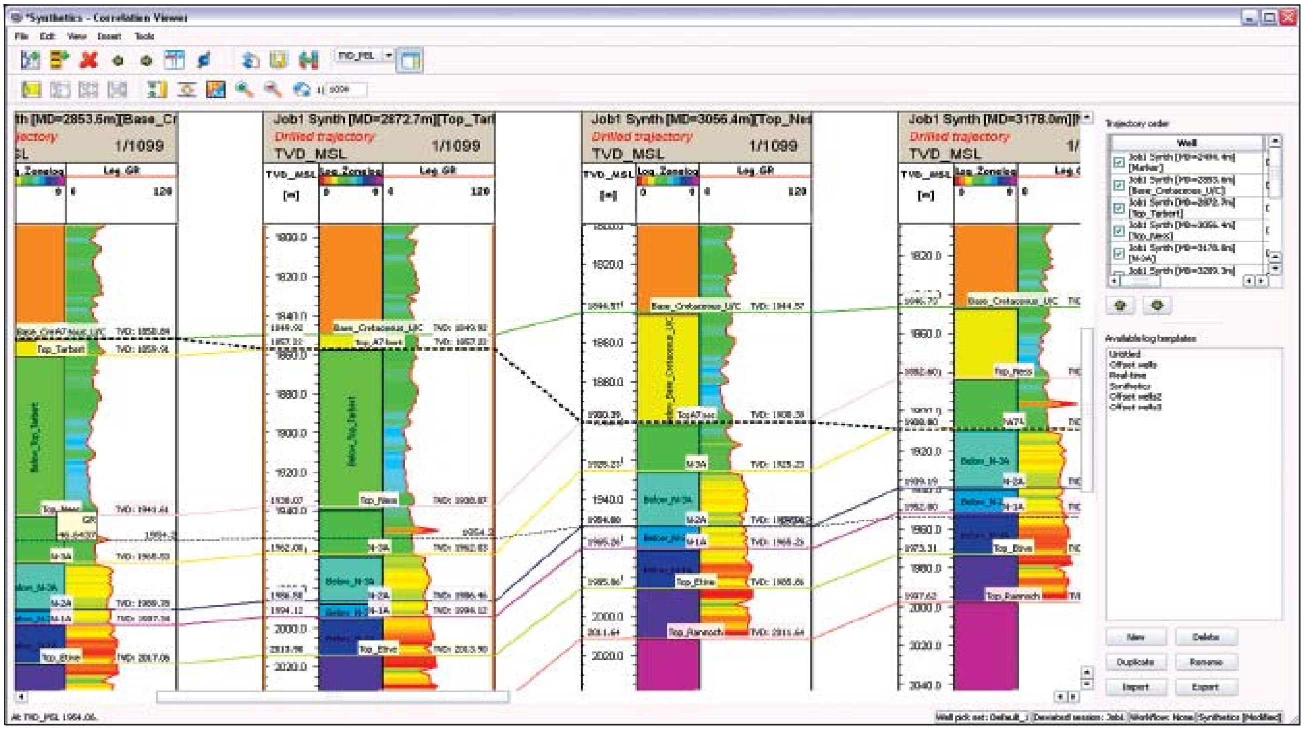

Figure 9

iting is taking place in constant dip and thickness mode and the deviated well session has led to the generation of synthetic vertical wells at control point locations.

The updating of the model has preserved the structural dip and isochore thickness and the workflow-based approach has enabled the well picks along the synthetic vertical wells to be used as input to the structural framework workflow. The local property grid update is also used to keep the grid in sync with the structural framework.

Finally, figure 9 provides an example of how real-time geosteering can help navigate within the reservoir. Editing takes place in constant thickness mode. The synthetic vertical wells can be displayed into a correlation view. A representation of the horizontal well position along these vertical wells (crossing points between both wells) helps the understanding of the stratigraphic position and quantifies the amount of update required.

In the figure 7 the horizontal well is displayed in a full 3D environment with the porosity grid and the LWD logs. The same well in figure 9 is represented here by a dash black line in the Correlation view combined with all the synthetic vertical wells. A modeled GR log and a zone description is also visualized along these synthetic wells.

Updating the Model While Drilling

Correlating horizons and zones between wells; Designing targets and well paths; Understanding the position of each of the LWD tool's sensors behind the bit within the geological model; Monitoring in real-time the proximity between the well and objects in the model; and Local updating functionality to update the model while drilling. These are all key elements in updating the model while drilling.

And for the operator the benefits are clear - a better characterization of reservoir entry, an optimization of the wellbore positioning within the reservoir (thereby increasing well production) and the ability to update the structural model while drilling, through the automatic repositioning of the targets and the redesigning of the planned trajectory ahead of the bit.

Roxar RMS 2010 is leading the way with a robust, real-time, integrated geosteering software tool, supported by well correlation, well planning and local updating functionality, which is having a major impact on reducing uncertainties in well planning and drilling today. dewjournal.com

about the author

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