PETRO NODE

Borehole Seismic Best Practices and Applications

Course Synopsis

The course is dedicated to geoscience professionals in an upstream oil and gas company. Upon the completion of this course, the participants will be able to:

- Select and justify the appropriate borehole seismic acquisition method(s) for exploration and development projects.
- Generate technical specifications for the seismic survey providers.
- Supervise field acquisition in a "wellsite witness" capacity.
- Perform basic quality control and identify the survey quality problems.
- Understand the basic processing chains for common surveys.
- Understand the survey uncertainty.
- Understand the borehole seismic processing results and be able to incorporate them into other geological, geophysical and petrophysical applications.

The course presumes basic knowledge of oilfield geology, electric logging and petrophysics. The expected participants level is from intermediate to advanced; the knowledge of seismic technologies, however, is not a requirement. The course does not include practical operation of borehole acquisition tools, seismic sources or any brand of specialized seismic processing software. Software licenses are not included.

During practical exercises, participants will be given two real-life scenarios for an on-land seismic acquisition and will be requested to formulate technical specifications, "select a contractor" and "supervise a job" based on provided sample/training dataset. Client-provided datasets may be also considered if available (prior confirmation is required at least two weeks in advance).

Due to the hands-on nature of the course, the audience may not include more than 15 students. Larger audiences may be considered; in such case, the amount of practical exercises will be reduced.

DAY 1

1. Introductions & Safety
2. Petrophysics refresher:
    - formation density
    - acoustic properties
    - acoustic impedance
    - reflection coefficient
3. Seismic fundamentals:
    - Snell's law
    - compressional waves
    - shear waves

- exchange waves
- surface waves
- tube waves
- anthropogenic noise and artifacts
- anisotropy
- Q-factor

4. Borehole seismic applications and types of borehole seismic surveys:
    - checkshots
    - vertical seismic profiles
    - seismic lookahead
    - vertical incidence (walk-above)
    - offset and multi-offset surveys
    - walk-away and imaging
    - 3D surveys
5. Advanced and “exotic” applications:
    - seismic-while-drilling (SWD)
    - seismic LWD
    - distributed sensors
    - simultaneous acquisition with surface seismic
    - simultaneous acquisition in several wells
    - inter-well tomography
    - hydrophone sub in a horizontal hole
    - microseismic monitoring
    - tiltmeters
6. Practical: formulating survey objectives.

DAY 2

1. Seismic sampling:
    - Nyquist theorem
    - frequency and sampling
    - coherence
    - stacking and SNR
    - time-domain filtering
    - space-domain filtering and level spacing
    - frequency-wavenumber (FK) displays
2. Borehole acquisition:
    - seismic sensors: geophones
    - seismic sensors: hydrophones
    - seismic sensors: accelerometers and GACs
    - distributed seismic sensors; fiber optics
    - passive gravity anchor vs spring-loaded vs active arms
    - borehole tools, their specifications
    - major seismic contractors, their advantages and disadvantages
    - tool selection
    - multiple-level (array) acquisition

- through-casing and through-drillpipe acquisition
- discussion (based on local experience)

3. Seismic sources, their advantages and disadvantages:
    - understanding “source signature”
    - thumper
    - dynamic mass
    - airguns
    - *Vibroseis*
    - explosives (dynamite)
    - source selection
    - considerations for building mud pits
    - considerations for compressors and pressure bottles
    - considerations for *Vibroseis*
    - discussion (based on local experience)
4. Synchronization:
    - acquisition system minimum qualification requirements
    - source controllers and sweep generators
    - radio controllers
    - *GPS* “heartbeat” and *GPS* time
5. Positioning:
    - checkshots/VSP minimum requirements in vertical holes
    - deviated holes, data requirement for seismic surveys
    - TVD and trajectory
    - “wireline depth” accuracy
    - “driller's depth” accuracy
    - satellite positioning systems (*GPS/Glonas*)
6. Group practical: formulating survey technical specifications.

DAY 3

1. Witnessing a borehole seismic survey, prior to the job:
    - source simulators
    - synchronization check
    - sensor orientation check
    - secondary sensors' checks
    - tool mechanical checks
    - source signature check
    - source consistency check
    - *Vibroseis* considerations
    - observer's log and traceability
2. Witnessing a borehole seismic survey, during the job:
    - depth correlation
    - making QC shots
    - monitoring array descent
    - main survey
    - repeat levels
    - real-time QC

- real-time shot rejection and stacking
- relative bearing and sensor azimuth
- “remote witnessing” over Internet
- how far up should the survey go?
- secondary depth check

3. Identifying and alleviating survey problems:
    - coherent and incoherent noise vs stacking
    - surface noise
    - electrical noise
    - electromechanical noise, transformer noise
    - near-by survey interference
    - tool creep
    - cable creep
    - WMC creep
    - poor tool coupling
    - washouts
    - excessive mud cake
    - poor cement or no cement behind casing
    - surface roll
    - Galperin waves (tube waves)
    - inconsistent source
    - airgun too deep, too shallow or not strong enough
    - firing interval too short
    - gimballed geophone problems
    - dealing with a failed shuttle
4. Group practical: survey quality control.
5. Witnessing a borehole seismic survey, after the job:
    - *Vibroseis* convolution
    - field stack
    - transit time pick
    - transit time accuracy
    - interval velocity
    - common misunderstanding of the interval velocity accuracy
    - common output formats
    - standard field data presentation
    - observer's log
6. Optional for locations with hydrofrac operations:
    - fundamentals of microseismic monitoring
    - tools and techniques used
    - velocity model calibration
    - event “leaching” and location
    - event uncertainty

DAY 4

1. Matching results to other seismic surveys:

    - Minimum-phase and Zero-phase signals
    - phase rotation
    - standard wavelets
    - spectral analysis and frequency filters
    - filtering in frequency domain vs recursive filters in time domain
    - understanding deconvolution
    - borehole seismic depth uncertainty
2. Basic processing chain:
    - geogram (synthetic seismogram)
    - time picking, time alignment and stacking
    - true amplitude recovery
    - checkshot processing and TZ
    - common TZ models
    - interval velocity inversion
    - downgoing wave separation
    - upgoing wave separation
    - “residual noise” and shear waves
    - waveshaping deconvolution
    - corridor stack
    - surface seismic correlation
    - handling vertical incidence surveys
3. Advanced processing chains:
    - three-component processing
    - normal move-out (NMO)
    - image reconstruction
    - migration
    - walk-away data and surface statics correction
    - Q-factor
4. Group exercise: present and discuss end-to-end field evaluation results
5. Q&A
6. Course feedback