Quantitative Seismic Analysis for Exploration and Production Applications

Course Price

£3050

Course Description

Traditionally, reflection seismic is used for its kinematic attributes, i.e. reflection traveltimes. However, we can also use reflection seismic for its dynamic attributes, i.e. reflection amplitudes, specifically, the behaviour of these amplitudes versus angle of incidence: AVA = amplitude versus angle, or, equivalently, AVO = amplitude versus offset. AVO attributes are used as independent evidence for the occurrence of hydrocarbons (in addition to structural evidence), as a hydrocarbon discriminator and as a lithology indicator.

This course starts with a discussion of new developments in seismic data acquisition that have an impact on the accuracy of the AVO attributes, e.g. long offsets, wide-azimuth geometries and broadband data acquisition. It deals with elastic constants, wave propagation, boundary conditions, rock physics, and fluid substitution algorithms. It gives an overview of the factors that affect seismic amplitudes and of proper ways to process the seismic data such that amplitude information is preserved, which is then followed by the extraction of the relevant attributes and their interpretation. All aspects that are related with seismic inversion are dealt with, theoretical as well as practical. An AVO workshop will be part of the course.

Seismic inversion is the process of converting seismic reflectivity data into (a) models of elastic properties of the subsurface, or into (b) a quantitative rock-property description of a reservoir.

Seismic inversion may be pre-stack or post-stack, deterministic or geostatistical, and typically includes other reservoir measurements such as well logs and cores. Using the Bayesian approach, in which all available information can be reconciled, a statistical assessment of the desired reservoir properties can be obtained.

The choice for a specific seismic inversion technique depends on the stage of development:

Reconnaissance with no well control within the seismic
Exploration and appraisal with well control within the seismic
Focused reservoir characterization with well control and key reservoir parameters with their uncertainties.

The course consists of the following four chapters:

Rock physics: elasticity theory and the Gassmann equation
AVO: formulation, processing and derivation of attributes
Geostatistics: estimation of variables, probability theory and Bayesian statistics
Seismic inversion: elastic and lithologic and deterministic and stochastic
The course will deal with all aspects of deterministic and stochastic inversion.

**Course Objectives**

Participants will get a full understanding and appreciation of the theory and practicalities of AVO analysis, the interpretation of AVO attributes the various methods of seismic inversion and the statistical assessment of inversion results. Anyone who deals with seismic and acts as a member of a multi-disciplinary team will benefit of this course.

**Who Should Attend**

Geophysicists and interpreters/geologists who want to familiarize themselves with all aspects AVO (= amplitude versus offset) and Seismic Inversion, i.e., anyone who wants to enhance structural interpretation with QI = quantitative interpretation. The theory is based on first principles; the applications exploit the latest developments in acquisition and processing and demonstrate how multi-disciplinary teams can share information in a meaningful way.

**Course Content**

1. **Developments in seismic data acquisition**

   Acquisition geometries

   Acquisition parameters

   Spatial sampling

   Arrays and point receivers

   Data partitioning and offset vector tiling (OVT)

New developments in receivers:

- MEMS (micro electro-mechanical system) devices
- Dual-sensor cables – GeoStreamer (PGS)
- Variable depth streamer – Broadseis (CGGVeritas)
- ObliQ – sliding notch acquisition (Schlumberger)
- UniQ – point receivers (WesternGeco)
- Isometrix – multi-sensor towed streamer (WesternGeco)
New developments in sources:

- low-frequency and high-frequency vibrators
- productivity enhancement for vibrator seismic (e.g. slip sweep)
- Time and depth distributed source – GeoSource (PGS)
- low frequency sources
- simultaneous sources (blended seismic)

New developments in acquisition geometries:

- multi-azimuth (MAZ) and full-azimuth (FAZ) marine seismic
- coil shooting
- long offsets

2. Elastic constants, rock physics and wave propagation velocities

Deformation and the strain tensor

Traction and the stress tensor

Stress-strain relations: Hooke’s law

Symmetry properties of the strain tensor, stress tensor and stress-strain tensor

The equation of motion and the wave equation

Definitions of elastic constants

Relationships between elastic constants

3. The wave equation, the boundary conditions and the Zoeppritz equation

The acoustic wave equation

The elastic wave equation

P-waves and S-waves

The boundary conditions

The Zoeppritz equation

Rock properties

The Gassmann equation to calculate effects of fluid substitution

4. AVO/AVA, theory and practice

Factors affecting amplitudes
Example of normal incidence reflection and transmission

The boundary conditions

The Zoeppritz equations for reflection and transmission coefficients

Approximate expressions for the reflection coefficients

AVO modelling

Modelling of tuning effects and wavelet stretch

Processing for AVO analysis

Estimation of AVO parameters

Calculation and interpretation of AVO attributes

Crossplotting of AVO attributes and AVO classification

5. True amplitude migration

Principle of true-amplitude migration

Generation of angle gathers

6. Methods for data inversion

Linear least-squares estimation

Linear least-squares estimation and methods for regularization

Damped least-squares estimation with the Marquardt-Levenberg method

Singular Value Decomposition (SVD)

Resolution matrix and covariance matrix

Resolution and reliability

Bayesian estimation, use of a priori knowledge

Iterative linearized least-squares estimation; Gauss-Newton method

Gradient search methods: Steepest Descent (SD) and Conjugate Gradient (CG)

Monte Carlo search

Simulated annealing (SA)
Genetic algorithms (GA)

7. **AVO inversion – elastic inversion**

Elastic inversion based on AVO behaviour

Angle stacks and Elastic impedance with its application

8. **AVO case studies**

9. **Seismic-to-well matching**

Model based wavelet estimation

Filter design to match different datasets

Reflectivity estimation from well data

Seismic-to-well matching methods

Least-squares wavelet estimation with well data

10. **Seismic inversion, deterministic and probabilistic**

From reflectivity to acoustic impedance

Least-squares estimation methodology

Singular value decomposition (SVD)

Resolution matrix and Covariance matrix

AVO inversion or elastic inversion

Probability theory and Bayesian approach to inversion

Deterministic inversion and stochastic inversion

Inversion case studies

11. **4D seismic**

Objectives and feasibility analysis

Rock physics

Fluid substitution with the Gassmann equation

Measurement of travel time differences and amplitude differences
Quantification of repeatability of acquisition and processing

Methods to assess the comparison of different datasets

Methods for cross-equalization of two datasets

4D modelling of different scenarios

The 4D workflow

12. Seismic attributes

Introduction to attributes, definitions and historical overview

Analytic traces: instantaneous amplitude, – phase, and – frequency

Attribute classification

The geometric attributes dip and azimuth

The coherency attribute

Curvature and reflector shape

Spectral decomposition and its applications

CPD Unit

Continuing Professional Development

35 HOURS CPD