



## **Optimal tools and technologies for geosteering in conventional and unconventional reservoirs.**

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### **Summary**

The following paper summarizes the geosteering technologies available to geonavigate horizontal wells in conventional, CBM, heavy oil and unconventional reservoirs. It provides recommendations on how to define a particular set of tools and geosteering technologies to place lateral wells in target zones and minimize capital spent on drilling.

### **Introduction**

Geosteering is the act of adjusting the borehole position (angles of inclination and azimuth) on the fly in order to reach one or more geological targets. Most of the horizontal wells drilled worldwide are geosteered. A number of geosteering technologies have been developed to understand the position of lateral wells in the reservoir based on various data, recorded downhole as well as at the surface.

Optimal geosteering tools and technologies exist for every play and geological target. This has become an increasingly important factor in the modern oil and gas price environment, because the effective selection of tools and better reservoir performance are critical to achieving targeted IRR for the lateral well.

The geosteering tools and technologies below are the most popular on the market today.

### **Gamma Ray**

In recent years, MWD gamma ray (GR) tools have become the industry “gold standard” for geosteering. When drilling the lateral, geologists compare real-time GR data with GR from the offset well, thus enabling them to calculate the relative stratigraphic position of the drilling bit.

The main advantages of this technology are its simplicity and cost – tools and services are relatively inexpensive, and it is easy to train new operational geologists.

Most of the challenges associated with the technology are related to potential geological/reservoir issues that cannot be captured by GR data. The target zone must have substantial vertical GR variability, and the reservoir should be laterally consistent. Moreover, GR data alone cannot capture properties such as porosity, water saturation and changes in the reservoir properties along the lateral. Depending on the local geology, the outcome of geosteering based on GR-only data can have substantial uncertainty, especially if the lateral crosses multiple faults and/or stays within the same layer with constant GR behavior.

Additional logs, such as LWD Density and Neurton, can be acquired at the lateral to reduce geosteering uncertainty.

Despite the pitfalls of this geosteering technique, it provides decent results in a lot of onshore shale/tight plays. Integrating the data with mudlogs, seismic, and nearby geosteering results can dramatically reduce the uncertainty.

### **Mudlogs, Cuttings, XRD/XRF**

Mudlogs and descriptions of cuttings are available for most drilled laterals. This data is very inexpensive to acquire and provides extremely valuable geosteering input. Additionally, in the heel section of the lateral it is common at the surface to get cuttings data quicker than GR data, so decisions on the trajectory of lateral wells can be made faster.

In addition to mudlogs, XRD/XRF data can be obtained from cuttings to provide mineralogical logs that can also be used in the geosteering process. This is critical not only in areas where GR MWD lacks sufficient resolution, but also in structurally complex scenarios with multiple faults and dip changes. The use of XRD/XRF data measured on cuttings has proved to be of great value for geosteering in numerous onshore plays.

### **Image logs**

Two- or four-channel real-time GR or density images are becoming standard data acquisition practice in most of the exploration and some of the development of onshore lateral wells. The same data from the tool's memory (8 to 32 channels) is used for post-drill analysis.

Image log data analysis results in true formation dips along the lateral as well as the location of intersecting faults.

Geosteering with image logs can be done even in the absence of good vertical well control in the drilling area. Knowledge of true formation dip can be used to optimize the landing point of the lateral and to reduce dogleg severity in lateral wells.

### **Resistivity forward modeling, resistivity inversion**

Resistivity LWD data are some of the most expensive real-time data to acquire. They provide unique information on formation apparent resistivity that can be used to calculate  $S_w$  and in some cases can be inverted to come up with distance-to-bed and 2D resistivity profiles of the area.

In order to geosteer with an LWD resistivity tool, geologists construct a 2D model of the media and set resistivity for all the layers. The geosteerer then adjusts the model to match the calculated or modeled resistivity curve with the one recorded by LWD. A good match between the model and the recorded data can be achieved with multiple models, which therefore makes it important to integrate the result with other geosteering technologies as well as with additional data – geological models, dynamic models, expected OWC/GWC position. The resistivity tool is not only able to identify the relative stratigraphic position of the bit, but also to capture features such as local thinning and thickening as well as inclined or throw faults.

Some LWD resistivity tools can provide enough data to calculate inverted resistivity profiles and to come up with distance-to-bed and distance-to-OWC/GWC information that can be used to optimize lateral well position and be incorporated into reservoir engineering models of the field.

Resistivity LWD tools are mostly used in offshore and/or in laterally discontinuous plays. Onshore usage of resistivity tools is typically limited to exploration and wildcat wells.

## **Data integration**

Data integration adds great value to the geosteering process. It is very important to cross-check current geosteering interpretation with additional data such as depth-converted seismic data, seismic attribute maps, geological models, and mapped structural horizons.

Unconventional plays are typically developed with multiple stacked or closely located wells. In cases such as these, it is important to cross-check current geosteering interpretation with geosteering from the nearby wells.

Where multiple logs have been acquired – for example GR and XRF/XRF from cuttings, operations geologists need to make sure that current geosteering interpretation is valid for all datasets.

## **Conclusions**

Selecting the proper tools and geosteering technology allows geologists to optimize lateral well placement, increase the percentage of the wellbore in the reservoir zone, reduce the capital needed to drill the lateral and minimize drilling risks.