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3D Far-Field Sonic Service

Automated subsurface feature extraction

APPLICATIONS

- Determining structural information, such as the dip and azimuth of bedding, fractures, and faults
- Assessing the connectivity of reservoir fractures from near the wellbore to the far field
- Mapping caprock or lithological boundaries in highly deviated wells
- Cased and openhole wells, from vertical to horizontal, in conventional and unconventional reservoirs

BENEFITS

- Provides quantitative dip and azimuth of reflectors for use in modeling workflows
- Reduces ambiguity in event detection and type
- Performs QC of each event from filtered waveforms rather than migration images
- Expedites processing and interpretation up to 10× faster with automated, consistent time picking and event analysis
- Delivers results at subseismic resolution to better inform completion design

FEATURES

- Deliverables in 3D space as well as a 2D projection image along the wellbore
- Automated processes for rapid, consistent time picking and event analysis
- 3D event analysis and optimized migration for consistent interpretation
- Seamless integration with borehole imaging data for validation of the near-wellbore structural environment
- Individual event ray tracing
- Processing of monopole and dipole waveforms for both enhanced resolution and deeper depth of investigation
- Azimuthal receivers at multiple stations

For modeling fractured reservoirs or conducting structural analysis, 3D far-field sonic service rapidly provides the true dip and azimuth of fractures and formation layers located well beyond the reach of standard sonic logging. The service determines connectivity for open fractures and identifies subseismic structural features, tracing them from the borehole wall through the near-field and far-field reservoir. The results, delivered in days rather than weeks, can be seamlessly integrated with reservoir, drilling, and completion plans.

Complementing traditional sonic imaging techniques and borehole imaging logging, 3D far-field sonic service employs a patented end-to-end workflow to data from azimuthal receivers at multiple stations. Now, data can be acquired on through-the-bit logging conveyance. Reflectors are determined simultaneously and automatically by using filtered premigrated waveforms for openhole and cased hole environments. The interpreted reflectors are displayed on the migrated image and have full traceability back to the raw waveforms.

Automated time picking and event analysis

Using the filtered azimuthal sonic waveforms, the automated time picking workflow enables rapid, reliable analysis of thousands of shot gathers to identify possible reflection events. Ray tracing inversion of the time picks and 3D slowness-time-coherence (3D STC) analysis of the underlying arrival event determine each event's raypath type, 3D position of the corresponding reflector, and a score value indicating the event's relative quality or prominence. A minimum threshold is applied to the scores, and the 3D event types and positions are used to guide the migration parameters.

Smart migration workflow

Traditional migration-only sonic imaging methods often require long turnaround times resulting from challenges in manually locating and interpreting events in the filtered wavefield based on their visual appearance. Instead, 3D far-field sonic service rapidly derives the migration parameters from the automated event analysis. The imaging results are consistent with event type and orientation of the true reflectors. Direct association of features in the migration image with features in the filtered wavefield (and vice versa) provides significant quality control.

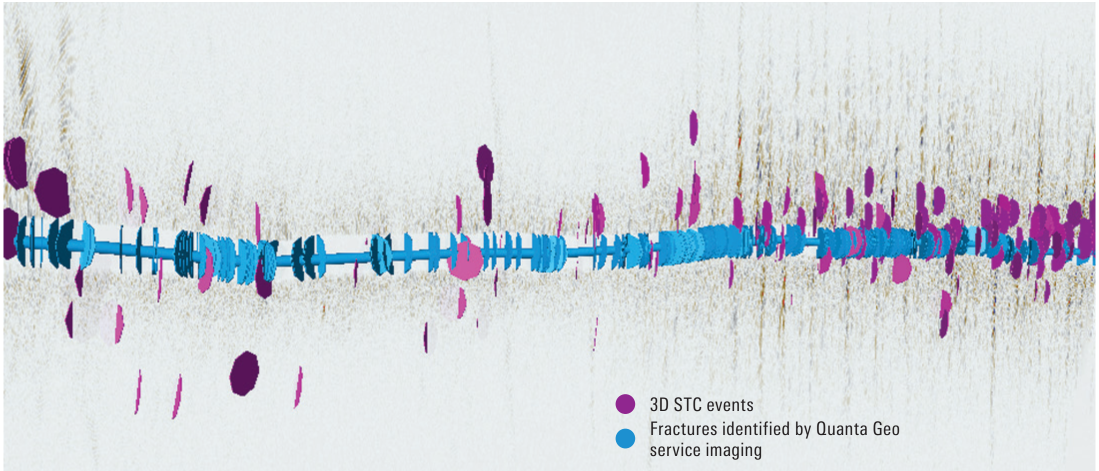
Reservoir insight beyond the reach of standard imaging

3D far-field sonic service confidently resolves fractures and structural features far beyond the borehole to enable

- optimizing completion and stimulation plans based on the intensity of the far-field fractures and integration with geological framework
- updating structural modeling for field development and appraisal drilling
- characterizing the reservoir, including structural pinchout, oil/water contacts, and stratigraphic sequences where seismic data is insufficient or unavailable.

Enhanced telemetry enables 3D far-field sonic service and standard sonic data acquired in a single logging pass at up to 3× the speed of conventional sonic logging. This provides an efficient opportunity to look at far-field reservoir imaging. Using this rich dataset, the new automated workflow rapidly delivers consistent, precise quantitative results up to 10× faster than conventional processing and analysis to bring new insight to understanding the reservoir.

3D Far-Field Sonic Service



In this unconventional well in the Wolfcamp, Quanta Geo photorealistic reservoir geology service and 3D far-field sonic service data were acquired in a single logging pass. The fractures identified at the borehole from Quanta Geo service imaging (blue discs) are displayed with 3D STC events (purple discs) on the migrated image produced using the Petrel* E&P software platform. Monopole data was used for high-resolution event analysis extending up to 15 m into the reservoir from this well. The completion was designed based on the intensity of the far-field fractures near the toe of the well (right).*

3D Far-Field Sonic Service Specifications

Measurement and Interpretation Features		Standard	Slim
Conveyance		Wireline	Wireline or through the bit
Length		12.58 m [41.28 ft]	8.87 m [29.11 ft]
Weight		383 kg [844 lbm]	66 kg [145 lbm]
Diameter		9.21 cm [3.625 in]	5.4 cm [2.125 in]
Max. temperature rating		177 degC [350 degF]	149 degC [300 degF]
Pressure rating	Min.	138 MPa [20,015 psi]	–
	Max.	207 MPa [30,023 psi]	121 MPa [17,500 psi]
Hole size	Min.	9.21 cm [3.625 in]	7.62 cm [3 in] 6.03-cm [2.375-in] min. drift ID
	Max.	55.88 cm [22 in]	22.23 cm [8.75 in]
Waveform acquisition[†]		X and Y dipole (1–8 kHz)—8 azimuthal elements, 1,000 samples at 40 us sampling Monopole (5–15 kHz)—8 azimuthal elements, 1,000 samples at 20-us/ft sampling	X and Y dipole (2.5–7 kHz)—4 azimuthal elements, 1,000 samples at 40 us sampling Monopole (5–15 kHz)—4 azimuthal elements, 1,000 samples at 30-us/ft sampling
Logging speed		Uses enhanced telemetry module for min. 1,000 ft/h for single pass with FAZ acquisition for dipole and monopole waveforms	1,800 ft/h
Combinability		Fully combinable with formation evaluation logging services	Combinable with other through-the-bit logging services
Logging environment		Open or cased hole	
Mud limitations		Aerated and foam muds typically outside operating range of acoustic tools	
Min. thickness of feature to resolve reflector[‡]		Compressional measurement (DTc), 7.5 in [0.625 ft]; Shear measurement (DTs), 18 in [1.5 ft]	DTc, 7.5 in [0.625 ft]; DTs, 7 in [0.58 ft]
Depth of investigation (max.)[§]		~80–100 ft (DTc) ~150–200 ft (DTs)	~60–80 ft (DTc) ~110–150 ft (DTs)
Max. accuracy for dip and azimuth[††]		±10°	±10°
Max. accuracy depth position of reflector[††]		±6 ft	±6 ft
Interpretation criteria for fractures[‡‡]		High dipping features	
Interpretation criteria for bedding and layering[‡‡]		Low-to-medium dipping features	
Interpretation criteria for faults[‡‡]		Change in formation dip over multiple depths	
Standard answer product		Reflector true dip and azimuth, 3D location within the reservoir[§§]	
Additional answer product		Migrated 2D images near wellbore and far field from monopole or dipole sources[§§]	

† Configurations may vary depending on formation.
‡ Assuming formation DTc of 55 us/ft and DTs of 110 us/ft
§ Based on case studies in homogenous isotropic media (salt)
†† Based on synthetic finite difference modeling
‡‡ Prior knowledge of formation geology highly recommended
§§ All data is delivered within Petrel platform and Techlog* wellbore software platform formats.

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