

## LWD Azimuthal Resistivity Logging in Unconventional Formations

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### Summary

The development of unconventional oil and gas resources is often critically dependent on accurate geosteering of horizontal wells. A new type of LWD Azimuthal Laterolog Resistivity logging tool has been introduced that is specifically designed for geosteering and formation evaluation in complex carbonates, shale-gas, shale-oil, heavy-oil, and coal-bed methane formations. Four case-studies from three years of commercial operations will be presented.

### Theory

A description of the tool design, unique real-time geosteering display, and log presentation software will be presented. Laterolog types of tools are capable of accurate measurement over a wide range of resistivity from 0.2 - 20,000 ohm.meters, enabling hydrocarbon saturation calculation even in tight carbonate formations. In contrast, conventional wave-propagation types are limited to less than 200 ohm.meter formations. However, the adaptation of the Laterolog principle to LWD has usually been limited to imaging applications with very shallow depth of investigation.

The new tool is able to detect approach to a parallel bed-boundary of contrasting (lower or higher) resistivity. Azimuthal wave-propagation tools can detect only nearby conductive anomalies, which prevents their application in geosteering wells (such as shales) where the target formation is often of lower resistivity than those on upper or lower boundaries. The new tool has thin-bed resolution of 0.15 meters, enabling it to image naturally-fractured zones for real-time production analysis while drilling, with significant potential cost-savings.

### Examples

The first tests in Canada were in extended-reach offshore drilling in Dolomite formations in Newfoundland, followed by the Montney Shale in NW Alberta. The tool has given good results in thin heavy-oil beds in fields near Lloydminster and in the Viking and Bakken formations in Saskatchewan. In the United States, the tool has found success in the Niobrara in SW Wyoming, the Bakken in North Dakota, and the Wolfcamp in West Texas. Interest in China led to tests in Talimu Oilfield (Xinjiang Province) in deep gas wells where the new tool was able to accurately measure resistivities ranging from 10,000 - 100,000 ohm.meter. Tests have also been run in Changqing oilfield (Inner Mongolia) where the Sulige tight gas-sands are particularly difficult to produce.

### Conclusions

Independent Directional-Drillers and MWD operators can provide pro-active geosteering using the new service with significant cost-savings for the producing companies.