Workflows for Seismic Reservoir Characterization (G004)

Tutor(s)

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Overview

This course will provide participants with the skills needed to design and implement workflows for seismic reservoir characterization using established best-practice and emerging technology. The course covers seismic conditioning, colored inversion, AVO theory including elastic and extended elastic impedance, DHIs, seismic net pay, well ties, rock physics and deterministic and probabilistic inversion, including the application ODiSI.

Duration and Logistics

A 4-day classroom course comprising a mix of lectures with examples (70%) and laptop-based exercises and discussion (30%). The manual will be provided in digital format and participants will be required to bring a laptop or tablet computer to follow the lectures and exercises.

Level and Audience

Advanced. Intended for practicing seismic interpreters. Participants should have a basic knowledge of the seismic method, including acquisition and processing, with a minimum of three years working with seismic data. However, the subject matter of this course, AVO and inversion, is covered from basic principles.

Objectives

You will learn to:

1. Appreciate the benefits of colored inversion – how and why it works and how to get the best results from a colored inversion application.
2. Understand the relationships between reflectivity and impedance, and between time and frequency.
3. Understand the model for AVO measurements and the difficulties in making accurate AVO measurements.
4. Understand the concepts behind AVO analysis, including intercept-gradient crossplots and the theoretical relationship between elastic and AVO properties.
5. Optimize AVO products for subsequent characterization work and create seismic products that correlate with specific reservoir properties.
6. Appreciate the risks of using attributes with no physical relationship with the desired objective.
7. Appreciate the limitations of the seismic net pay method and to know when it is, and is not, applicable.
8. Understand the principles and pros and cons of deterministic and probabilistic inversion and how to select the appropriate inversion strategy for any given problem.

Course Content

Day 1

Introduction

- Colored inversion
- Bed thickness statistics
- Convolutional model in time and frequency
    - layers exercise
- The Fourier transform
    - phase representation of time shifts and noise
    - sine waves exercise
- Band-limited impedance
    - frequency domain characteristics
- Coloured inversion
    - transforming from band-limited reflectivity to band-limited impedance
- CI applications
    - parameter optimization
    - examples of application
- Blueing – optimizing reflectivity data
    - characteristics of reflectivity and relative impedance data

Wavelets

- Wavelet spectra
    - tapers to avoid ringing
    - logarithmic frequency scales
    - phase rotation and envelope functions
    - wavelets exercise
- Optimizing wavelets in the presence of noise
- Spectral estimation
    - frequency domain resolution
    - spectral estimation exercise
- Controls on wavelet resolution
- Broadband seismic – the importance of low frequencies
- Wavelet transforms
- Spectral decomposition
- Well ties for wavelet estimation
- Mechanisms causing frequency loss
    - anelastic attenuation – Q
    - internal multiples – stratigraphic filtering
    - surface ghosts

Day 2

AVO measurements

- Wave propagation modes and energy partition
    - Zoeppritz equations
    - linearization – the standard ‘Shuey’ equation
    - alternative equations: Aki-Richards, Fatti, Mallick-Wang
- Angle estimation
- Controls on AVO response
    - AVO curves (standard) exercise
- Background AVO trends
- AVO parameter estimation – curve fitting
    - measurement errors – noise and bias
    - 2-term and 3-term equations
    - angle stacks
    - intercept and gradient estimation
- Causes of measurement errors
- Error mitigation – data conditioning
    - AVO measurements exercise
- Introduction to anisotropy
- The effects of anisotropy on AVO response
    - AVO curves (Ruger) exercise
- Modelling anisotropy

AVO crossplots

- Intercept-gradient crossplots
- Background trends and noise characteristics on crossplots
- AVO classes
    - AVO moveout exercise
- Bulk and shear moduli – fluid substitution
- The effect of fluid substitution on AVO response
    - AVO curves (Dong) exercise
- Fluid substitution crossplots – AVO exploration screening
    - the effects of measurement errors
    - geological domains for analysis
- Chi-projections
- The relationships between elastic property reflectivities and chi-projections

Day 3

AVO well analysis

- AVO impedances
    - elastic, extended elastic and gradient impedances
    - AIGI crossplots
    - AIGI coordinate rotation exercise
- Well ties with AVO stacks
- Reservoir property trends in AIGI space
- Fluid and lithology projections
- Selecting chi angles using well data
    - log chi scan exercise
- 3-term projections

AVO seismic analysis

- The effects of gradient measurement errors, noise and anisotropy on chi angles
    - Chi scanning
    - AVO layers exercise
      Rock physics modelling
    - controls on AVO effectiveness
- Bayes theorem
    - application to exploration risking

Attribute maps

- Factors affecting seismic amplitudes
- Multi-attributes and the risks of spurious correlation
- Net-to-gross and binary systems
- Reflectivity and relative impedance tuning
- Estimating net-to-gross – the seismic net pay method
    - seismic net-to-gross
    - detuning
    - calibration
    - simple wedge filter exercise
    - SNP limitations
- Examples of application
    - net-to-gross exercise
- Map calibration

Day 4

Inversion principles

- Non-uniqueness
    - inversion exercise
- Causes of inversion uncertainty
- Seismic inversion for facies probabilities
- Inversion algorithms
    - ODiSI sim exercise
- Bayes theorem for distributions
- Bayesian framework for seismic inversion

Facies probabilities

- Inversion classification scheme
- One Dimensional Stochastic Inversion – ODiSI
    - application design
    - examples
    - uncertainty quantification