Optimize Full Waveform Sonic Processing

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AGENDA

• Introduction to Geolog.
• Introduction to Full Waveform Sonic Processing in Geolog.
  – Data Preparation.
  – Pre-Processing
  – Processing.
  – Post-Processing.
• Best Practices – Custom menu.
• Live demo.
  – DSI Processing.
• Wrap up.
Introduction to Geolog

- Saturation Height Modeling
- Optimizing petrophysics
- Deterministic petrophysics
- Programming
- NMR processing
- Geological correlation
- Geosteering
- Production Logging
- Electro facies analysis
- Geomechanics
- Casing Inspection
- Sonic Full Waveform Processing
- Uncertainty Analysis
- Borehole image interpretation

Common platform
Single / multi well environment
Integrated data store (EPOS)
Acoustic measurement applications

- Formation compressional (P) and shear (S) wave slowness (inverse of velocity).
- Formation porosity estimation.
- Seismic applications.
  - Time-depth curve
  - Synthetic seismograms
  - AVO
- Formation mechanical properties (Bulk, Shear and Young’s moduli, Poisson’s ratio).
  - Borehole stability analysis
  - Formation stress and fracture analysis
  - Sanding potential
- Modelling (fluid substitution).
- Formation Shear anisotropy.
Sonic Processing in Geolog

- Vendor independent Full Waveform Sonic Log Processing, supporting every tool on the market.
- Full set of tools for pre-processing and processing, allowing to obtain the best semblance and picking possible.
- Complete set of post-processing routines, including the calculation of Mechanical Properties and Sonic Anisotropy.
Full Waveform Sonic Processing in Geolog

- **Standard Workflow**
  - **Data Preparation**
    - Load Spec
    - Waveform Unpacking
    - Load Start Time
    - Remove Bad Receivers
    - Reverse Receiver Order
    - Create Other Attributes
  - **Preprocessing**
    - Time Average Filter
    - Depth Average Filter
    - Frequency Filter
    - F-K Filter
    - Amplitude Recovery
  - **Processing**
    - Semblance Processing
    - Slowness Picking
  - **Post-Processing**
    - Calculate Mean
    - Dispersion Correction
    - Anisotropy
    - Traveltime
    - Mechanical Properties

- **Optional**
  - only required if waveforms are split into separate receiver array logs
  - only required if spec file does not exist, e.g. new tool
  - mandatory module to prepare acoustic waveform log for processing
  - only required to extract individual cross-dipole components from packed array logs, e.g., PWFX
  - only required if sampling start time ≠ 0

- **Comment**
  - computes frequency spectrum, instantaneous phase & amplitude. Not part of slowness processing workflow
  - removes relatively regular events in the time direction
  - removes regular events in the depth direction
  - band pass filter to remove low and/or high frequencies
  - removes/extracts reflective waves (Chevron patterns)
  - removes gain and/or normalization to obtain original waveform amplitude. Not part of processing workflow.
  - creates semblance projection log
  - picks slowness by tracing the coherence maxima on semblance log
  - calculates mean of transmitter and receiver slowness
  - Dipole data acquired at higher frequencies (>2kHz) might need to be corrected for dispersion
  - Anisotropy from Xdipole data, using Alford rotation.
  - Computes dynamic mechanical rock properties
Data preparation
Load Specification File

- Loads tool specific parameters required for sonic processing into the log attributes of the sonic waveforms.
- The specification file contains all tool information required for sonic waveform processing.
- If the tool to be used is not handled by default, a new specification file can be easily created.
Data Preparation - General

- If waveform recording did not start at time 0, set the correct start time for waveforms for later processing.
- Exclude a particular receiver if data is bad or, replace bad data by missing values.
- All processing steps in Geolog require Waveform in packed form. Depending on the data from the field, waveforms can be packed or unpacked as needed.
- Correct Receiver order can be easily check using the Array Data viewer in a layout, and corrected using a dedicated module.
Pre-processing
Pre-Processing – Waveform Filtering

• Time-Average Filter:
  – Remove regular event (e.g.: low background frequency), by calculating an average in time direction and extract it from the original value.
Pre-Processing – Waveform Filtering

- Depth-Average Filter:
  - Remove regular event (e.g: casing signal, tool generated noise) by calculating a moving average in depth direction.
  - User can then remove this average from the original data (remove coherent casing signal) or output the mean (removes “chevron” patterns).
Pre-Processing – Waveform Filtering

- Frequency Filter:
  - To remove unwanted frequency component.
Pre-Processing – Waveform Filtering

- **F-K Filter:**
  - To remove or isolate reflections (i.e. chevron patterns), which might be caused by fractures, dipping bed boundaries or abrupt changes in hole diameter.

![Diagram showing waveform filtering and processing steps.](image-url)
Processing
Semblance processing

Moving time step

Slowness end
Moving time window length
Slowness step
Slowness start
Processing start time

Semblance map at each depth

Processing end time
Semblance processing
Semblance processing allows controlling both the processing time and slowness limits, as well as the windows length and step.
Picking

- Auto picking with seed or existing curve (manual curve insert in layout)
- Data could be adjusted manually in a layout, and/or smoothed as needed.
Post-Processing
Post-processing and Utilities

- **Calculate Mean:**
  - Calculate mean of 2 slowness logs.

- **Dispersion Correction:**
  - Calculates the dispersion curve of the flexural wave and applies the correction at each depth position.

- **Traveltime:**
  - Calculates the travel time of a selected arrival at a given receiver.

- **Create other attributes:**
  - For in-depth analysis of waveform, instantaneous phase, amplitude and frequency component can be extracted.

- **First Arrival Detection:**
  - This module is to detect the first arrival and pick the onset time automatically.

- **Mechanical Properties:**
  - Calculate VP/VS, Poisson ratio and elastic parameters.
Mechanical properties

- Calculate VP/VS, Poisson ratio and elastic parameters.
Anisotropy Analysis
Anisotropy analysis – Alford Rotation

- Cross Dipole tools have 2 dipole transmitters and 2 sets of multiple receivers placed 90 degrees apart.
- This configuration allows recording 4 sets of waveforms, 2 inline (XX, YY) and 2 cross-line (XY and YX).
Anisotropy analysis – Alford Rotation

• When the tool is aligned with the anisotropy axis, the shear wave splits on fast and slow directions:
  - Energy of the inline waveforms would be maximum.
  - Energy of the Cross-line waveforms would be 0.
• As the orientation of the tool is recorded, the orientation of the fast and slow shear wave propagation can be obtained.
• The Alford method: mathematical technique that allows reconstructing measurements done at any orientation.
Anisotropy analysis in Geolog

Geolog uses the Alford Rotation for Sonic Anisotropy. Three indicators of formation anisotropy are calculated:

- **Energy anisotropy:**
  - Principal measure of anisotropy. It is less affected by processing, thus more reliable than the other anisotropy indicators.
  - Energy anisotropy is the percentage of the cross-components (XY, YX) relative to all four components (XX, XY, YY, YX). The minimum and maximum cross-line energy for each depth frame are computed.
  - The difference between the maximum and minimum cross-energy is a measure of the strength of anisotropy.

- **Slowness anisotropy:**
  - Difference between the fast and slow slownesses calculated by semblance processing from the rotated waveforms. It is calculated by dividing the slowness difference by the average of the fast and slow shear slowness to get a percentage difference.

- **Travel time anisotropy:**
  - Difference in arrival time between the fast and slow shear waves at the receivers. The travel time is obtained by first arrival picking from the fast and slow waveforms.
Anisotropy analysis Workflow

• Calculate DTSM and Travel time for first receiver.
• Amplitude Recovery:
  – Converts waveform amplitudes back to its original form from gain control and/or normalization factor applied to data during data acquisition. Waveforms may be unpacked after recovery.
• Cross Dipole Processing:
  – Calculates Fast and slow Waveforms, Fast Shear Azimuth, Energy Map and Anisotropy Map.
• TT and DTS Anisotropy:
  – Calculates Traveltime and Shear Anisotropy, using the shear wave picked from the fast and slow waveforms.
• Analysis:
  – Automatic analysis to select the anisotropic zones, by analysing the three indicators.
Best Practice – Custom Menu

- Creating a custom menu per tool type can be an invaluable tool for processing sonic data in Geolog.

- The same module can be included different times, pointing to a different spec file relevant to such step.
Full Waveform Sonic – Live Demo
Wrap Up

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• Complete set of post-processing routines, including the calculation of Mechanical Properties and Sonic Anisotropy.
Thank You!

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• Isotropic AVO Methods to Detect Fracture Prone Zones in Tight Gas Resource Plays
  Bill Goodway, John Varsek and Christian Abaco (EnCana Corp., Calgary, AB, Canada) – 2007 CSPG CSEG convention

• Shear data in the presence of azimuthal anisotropy