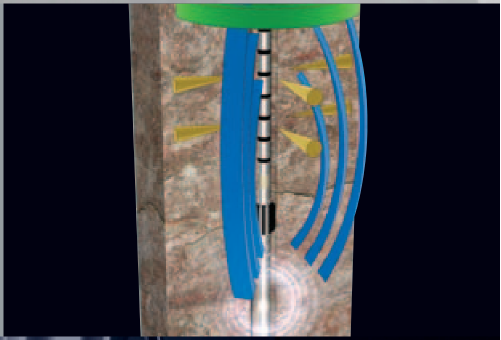
Schlumberger

Sonic Scanner



Acoustic
scanning
platform

Applications

- Geophysics
  - Improve 3D seismic analysis and seismic tie-ins
  - Determine shear anisotropy
  - Input to fluid substitution
- Geomechanics
  - Analyze rock mechanics
  - Identify stress regimes
  - Determine pore pressure
  - Evaluate well placement and stability
- Reservoir characterization
  - Identify gas zones
  - Measure mobility
  - Identify open fractures
  - Maximize selective perforating for sand control
  - Maximize safety window for drawdown pressure
  - Optimize hydraulic fracturing
- Well integrity
  - Evaluate cement bond quality

Benefits

- Enhance hydrocarbon recovery
- Make real-time decisions with real-time quality control
- Improve reserves estimates
- Decrease operating time and reduce job costs by eliminating multiple logging runs
- Reduce uncertainty and operating risk

Features

- Robust measurement of compressional and shear slownesses
- Increased logging speed (1,097 m/h [3,600 ft/h])
- Multiple monopole transmitter and receiver spacing
- High-fidelity wideband waveforms and dispersion curves
- Large receiver array
- Predictable acoustics
- Enhanced behind-casing measurements with simultaneous cement bond log (CBL) and Variable Density* cement bond quality measurements
- Extremely rugged electronic package

Adding radius to borehole acoustics

For decades, the oil and gas industry has used borehole acoustic measurements throughout the lifecycle of wells to evaluate rock properties in the near-wellbore region. As the industry continues to develop new methods for producing hydrocarbons more efficiently, a focus on well integrity has become ever more important.

Schlumberger has designed a tool using the latest acoustic technology for advanced acoustic acquisition, including cross-dipole and multispaced-monopole measurements. In addition to axial and azimuthal measurements, the tool makes a radial measurement to probe the formation for near-wellbore slowness and far-field slowness. Typical depths of investigation equal two to three times the borehole diameter.

The new Sonic Scanner* acoustic scanning platform provides advanced types of acoustic measurements, including borehole-compensated monopole with long and short spacings, cross-dipole, and cement bond quality. These measurements are then converted into useful information about the drilling environment and the reservoir, which assists in making decisions that reduce overall drilling costs, improve recovery, and maximize productivity. The following field examples demonstrate the greater flexibility in acoustic measurements offered by the Sonic Scanner tool.

Achieving a better understanding of acoustic propagation

To enable a deeper understanding of acoustic behavior in and around the borehole, the Sonic Scanner tool allows accurate radial and axial measurements of the stress-dependent properties of rocks near the wellbore. The Sonic Scanner platform provides multiple depths of investigation, excellent waveform quality, and presentations that reduce the complexity of sonic logging, without compromising the depth of information.

The more comprehensive understanding obtained by using the Sonic Scanner platform helps to improve fracture planning, sand control, and perforating design.

Overcoming earlier acoustic measurement barriers

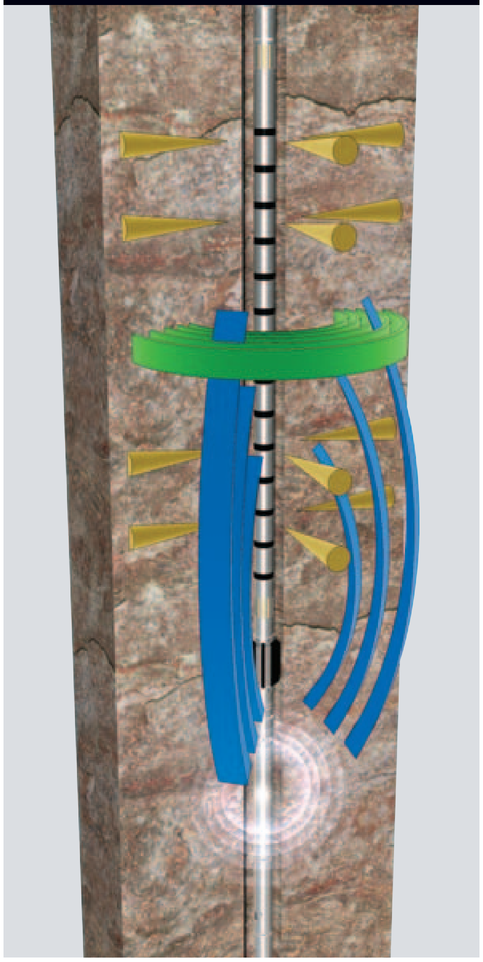
Regardless of the formation type, the Sonic Scanner platform design overcomes earlier acoustic measurement barriers to successful formation characterization and quantification because it

- uses a wide-frequency range that enables characterizing formations as
  - homogeneous or inhomogeneous
  - isotropic or anisotropic
- uses long- and short-monopole transmitter-receiver spacing
- is fully characterized with predictable acoustics.

Earlier technologies attempted to operate close to the tool's low-frequency limit, or they depended on previously acquired formation information to anticipate formation slowness prior to data evaluation.

The wide-frequency spectrum used by the Sonic Scanner tool allows data capture at high signal-to-noise ratios and extracts maximum data from the formation. This design feature also helps ensure that data are acquired regardless of the formation slowness. The monopole transmitters have

Figure 1. The Sonic Scanner tool provides the benefits of axial, azimuthal, and radial information from both the monopole and the dipole measurements for near-wellbore and far-field slowness information.



enhanced low-frequency output over the entire range of sonic frequencies; and the dipole transmitters are designed for high-output power, high-purity acoustic waves, wide bandwidth, and low power consumption.

The Sonic Scanner receivers feature a longer azimuthal array than other acoustic tools; i.e., 13 stations and 8 azimuthal receivers at each station. With the two near-monopole transmitters straddling this array and a third transmitter farther away, the short- to long-monopole transmitter-to-receiver spacing combination allows the altered zone to be seen and provides a radial monopole profile.

Seeing beyond the altered zone

The long-spaced transmitter-to-receiver concept in earlier acoustic tools was designed for “seeing” past the altered zone and attempted to provide an unaltered slowness measurement.

The range of Sonic Scanner transmitter-to-receiver spacings is both short and long enough to see the altered zone and thus provide a radial monopole profile. These features improve measurement accuracy of the fluids and the stress-dependent properties of the rocks near the wellbore; and that benefits fracture planning, sand control, and perforating design, as well as shallow-reading-device point selection.

The wide-frequency spectrum from the dipole transmitters used in the Sonic Scanner platform eliminates the need for multiple logging passes that were common with the earlier-generation acoustic tools. New telemetry, optimized with software and hardware, enables increased logging speeds and decreased operating times.

Obtaining well integrity measurements with high accuracy

The Sonic Scanner tool provides a discriminated cement bond log (DCBL) that can be obtained simultaneously with the behind-casing acoustic measurements. The two monopole transmitters positioned at either end of the Sonic Scanner tool allow 3-ft and 5-ft cement bond log (CBL) and cement bond quality measurements that are independent of fluid and temperature effects and do not require calibration.

To demonstrate the DCBL measurement accuracy, a logging run made with a Sonic Scanner tool is compared with measurements from a CBT* Cement Bond Tool. The DCBL measurements are indicated in blue and the CBT measurements are in black. A very good match is shown between the measurements of the CBT tool and the azimuthally averaged Sonic Scanner platform. The transit time scattering shows ±0.31-in eccentering in the 7-in, 23-lbm/ft casing. The two bond index measurements show good agreement, even in the zone of high eccentralization near the top of the interval.

Removing uncertainties about formation geometry and structure

A recurring problem encountered in reservoir modeling and simulation is the lack of available image data having a fine scale. Until now, the only available alternatives have been to work with surface seismic data, often too coarse in quality, or near-wellbore imaging and its associated limitations. Coupled with the scale of seismic measurements, additional uncertainties arise regarding geometry and structure, formation property variation, and fluid movements.

Figure 2. A very good match is shown between azimuthally averaged Sonic Scanner platform and CBT curves (1). Curve scattering indicates 0.31-in eccentering (10 % of the internal radius) in the 7-in casing (2). A good match between bond index measurements is indicated (3).

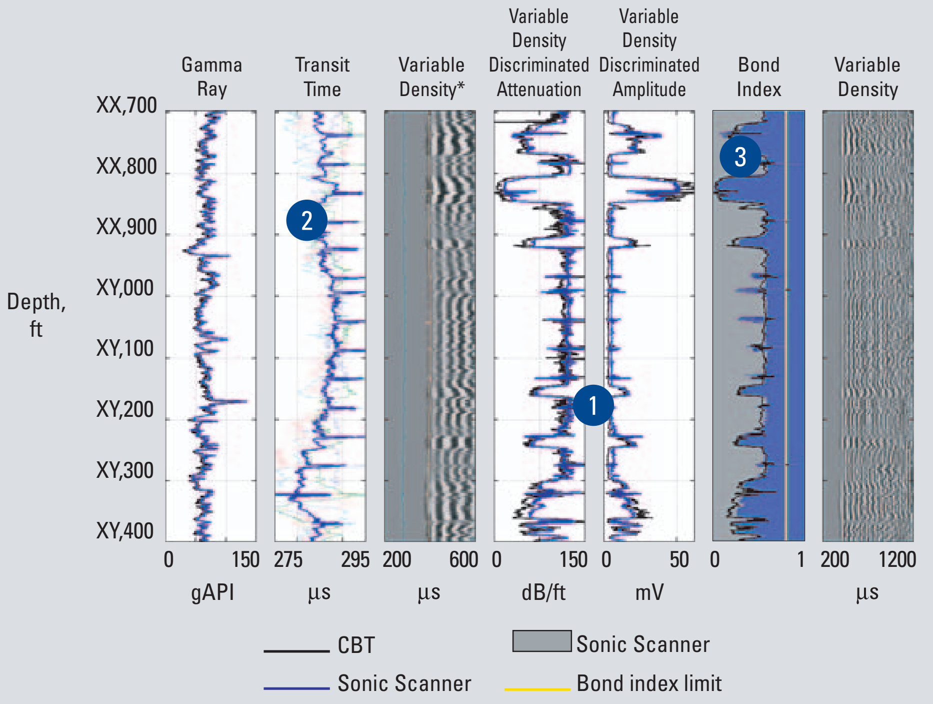


Figure 3. Excellent resolution obtained from the Sonic Scanner tool compared with the surface seismic image.

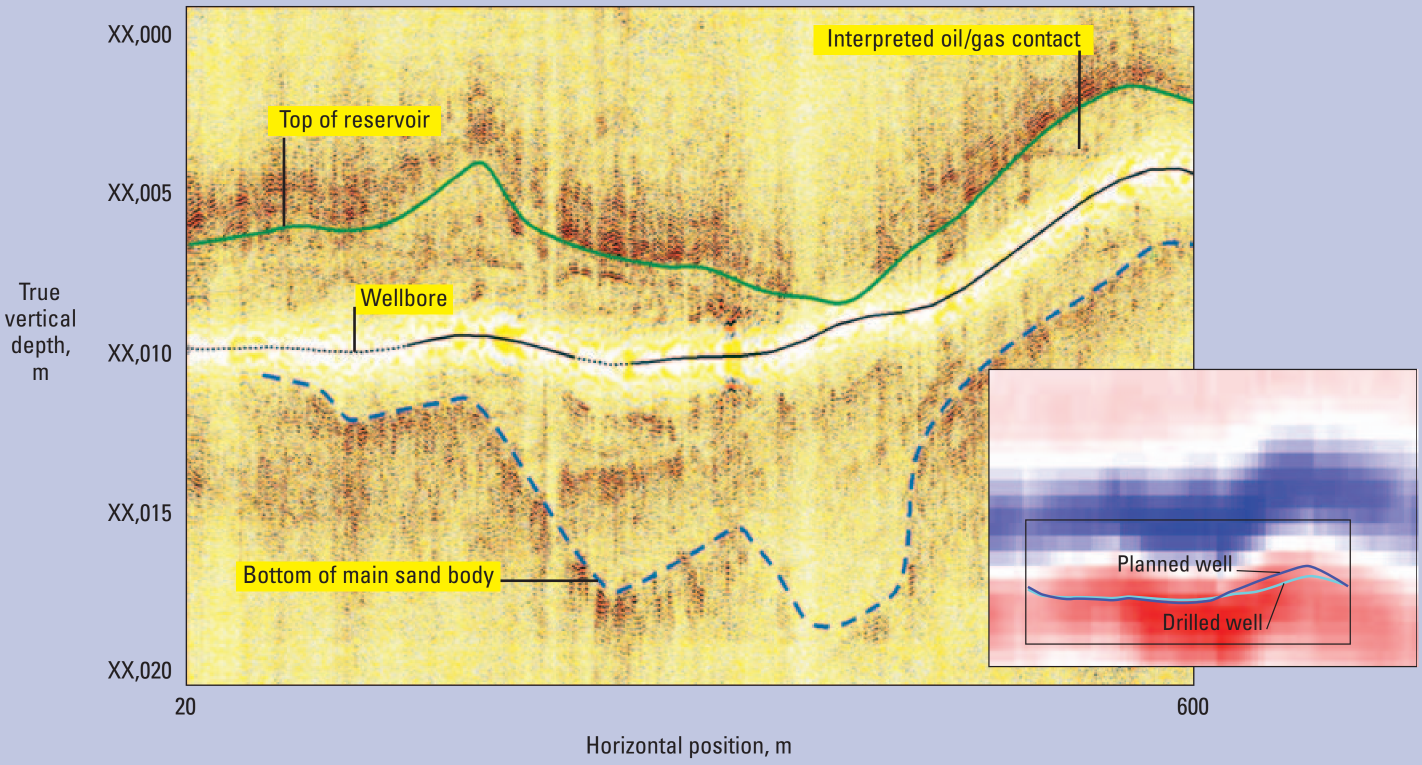
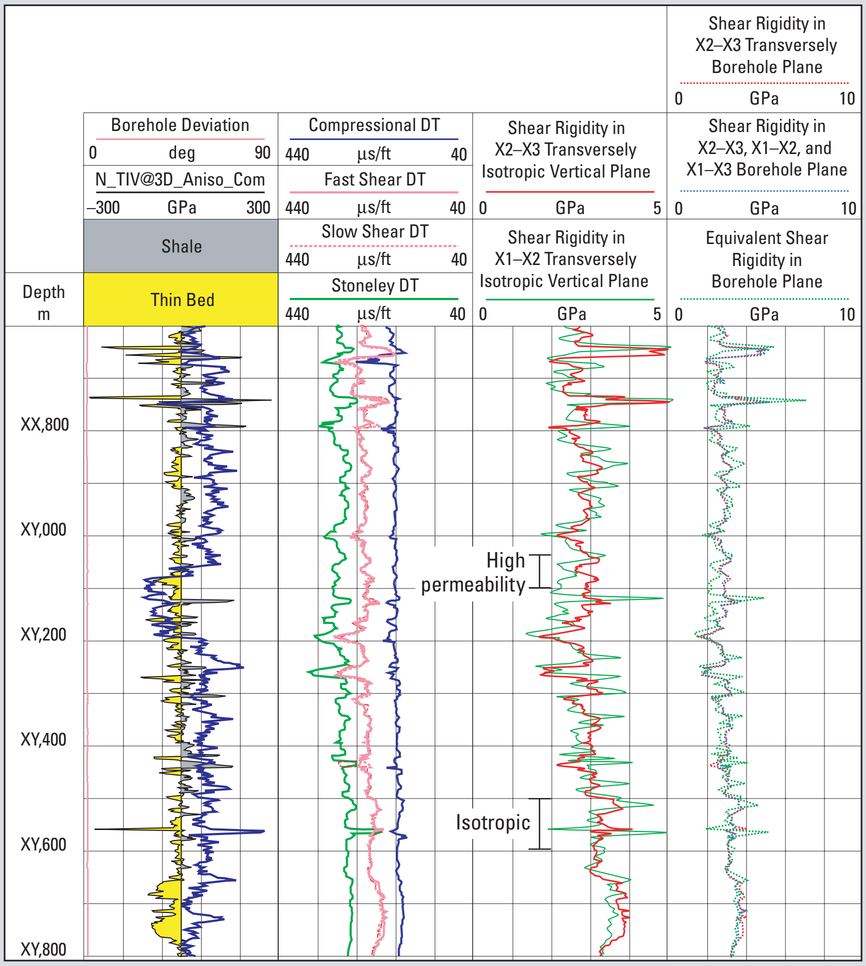


Figure 4. In this example, the high-gamma ray activity indicates a shaly interval. An isotropic zone (N = 0) extends from XY,500 to XY,600 m, and a high-permeability zone exists from XY,005 to XY,100 m.



The inset image in Fig. 3 shows the surface seismic data with normal, rather poor, resolution. In the Sonic Scanner image of Fig. 3, the solid green line indicates the interpreted reservoir top, and the dashed blue line is the interpreted bottom of the main sand body. The purple line shows the wellbore path.

The relative horizontal position along the bottom scale is 20–600 m from left to right, and the vertical scale (deep reading) is in increments of 5 m, showing clearly more than 15 m of excellent resolution compared with the surface seismic image.

The Sonic Scanner image measurements are used to update the geological model and as input to the reservoir simulator for predicting pressure with production.

Obtaining transversely isotropic formation parameters

A 3D anisotropy algorithm transforms the compressional, fast-shear, slow-shear, and Stoneley slowness Sonic Scanner measurements with respect to the borehole axes to anisotropic moduli referenced to the earth's anisotropy axes. These moduli help to classify formation anisotropy into isotropic, transversely isotropic (TI), or orthorhombic types. The moduli also assist in identifying microlayering or thin-bedding-induced TI anisotropy ($N < 0$ implies microlayering-induced intrinsic anisotropy; $N > 0$ implies bedding-induced anisotropy), relative magnitude of principal stresses, and fluid mobility in porous rocks.

Figure 4 shows the 3D anisotropy algorithm's ability to generate the TI parameters. With reference to a borehole that is parallel to the X3 axis, shear modulus or rigidity in the X2-X3 plane and shear rigidity in the X1-X2 plane enable quicklook interpretation of formation anisotropy, stress, and mobility effects.

Determining formation mobility

Because there is essentially no continuous logging measurement of mobility available, other methods have to be considered. One method is to measure formation mobility, which is the ratio of permeability to viscosity.

Mobility, however, is not always available when it is needed because porosity estimates are often preliminary, wireline cores require an additional run into the well, and whole cores are expensive.

When the borehole is in reasonably good condition, Stoneley waves can be used to measure a continuous mobility profile in sands and carbonates. These data can serve as an extension of core permeability over a continuous interval to save on coring costs, or to get a quick permeability estimate for selecting the perforating interval.

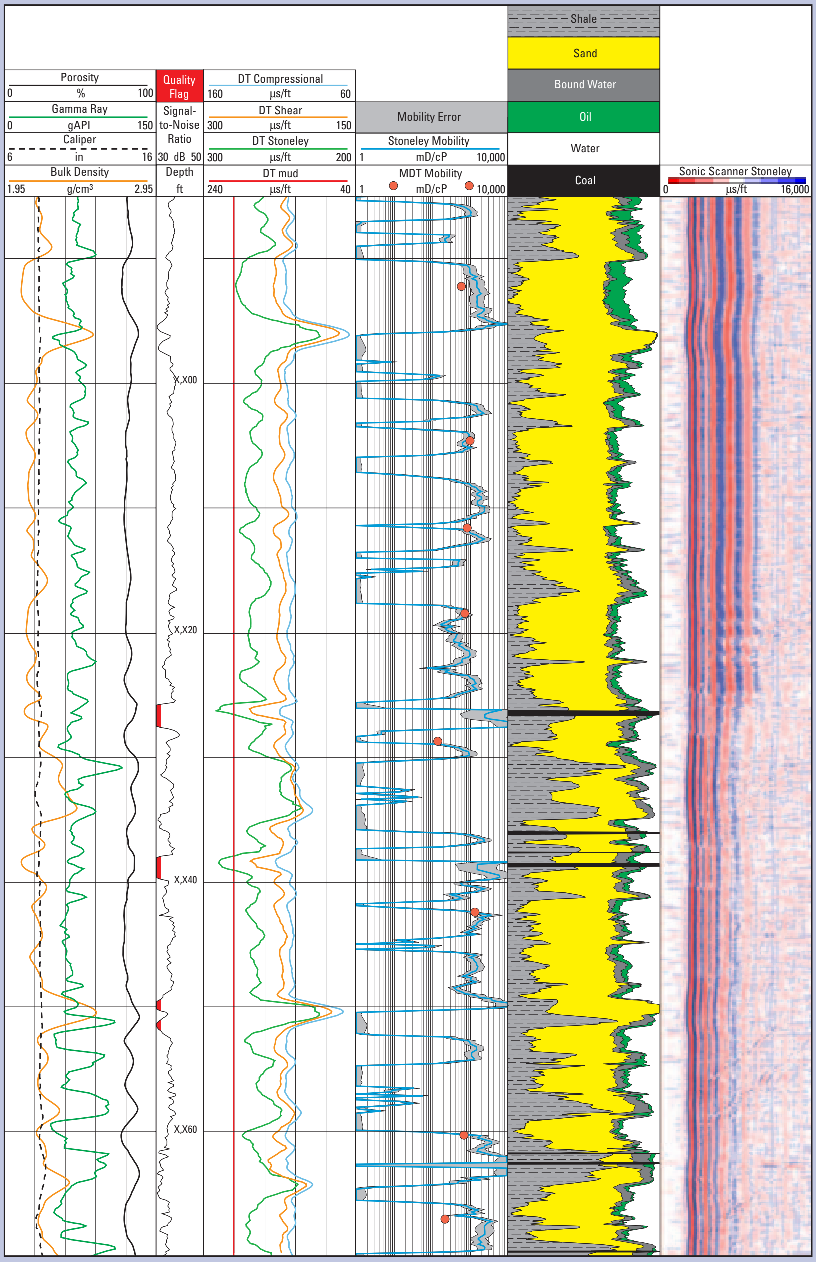
Minimizing the effects of tool presence on sensitive Stoneley wave measurements is extremely important. The design of the Sonic Scanner tool, coupled with extensive laboratory and field testing, enables highly accurate prediction of the effects of the tool on acoustic measurements in all environments.

The example in Fig. 5 demonstrates how the Sonic Scanner Stoneley waves can be used to measure a continuous mobility profile and obtain a quick permeability estimate. Other applications of Stoneley permeability include formation evaluation, production testing strategy and programs, and reservoir modeling.

Evaluating the mechanical properties of formations

Acoustic measurements have typically been acquired in 1D as a function of depth, but seldom in 2D simultaneously as a function of depth and azimuthal direction. And interpretation has almost always been based on the assumption that the formations were homogeneous and isotropic—a debatable assumption,

Figure 5. Mobility measured by the Sonic Scanner tool is shown in Track 4. The red dots indicate mobility values measured by the MDT Modular Formation Dynamics Tester, which show good agreement.*



at best, because of fracture alignment, dipping beds, unbalanced stresses, and formation damage from drilling.

The Sonic Scanner tool enables a full 3D characterization of the formation by adding the radial dimension from the multiple transmitter-receiver spacings, along with wideband frequency measurements and acquisition of all acoustic modes propagating in the borehole. From the expanded set of measurements, dominant formation data can be evaluated and the appropriate processing techniques can be selected to extract 3D acoustical properties.

In a tight-gas reservoir, formation evaluation data and wellbore images were combined with Sonic Scanner shear wave anisotropy and Stoneley wave data shown in Fig. 6. Wellbore stability simulation was used to ensure consistency between the mechanical earth model and the logging and drilling data. The mechanical earth model was then applied to optimize subsequent drilling operations.

Detecting and evaluating open fractured intervals

Understanding the mechanisms of anisotropy can be important when selecting the right hydraulic fracture fluid for a well, especially if there is stress-induced anisotropy or intrinsic anisotropy related to the presence of natural fractures. The Sonic Scanner tool can be used in evaluating the type of anisotropy, in addition to differentiating between open natural fractures and drilling-induced fractures.

The fractures shown in the FMI* Fullbore Formation MicroImager log in Fig. 7 are near vertical. Upon foot-by-foot examination, they were originally interpreted to be drilling induced. Stoneley wave measurements from the Sonic Scanner tool made it clear that the fractures were open natural fractures and not drilling induced.

The additional sonic data undoubtedly prevented the operator from making an incorrect interpretation, which would have led to selection of a high-gel fracture fluid that would have destroyed the permeability of the naturally fractured formation. In this situation, encapsulated breakers are much less effective, and an effective treatment can be designed.

In addition to preventing fluid loss, this information would also be critical in preventing cement loss during completion operations.

Figure 6. A mechanical earth model can be constructed and compared with independent measurements of rock properties and in situ stresses.

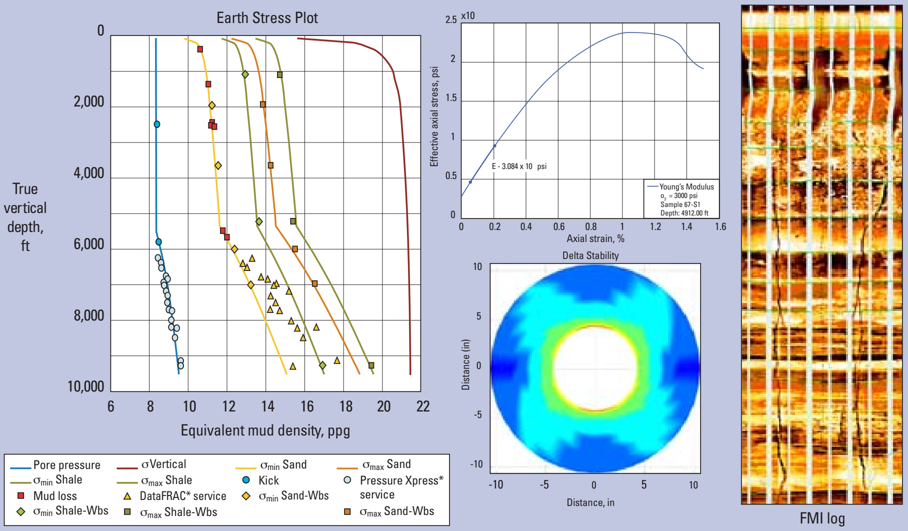
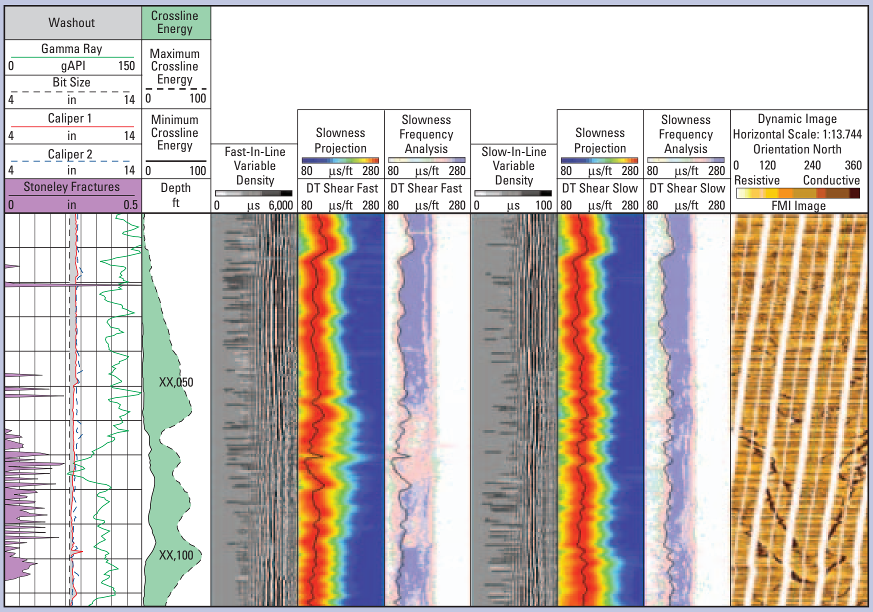


Figure 7. Stoneley wave measurements enabled determination that the fractures were natural, not drilling induced.



Sonic Scanner Measurement Specifications	
Output	Compressional and shear DT, full waveforms, cement bond quality waveforms
Max. logging speed	1,097 m/h [3,600 ft/h][†]
Range of measurement	Standard shear slowness: <4,921 µs/m [1,500 µs/ft]
Vertical resolution	<1.82-m [6-ft] processing resolution for 15.24-cm [6-in] sampling rate[‡]
Accuracy	DT: <6.56 µs/m [2 µs/ft] or 2% up to 35.6-cm [14-in] hole size <16.40 µs/m [5 µs/ft] or 5% for >35.6-cm [14-in] hole size
Mud weight or type limits	None
Combinability	Fully combinable with other tools

[†] Acquisition speed depends on product class and sampling rate.

[‡] Vertical resolution of <60.96 cm [<2 ft] is possible.

Sonic Scanner Mechanical Specifications	
Max. temperature	177 degC [350 degF]
Max. pressure	138 MPa [20,000 psi]
Borehole size	
Min.	12.07 cm [4.75 in]
Max.	55.88 cm [22 in]
Outer diameter	9.21 cm [3.625 in]
Length	12.58 m [41.28 ft][†] 6.7 m [22 ft][‡]
Weight	383 kg [844 lbm][†] 188 kg [413 lbm][‡]
Tension	157 kN [35,000 lbf]
Compression	13 kN [3,000 lbf]

[†] Advanced toolstring, including isolation joint

[‡] Basic toolstring, near monopoles only

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