Acoustic logging tool collects shear data downhole

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A NEW GENERATION crossed-dipole acoustic-logging tool acquires data that can be utilized to calculate shear anisotropy. The WaveSonic™ tool was designed using a systems approach so that tool functions such as transmitted pulse shape, center frequency, amplitude and duration are programmable from the surface. WaveSonic is a crossed dipole sonic tool of an entirely new design using new generation technology to acquire data that can be used to calculate shear anisotropy.

The tool's unique and robust design enhances the ability to acquire wireline acoustic waveforms, providing improved reservoir understanding through increased knowledge about the well's naturally occurring fractures and tectonic stresses.

By using data gained from the tool to determine fast and slow shear slowness and fast shear slowness direction, production well placement and drilling and completion design can be optimized, ultimately increasing net present value, the core goal of any asset program.

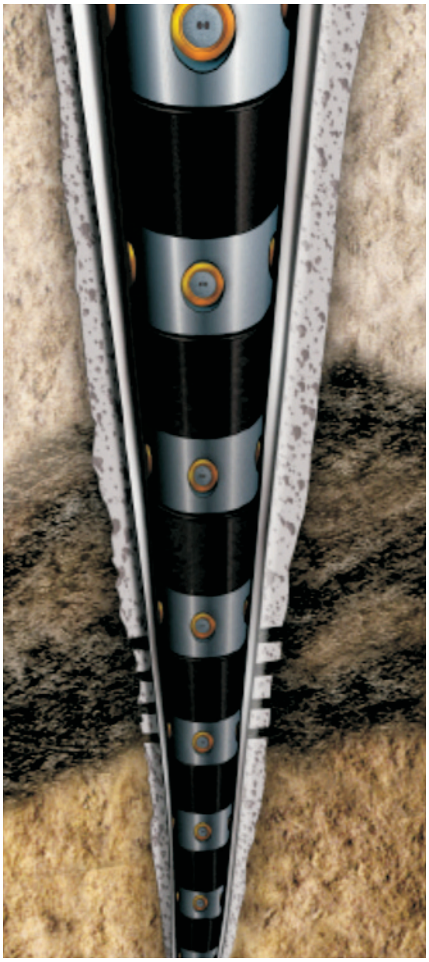
KEY FEATURES

The key mechanical design requirement was physical strength, so that the crossed dipole sonic tool could be positioned anywhere in the tool string, allowing extremely "heavy" tools, such as new generation pump-through formation test tools and nuclear magnetic resonance tools, to run in combination below (or above) this tool.

The tool's flexural wave propagation is controlled by a surface computer, eliminating the need to pull out of the hole to change logging parameters. Shear data is collected in orthogonal X-Y directions and oriented by a navigational package.

From these measurements, shear slowness anisotropy and direction can be determined. Then, the values can be placed into a model to determine maximum and minimum principal stresses and orientations. Model information can be used to optimize completion and stimulation design, and in cases where natural fracture information is desired, crossed dipole data can be used to help detect and orient fracture systems.

One of the tool's key features is its ability to control the frequency of the crossed dipole source, allowing flexural shear wave transmission in reservoir rocks having a broad range of shear slowness values. "Bender Bar" dipole transmitters are comprised of "X" and "Y" dipole sources mounted orthogonally at the same position of the tool. This ensures maximum use of all received waveforms for post-processing analysis.



Halliburton's third generation crossed dipole sonic tool makes it easy to determine fast and slow shear wave travel times and their orientation in the formation.

Eight receiver rings spaced 0.5 ft apart make up the receiver array. Each ring includes four independent receivers that are matched for frequency response and oriented in the direction of the "X" and "Y" transmitters. With a logging speed of 30 ft per minute, the transmitters (monopole and X- and Y-dipole) are fired sequentially and waveforms are digitized and sent up hole in real-time for every 0.5 feet of log.

SHEAR SLOWNESS ANISOTROPY

Shear slowness anisotropy measures the difference in flexural wave propagation slowness based on its corresponding anisotropy. This data can be used to understand far-field reservoir stresses and naturally occurring open fractures. Key applications include:

- Directional drilling – to determine the direction of greatest borehole stability.
- Completion design – to determine far field stress magnitude and orientation.
- Natural fracture detection – for location and orientation.
- Surface seismic applications – to validate 3D seismic data such as AVO analysis.
- Reservoir management – to determine fracture orientation, well drainage patterns, and future well placement.

Shear Slowness Anisotropy Analysis uses an inversion technique to provide simultaneous solution of all waveforms. By firing the "X" and "Y" dipole transmitters and using the "in-line" and "cross-line" received waveforms, fast and slow shear wave slowness (travel times), fast shear slowness direction, and waveform energy can be determined.

STRESS ANISOTROPY

Geologic knowledge of the Devonian Shale in the southeast United States, combined with pressure data from numerous stimulation treatments, indicates tectonic stresses in this formation in this area. Borehole imaging log data indicated that natural fractures were not present.

The mud system and drilling program were designed for minimal formation damage and shale alteration. Borehole imaging log data indicated that there were no natural fractures; therefore, the mud system and drilling program were designed for minimal formation damage and shale alteration. An oriented whole core was acquired and anelastic strain relaxation measurements were performed to determine stress field orientation.

A complete suite of open hole formation evaluation and imaging services were also obtained.

The data indicated that there was approximately a 500 to 600 psi difference in the minimum and maximum principal stresses. This was attributed to tectonic stresses.

During hydraulic fracturing, tensile failure occurred in the minimum stress direction and a hydraulic-induced fracture was propagated in the direction of maximum stress.

The well was completed and a mini-fracturing treatment was performed by under-balance perforating from X857 to X860 in the minimum stress direction. This produced a breakdown pressure of 3,238 psi. A bridge plug was set above the open perforations. The well was perforated from X850 to X860 again using 180 degree phasing TCP guns oriented with a gyroscope in the maximum stress direction and with the same underbalance conditions.

By using data gained from WaveSonic to determine fast and slow shear slowness and fast shear slowness direction, production well placement and drilling and completion design can be optimized.

A mini-fracturing treatment using the same fluids and live annulus for downhole pressure measurements was performed.

The stress anisotropy from dipole slowness data confirmed with breakdown pressure information (approximately 12-13 percent in this interval

Radioactive tracers (RotaScan™) were used on each of the mini-fracturing tests. Data analyses indicated near wellbore tortuosity in the lower minimum stress direction perforated interval.

Both the pressure treatment data and radioactive tracers confirmed that near wellbore tortuosity was due to perforation and stress orientation effects. ■