Real-time seismic now available from an LWD tool

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A RECENTLY COMMERCIALIZED downhole seismic-while-drilling system enables the operator to look ahead of the drill bit, reducing uncertainty and risk and resulting in potential savings in the millions of dollars. Much of the time and cost savings is a result of gathering downhole seismic data and transmitting it to surface without halting drilling operations for surveys that typically take several days to accomplish.

Schlumberger's seismicVISION* system delivers checkshot and interval velocity data that results in the continuous correction of the seismic map obtained from surface seismic surveys. Acquiring and transmitting data in real time via mud pulse telemetry reduces the uncertainty of drill bit location on the seismic map. This information enables the operator and driller to identify the depths of both geological targets and potential hazards, enabling decisions to be made in relevant drilling time.

The system includes a logging while drilling (LWD) tool with seismic sensors positioned near the drill bit, a seismic source at the surface located either on a drilling rig or a source vessel, and a measurement while drilling (MWD) system for real-time telemetry.

Stored four-component (4C) waveform data for vertical seismic profiling (VSP) is retrieved from the tool when it is tripped out of the hole and can be processed within several hours at the site or transmitted to a central processing location for more precise interpretation to provide a seismic image of the next section to be drilled.

The seismicVISION tool is available in 6 ¾-in., 8 ¼-in. and 9-in. collar sizes and is compatible with all of Schlumberger's other LWD tools.

REDUCING UNCERTAINTY

Surface seismic data is useful for providing structural maps of the subsurface geology in two-way time. Geologists or geophysicists may see anticlines and locate potential drill sites, however, they can't accurately determine the depth of the geological targets. Additionally, there may be potential hazards that can be seen from the surface seismic data but again it is impossible to accurately predict their depth. Depth uncertainty in the deepwater market can be on the order of hundreds to a few thousand feet.

The checkshot data is used to place the bit on the seismic map to aid in bit navigation, select casing points and prepare for potential hazards ahead of the bit such as faults, pore pressure variations or formation variations. The time and-depth information becomes more accurate as the drill bit approaches the target.

Checkshot data and other indicators are transmitted in real-time via Schlumberger's PowerPulse* MWD system. The mud pulse telemetry tool is capable of data transmission rates from 6-16 bits per second. Patented zero-gap modulators increase signal-to-noise ratios to minimize effects of drilling pumps, motors and other rig-associated noises. Combined with the company's LWD services, PowerPulse provides real-time formation evaluation while drilling.

The tool contains a processor and memory that receives seismic energy from a conventional air gun array located on the rig or a source vessel. Seismic signals are stored in the tool and processed when it is brought to surface at the end of a bit run.

A patented technique enables source activation and data acquisition during pauses in drilling operations when the downhole environment is quiet such as during pipe connections while drilling and tripping.

The system is capable of operating in downhole environments up to approximately 150°C and pressures to about 25,000 psi. To date the system has been used in vertical to horizontal wellbores, wells greater than 25,000 ft in both open and cased holes, hard and soft formations and from moored and dynamically positioned rigs.

OPERATION

The system utilizes a conventional air-gun array as the source at the surface. The 4C data is stored in the tool's memory with real-time checkshot data transmitted from the tool to the surface via mud pulse telemetry. Source firing is conducted during pipe connections to eliminate noise in the data as well as eliminate lost rig operating time typically resulting from logging operations.

Checkshot data acquired during the first bitrun is used to situate the bit on the surface seismic map, calculate interval velocities and make initial depth predictions.

The recorded and stored data is processed after the bitrun to obtain final interval velocities and produce a fast turnaround VSP corridor stack for comparison with the surface seismic.

seismicVISION enables the operator to look ahead of the drill bit, reducing uncertainty and potentially savings of millions of dollars.

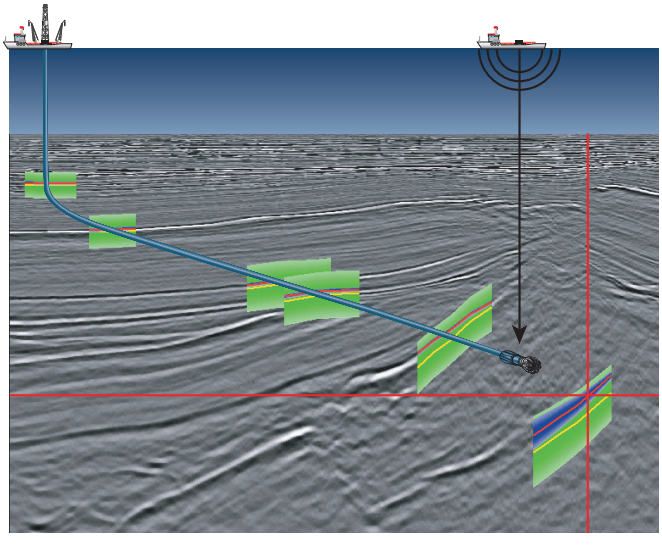
Obtaining a good seismic tie between the downhole data and surface seismic eliminates depth uncertainty caused by small static shifts or phase differences.

The surface seismic can be shifted and phase corrected should there be a mismatch of the surface and VSP data. Once this is accomplished the VSP and corrected surface seismic should pro-

vide the same predicted depth for a particular target.

The velocity utilized to predict ahead of the bit position in subsequent bitruns is based upon an extrapolation of the VSP time/depth curve and can be continuously updated in real time using checkshot data from the current run. This approach can be used for subsequent bitruns to enable accurate depth predictions for additional deeper targets.

Once the tool is pulled out of the hole it takes about 40 minutes to download the data if the system's memory is full. In deepwater wells, it could take a couple of days to trip back into the hole. The quick data processing turnaround means that the processed product will



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be available to the operator before the next bitrun.

The basic interpretation is performed on the rig, however, Schlumberger's InterAct data transfer service can be utilized to transmit the data to a processing center for a fast turnaround of the processed data back to the rig. A final report would include time, depth, velocities and the look-ahead image and seismic tie to the surface seismic data.

How far ahead of the drill bit that the system can "see" depends on several factors but generally the tool can provide a look ahead of several thousand feet. The longest look-ahead so far is approximately 7,000 ft, providing plenty of opportunity to make drilling decisions.

LOOKING AHEAD

The present generation of seismicVISION can be considered Phase I. Phase II is expected to be commercialized this summer and will include additional functionalities and capabilities, the most anticipated of which is real-time transmission of downhole waveform data.

In the future, Schlumberger anticipates that receiving waveform data in real time will result in near absolute confidence in the data's quality as well as a real-time look-ahead capability. The downhole seismic information necessary to make critical drilling decisions will then be processed and available to the operator within an hour from the time it is received.

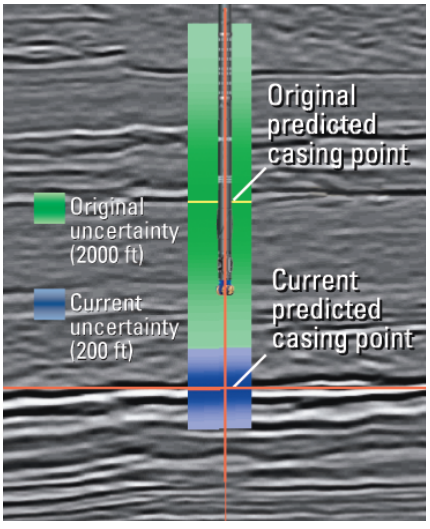
CASE STUDY

Acquisition of time, depth and velocity information from the seismicVISION service was used to identify casing points in real time in a deepwater Gulf of Mexico project. Utilizing the seismic service reduced the depth uncertainty from more than 1,000 ft to less than 50 ft, resulting in the success of the drilling program. These wells were drilled to more than 20,000 ft in more than 9,000 ft of water.

Checkshot measurements and quality indicators were acquired with a surface seismic source and downhole hydrophone and geophone receivers in the LWD tool. The seismic source was a 760-in.^{3} 8-gun airgun array charged to 2,000 psi and deployed from a crane on the rig. The source was activated during pauses for drill pipe connection or disconnection.

Ten shots were fired at each connection and recorded by the seismicVISION system. Time-pick data and quality indicators were retrieved automatically and transmitted to the surface via PowerPulse MWD.

In two wells, the real-time downhole seismic data accurately defined casing points as being outside the depth range of the original predictions. This eliminated the need for one casing string in



Acquiring and transmitting data in real time enables the operator and driller to reduce uncertainty ahead of the bit, potentially saving a casing string.

one of the wells. In another exploration well, the real-time data identified the target as much deeper than predicted. The seismic data allowed the operator to continue drilling ahead rather than abandoning the well, resulting in recovery of a large volume of hydrocarbons.

Although the wells were vertical, the hydrophone waveforms were of sufficient quality for vertical seismic profile processing. In one well the hydrophone saw reflections from more than 7,000 ft ahead of the bit, providing the operator with sufficient time to make drilling decisions or changes.

The bottom hole assembly also included Schlumberger's sonicVISION*, resistivity and density-neutron LWD tools.

The sonicVISION data was calibrated using the while-drilling checkshots and then used to generate synthetics that further increased the accuracy of the seismic positioning. The seismic data was transmitted to the surface without slowing the continuous LWD data transmission.

* Mark of Schlumberger