Demonstrating Capability

Major improvements have been made over the last two decades in measuring drilling parameters (MWD) and logging formation characteristics (LWD) whilst drilling. During the logging of two North Sea fields, the advantages and quality of real time data in horizontal wells have been fully demonstrated.

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Measuring the properties of geological formations and reservoir fluids has traditionally been performed with logging tools run on an electric wireline, a technique that was developed in the 1920's. For a long time this was the only method of acquiring accurate subsurface data in boreholes.

The benefits of wireline logging are obvious - the measurements are performed in a static environment, the contact between the tools and the formation is good, the depth control is excellent, and the tools used are proven through several decades of operations.

With high rig costs and increased focus on operational efficiency, there are also certain inherent disadvantages with wireline logging. The data acquisition requires a halt in the drilling operation and, given that there is a problem in getting the tool into the hole or retrieving it, wireline logging introduces added risk for time delays and in a worst-case scenario, the hole may be lost.

Wireline logging is therefore now used in wells with added focus on the quality of the formation data, in wells where the risk of getting stuck is low, or where there is a requirement for specialized services, such as sampling of formation fluids.

Steering the drill-bit

Since the early 1980's, huge resources have been spent on developing a method to perform data acquisition simultaneously with the drilling operations, i.e. in real time. This technique is called Logging While Drilling (LWD). Since the introduction of the Gamma Ray tool more than 20 years ago, there has been a rapid development of more advanced LWD measurements.

Through LWD, it is possible to optimize well positions, avoid drilling hazards and drill more efficiently. The operators expect the downhole data to be as updated as possible, i.e. they want real-time data and data acquired as close to the drill bit as feasible.

Engineers from Baker Hughes INTEQ on the rig floor following the MWD/LWD tools being run down the well.

Recent developments in LWD have made it possible to acquire high-resolution electrical borehole images. For the geologist, real-time interpretation of structural and sedimentary features from borehole images can be used to steer the drill bit in the reservoir section. The purpose would be to stay inside a desired sedimentary package based on the rapid interpretation of sedimentological criteria (e.g. sedimentary steering by using predictive models of sandbody geometry and internal architecture). This can give forewarning of approaching features in the proposed drill path, such as.fracture intensity increasing towards a fault zone, and avoid or mitigate adverse features that may have a negative impact production , for example by avoiding reservoir roof rocks by steering away in advance.

North Sea experiences

On several field developments, INTEQ has provided multiple advanced formation evaluation measurements and thereby replaced the need for wireline logging.

Data acquisition wells operated by Norwegian oil company Hydro in the North Sea, such as Oseberg West Flank and Grane, are based on LWD-acquired formation evaluation data. It has been demonstrated that LWD systems can provide data for comprehensive formation evaluation and petrophysical analyses, and that the LWD technology is capable of operating with high reliability and at the same time delivering excellent data quality[1].

In Grane well A, comprehensive formation evaluation data was obtained throughout the 1,617m reservoir section and acquired in a single drilling run to TD over 107 circulating hours. In Grane well B, the same data was acquired in a 2,030m horizontal reservoir section that was drilled in a single run of 236 circulating hours.

Spending up to 2 weeks in the hole with continuous operations is quite impressive, given the tough drilling conditions coupled with highly advanced electronics and computer technology integrated in the downhole tools.

The data collected in these wells was extensive and included gamma ray, resistivity, neutron porosity, formation density, image logs, acoustic travel time, formation pressure and mobility (TesTrakTM) and extra deep reading resistivity measurements.

By collecting the data during drilling in a single run, the whole logging process is made more efficient and the wells are put on stream earlier than if an extensive wireline logging program been selected.

The technology

The LWD technology adds significant value for several reasons:

(a) Reservoir geometry is better understood by combining different log measurements with seismic data. The near-wellbore measurements, such as gamma ray and density wellbore images, can be used to interpret stratigraphy while the variety of resistivity measurements may be employed to interpret wellbore geometry. By combining this information with formation pressure and the seismic interpretation, the reservoir model may be improved. The understanding of log responses in horizontal wells is a key factor in this.

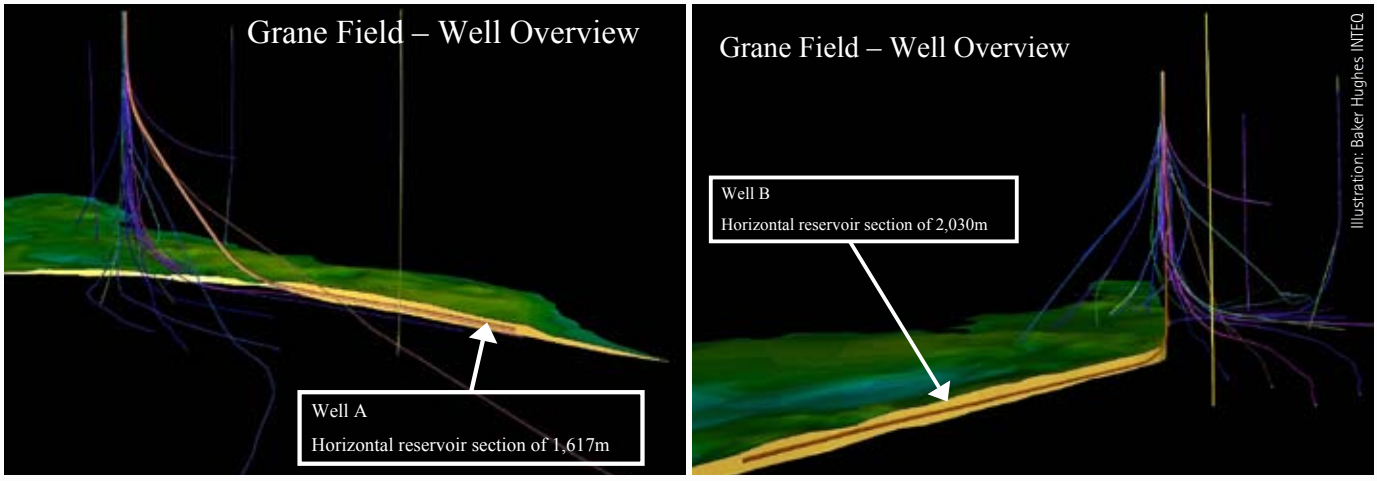
(b) Acoustic compressional (P) and shear wave data (S) are provided in a full range of formation types. In acoustic terminology, formations are split into fast and slow. Acquisition of shear waves in slow formations has been a challenge. The unique quadruple acoustic excitation method also enables the acquisition of quality shear

Mud Pulse Telemetry

Mud pulse telemetry is today the most commonly used method of transmitting data from the measurement tools in the well-bore to the rig at the surface.

While drilling, mud is pumped from the surface down through the drill-string, through the measurement and logging tools (MWD/LWD), then through the drill bit and back to the surface through the annulus between the drill-string and formation.

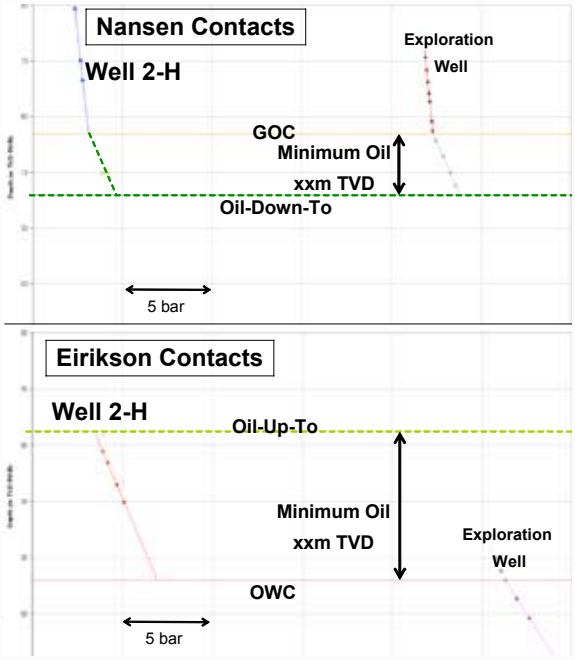
The increase in number of advanced measurements puts a higher demand on data transmission speed. Mud pulse telemetry is limited with regard to bandwidth and can only give 10-12 bits per second (bps) data transmission. To maximise the real-time value from the advanced measurements, will need kilo-bps capacity. The newly introduced wired drillpipe technology can be the solution for supplying this capacity. Several oil companies in the North Sea are currently planning test runs.

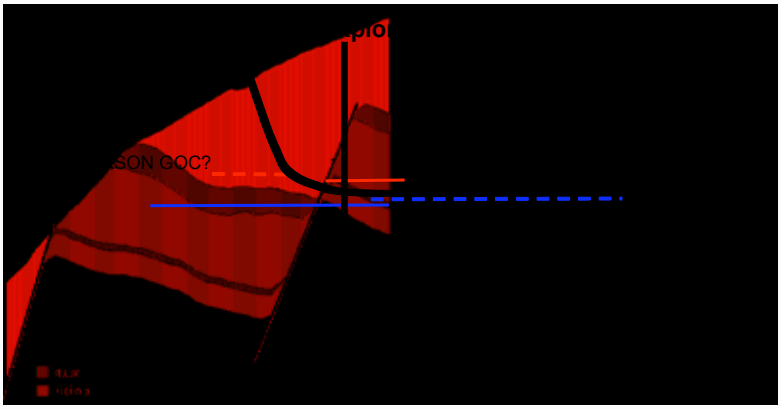


Well profiles for Grane wells A and B.

1) In technical papers written jointly by Hydro and Baker Hughes INTEQ, LWD operations from the Grane and Oseberg West Flank fields were presented that exemplified how combinations of highly advanced LWD technologies have been run successfully ("Multiple Advanced Logging-While-Drilling Technologies Optimized for Drilling and Well Placement" given at the Offshore Technology Conference in May 2006 and "Application and Interpretation of Multiple Advanced LWD Measurements in Horizontal Wells" at the Society of Professional Well Log Analyst - SPWLA Annual Conference in June 2006).

Illustration: Hydro





Interpreted pressure results of Oseberg West Flank Well 2-H. The upper plots display the reservoir fluid gradients and the fluid contacts interpreted in the Nansen and the Eiriksson formations. The lower cross section summarises the interpreted fluid contacts (GOC – gas-oil-contact; OWC – oil-water-contact).

data in the full range of formations (fast and slow).

(c) In minimal time, accurate formation pressure tests are acquired through a combination of good drilling practices, teamwork on the rig and the downhole intelligent optimisation system. Less than five minutes were needed to obtain three formation pressures per depth station. For these two case wells, formation pressures were acquired at a total of 62 depth stations, with a sealing efficiency of 98.5%. Formation pressure data was used for gradient plots and provided information on the type of reservoir fluid encountered and pressure communication in the reservoir.

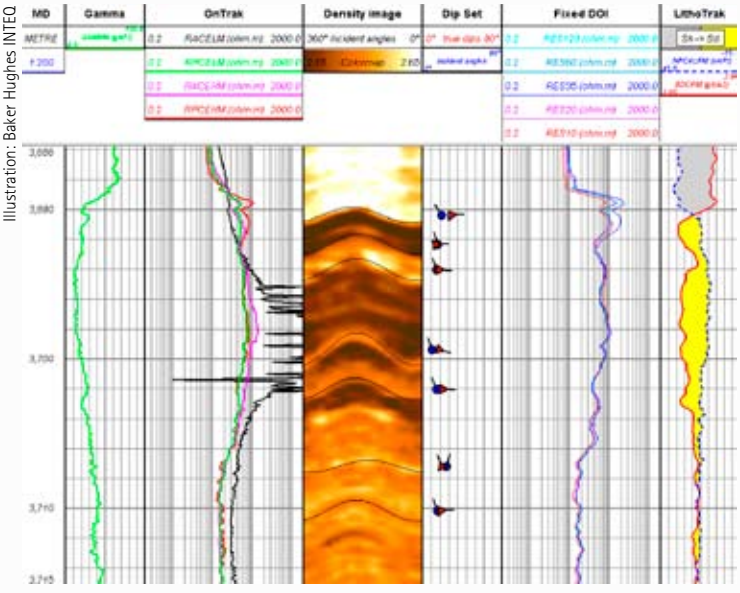
In horizontal wells, special resistivity responses are experienced when crossing formation boundaries. Software processing methods such as inversion, enhance the measured resistivity. Combining inverted resistivity data with borehole image interpretation will help to enhance the determination of bed thickness as well as increase the accuracy of the true resistivity for that particular bed and improve the definition of the bed thickness. The result is a better definition of reservoir thickness and extent and a clearer idea of the amount of hydrocarbons present.

In real-time

The family of LWD-services has developed into reliable and value-adding services for today's advanced world of drilling and logging wells. The wealth of information now available in real-time helps to position the well accurately and facilitates in the mitigation of drilling hazards.

The main advantages of using MWD and LWD are thus optimisation of well placement, increased operational efficiency by reducing non-productive-time, improved knowledge of the reservoir and hence, enhanced production.

Illustration: Baker Hughes INTEQ



Comparison log between industry standard LWD resistivity logs (track marked OnTrak) and inverted resistivity log (track marked Fixed DOI) to show the enhanced interpretation available when combining the density image log with the fixed depth of investigation resistivity curves.

MWD and LWD

Measurement While Drilling (MWD)

MWD includes measurement and acquisition of directional data (wellbore inclination and azimuth), pressure in the wellbore and drilling dynamics measurements such as vibration and shock. MWD thus provides geometrical information on well position and helps to drill the well safely and efficiently.

Logging While Drilling (LWD)

LWD is logging the properties of the formation and reservoir fluids while drilling and before drilling fluids invade the formation, similar to open-hole, wireline logs. The most frequently used measurements include gamma ray, resistivity, density, porosity, acoustic travel time and formation pore pressure.