TETRA TECH RPS ENERGY | TRAINING

N470: AVO Reflectivity, Pre-stack Inversion and Quantitative Seismic Interpretation

Instructor(s): Bill Goodway

Format and Duration

Classroom - 3 Days
Virtual - 6 Sessions

Summary

Utilization of AVO (Amplitude Versus Offset) reflectivity-based pre-stack elastic and anisotropic seismic inversion methods has increased in the last decade, thereby providing geoscientists and engineering teams with direct subsurface investigation methods to characterize reservoirs and plan drilling projects. During the same period, improvements in seismic reflection imaging and QI analysis have enabled more reliable predictions of reservoir lithology, porosity, and fluids while also yielding useful insights regarding fluid flow and hydro-fracture stimulation through detailed 3D mapping of reservoir inhomogeneities, stresses, and fractures. The ability to optimize well locations through AVO/QI inversion methods can significantly impact production through the understanding and mapping of reservoir parameters that control production drivers. These methods can be directly utilized in chance of success play risking for conventional exploration and to maximize ROR in unconventional plays by efficiently optimizing frac stage, well and pad placement.

Business Impact: A course providing geoscientists with the practical skills necessary to utilize seismic inversion methods and Quantitative Interpretation (QI) techniques to characterise reservoirs and plan drilling projects for both conventional and unconventional reservoirs.

Learning Outcomes

Participants will learn to:

1. Apply fundamental principles of rock physics and seismic wave propagation to plan and execute effective seismic inversion projects.
2. Utilize petrophysical models to calibrate seismic inversion products using well control.
3. Characterize commonly utilized seismic inversion techniques and select appropriate methods to achieve project objectives.
4. Create milestones and a list of deliverables with a multidisciplinary team to ensure project goals are realized.
5. Investigate the sources of computational error and validate inversion products to ensure that results are a reasonable representation of subsurface geology.

Training Method

This is a classroom or virtual classroom course comprising a mixture of lectures, discussion, case studies, and practical exercises.

Who Should Attend

Geoscientists having a proficient understanding of rock physics and seismic imaging and would like to learn more about seismic inversion applications used to characterize conventional and unconventional

N470: AVO Reflectivity, Pre-stack Inversion and Quantitative Seismic Interpretation

Instructor(s): Bill Goodway

Format and Duration

Classroom - 3 Days
Virtual - 6 Sessions

reservoirs.

Course Content

This course will demonstrate that seismic interpretation workflows combining AVO inversion products with petrophysical log analysis can provide profound geological and engineering insights from observed relationships between seismic data and elastic reservoirs parameters such as Poisson's Ratio (ν), Young's Modulus (E), shear modulus (mu, or μ) and incompressibility (lambda, or λ) or bulk modulus (K).

In the relatively recent paradigm of horizontal well hydro-fracture stimulation of fully charged tight unconventional reservoirs with low porosity, the application of AVO and Amplitude Variation with Azimuth (AVAZ) inversion methods can be simplified to extracting lithology and geo-mechanical properties from seismic data.

Consequently, this course will address the rock-mechanics and petrophysics workflows necessary to map tight shale lithology, porosity, OOIP/OGIP, closure stress, and brittleness to quantifiably characterize hydrocarbon reservoirs and to assist in wellbore design and hydro- fracture stimulation.

In addition, the course will illustrate the following topics:

- Seismic processing and imaging for AVO pre-conditioning including the impact of: seismic wavelets and deconvolution, bandwidth-amplitude/phase, resolution/tuning thickness, NMO/statics correction and migration (PSTM/PSDM) to optimize amplitude preserved fit-for-purpose pre-stack AVO datasets
- Errors in AVO reflectivity methods including case study examples of how AVO reflectivity methods reduced exploration drilling and delineation risk
- Borehole VSP/log petrophysical calibration of the expected AVO response through walkaway VSP AVO case studies including inversion of walkaway VSP, P-P and P-S “AVO gathers”
- Quantitative comparison of P-wave, S-wave impedance and Vp/Vs ratio from 3D surface seismic using AVO reflectivity equations and inversion corroborated by logs and walkaway VSP
- Examples of AVO used to estimate elastic parameters and litho-facies from 3D data QI inversion and seismic attribute analysis using both deterministic and geo-statistical approaches

The aim of this course is to cover the basic principles of rock physics involved in seismic wave propagation and inversion through related case history examples of workflows designed to calibrate seismic data sets and produce reliable interpretation products for wellbore placement/design and reservoir modeling.

Part 1 - AVO basics:

- Brief overview of theory and methods from Hooke’s Law and moduli involved in AVO

N470: AVO Reflectivity, Pre-stack Inversion and Quantitative Seismic Interpretation

Instructor(s): Bill Goodway

Format and Duration

Classroom - 3 Days
Virtual - 6 Sessions

Rock properties and seismic theory:

- P-wave & S-wave velocities, mudrock line
- P-wave, S-wave propagation and wave equations
- P-wave, S-wave velocities AVO attributes and DHI's

Seismic petrophysics:

- Seismic log-based motivation for AVO: Lambda, Mu, LambdaRho, MuRho
- Gassmann fluid replacement modeling and DHI's

AVO methods based on linearized reflectivity with offset equations:

- Processing to preserve and enhance AVO response

Part 2 - AVO methods based on linearized reflectivity with offset equations:

- AVO reflectivity equations, methods and Rp, Rs analysis including Lamé reflectivity
- Examples of AVO inversion for elastic parameters from 3D data
- Errors in reflectivity methods
- Case study example of how AVO reflectivity methods reduced exploration drilling and delineation risk

Borehole VSP/log petrophysical calibration:

- Walkaway VSP AVO case study including Lamé parameters
- Inversion of walkaway VSP, P-P & P-S "AVO gathers" and surface P-P seismic: Gas Sand Example
- Quantitative comparison of P-, S-impedance and Vp/Vs ratio from walkaway VSP inversion to log sonic curves and surface seismic

Part 3 - AVO inversion:

- AVO QI inversion equations and methods: Elastic Impedance (EI) and Lambda-Mu-Rho (LMR)
- Resolution and sensitivity of QI inversion methods for elastic parameters
- AVO/LMR/EEI examples: Alberta Land, GOM, Offshore Brazil and log calibration

Part 4 - Review and Case Study

AVO inversion Case Studies:

- Offshore West Africa with VTI anisotropy effects on AVO and Errors in QI inversion methods (EI, LMR)
- Mackenzie Delta, E Coast Canada showing how AVO reflectivity and inversion methods did and did

not reduce exploration drilling risk
- Reservoir characterization in the presence of thin beds and elastically ambiguous facies through Direct Probabilistic Inversion

Part 5 - Seismic geomechanics:

- Brittleness vs. Geomechanics, Mohr-Coulomb, min closure stress, bound in-situ moduli/ratios
- Seismic Petrophysical Log Analysis and Anisotropy to Estimate In-situ Stress

Case Study on AVO inversion for Unconventional Plays:

- AVO Inversion QI for Lithology and Effective Stress

Part 6 - Case Studies

Case Study on AVO inversion QI for Unconventional Tight Gas:

- Horn River NEBC: 3D AVO/LMR seismic attributes to predict completions performance and production
- In-situ stress estimation from VTI and HTI anisotropy
- Microseismic and 3D AVO/LMR attributes for Geomechanics, OGIP, minimum closure and stress anisotropy mapping

Case Studies-New Methods for Unconventional Plays:

- Microseismic combined with 4D: a better way to map stimulated reservoir volume
- Direct Probabilistic Inversion for Anisotropy and Lithofacies in Unconventional Oil Reservoirs

Establishing project objectives with multi-disciplinary teams

- Integrated multi-disciplinary case histories
- Characterization of shale and tight sand reservoirs

Review of Client data (Internals only).