N505: Use of Time-Lapse Seismic Data in Reservoir Surveillance and Management

Instructor(s): Giles Watts

3 Days	Competence Level: Skilled
Classroom Course	

Summary

This course will provide an overview of the use of Time Lapse (4D) seismic data in field development. It provides participants with the skills to use 4D seismic data in new well planning, reservoir management and well management. The course covers 4D acquisition, processing and interpretation with an emphasis on the practical application to real field development problems and the value generated from analysis of time-lapse to understand the behaviour of producing reservoirs. It starts from first principles and introduces the participant to the full range of 4D technologies and practices including some of the latest developments such as permanent seismic monitoring, automatic history matching with 4D seismic and the use of artificial intelligence.

The emphasis of the course is on integration of 4D seismic with other subsurface data and the collaboration of subsurface disciplines to work together to make the best use of time-lapse seismic data to solving real problems in field development.

Learning Outcomes

Participants will learn to:

1. Understand how the seismic signal changes in time and is influenced by dynamic processes such as changes in pressure, saturation, temperature and compaction
2. Understand the relationship between reservoir processes and data sampling to determine how often 4D seismic should be acquired to maximise value
3. Conduct feasibility studies including core analysis for pressure sensitivity and petrophysical studies for analysing the impact of changes in saturation on the seismic signal.
4. Distinguish the different methods of acquiring 4D seismic data, the different quality of data acquired and when each should be used
5. Appreciate the issues and limitations involved in processing 4D seismic data and the implications for interpretation and value generation such as the vertical and horizontal resolution.
6. Understand the range of analysis techniques and workflows available for relating 4D seismic data to reservoir properties.
7. Integrate 4D seismic data with data from other subsurface disciplines for better management decisions
8. Build 4D data into full field simulator models, sector models and single well models for evaluating different field management scenarios.
9. Interpret 4D seismic data in field management scenarios through selected case examples. Understand the influence of baffles and barriers on 4D seismic data. Relate 4D seismic data to pressure, compaction, water saturation and gas saturation. Appreciate the importance of uncertainty quantification.
10. Engage management through communicating the value of seismic of 4D Seismic in different field management situations including well planning, waterflood management, maximising field recovery and well surveillance.

Duration and Training Method

This is a 3-day classroom course using examples, computer exercises, and case studies and discussion.

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Participants are required to bring along a laptop or Macbook running Microsoft Office.

Who Should Attend

This course is designed for geoscientists and engineers working in field management. It is suitable for people from all subsurface disciplines including geologists, geophysicists, petrophysicists, reservoir engineers, geomechanics experts and subsurface managers. Different aspects of the course will involve detail in different subsurface specialisms but the emphasis is on integration and collaboration to solve reservoir problems.

Prerequisites and Linking Courses

There are no prerequisite courses but participants should have a basic understanding of seismic data and be familiar with the concepts of reservoir management and surveillance. Experience working in a subsurface asset team would be an advantage. Courses N085 (Introduction to Seismic Interpretation) and N004 (Rock Physics and Seismic Amplitude Interpretation) cover some useful background.

Course Content

Introduction

- Overview and objectives
- A brief History of Time-Lapse Seismic with examples
- Relating 4D to Business Decisions.
  - Maximising Reserves Recovery
  - The three criteria for value.
  - Cost vs quality vs timing
- Forward trends in the industry

Fundamental Principles

- Basics of the seismic method
  - P-waves, shear waves
  - 2D vs 3D vs 4D seismic
  - Reflections, refractions, ghosts, noise
- Seismic Response to production (some maths here)
  - Seismic response to velocity, density, Poisson's ratio
  - Visco-acoustic, visco-elastic, anisotropy and attenuation
  - Seismic sampling - Frequencies and resolution
  - 4D noise and repeatability
  - 4D sensitivity
- Reservoir Behaviour during production and how this impacts seismic data
  - Pore pressure and compaction
  - Pore fluids
  - Temperature

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An Introduction to the Reservoir Management & contribution from 4D seismic

- Well planning
- Water management
- Gas management and CO2 monitoring
- Well management and surveillance
- Tools for managing reservoirs - Static Modelling, Dynamic Modelling, Geomechanics

4D Acquisition

- 4D Towed Streamer
- Repeat Nodes Surveys
- Repeat VSP Surveys
- Permanent Reservoir Monitoring (Land)
- Permanent Reservoir Monitoring (Marine)
- Well Based monitoring including 4D VSPs and fibre optic monitoring
- Recent Advances: Seabed Sources, semi-permanent nodes, Fibre-optic seabed monitoring
- Choosing the right 4D technology: Cost vs quality vs timing

4D Processing

- Processing overview and Parallel Processing
  - Matching the data volumes and matching the people
  - Towed streamer vs OBS
- Seismic Repeatability and the treatment of 4D noise
  - Ambient noise
  - Positioning and timing changes
  - Overburden effects
  - Tides, currents and temperatures
  - Recording equipment characteristics
  - Acquisition issues
  - Processing sequence and software issues
- Amplitude and timeshift preservation
- Calibration to a reference horizon
- Resampling and interpolation
- 4D imaging
  - Migration of 4D data
  - Full Waveform Inversion
  - Joint inversions

4D Analysis

- The Petro-elastic model
- Rock Properties
  - Porosity and Permeability

  - Velocities in porous rocks
  - Compressional waves, shear waves, and moduli
  - Bulk density and bulk stiffness
- Pressure/Stress Sensitivity
  - Laboratory core pressure measurements
  - Velocity versus Stress
  - Pore pressure and confining pressure
  - Attenuation and Dispersion
- Fluid Sensitivity
  - Pore fluid properties: oil, gas, brine, fluid mixtures
  - Velocity versus Porosity relationships
  - Gassmann Modelling and Fluid Substitution
  - CO2 injection modelling

Presenting and Integrating 4D data

- Presentation of time-shift data
- Quadrature Plots vs AI inversion (including coloured inversion)
- Elastic Impedance, lithology and fluid impedance volumes
- 4D AVO and AI-GI cross plots
- Separating pressure and saturation effects
- Seismic to simulator: closing the loop
- Managing Multiple Datasets
- Deeper integration techniques: Artificial Intelligence (AI) and Machine Learning (ML)

Practical Workflows and working in Asset Teams

- Working with Geologists: integrating 4D data in static reservoir models
- Working with Reservoir Engineers: Integrating 4D data with Reservoir Models
- Working with Well Planning Teams: Using 4D data in well planning
- Working with Production Engineers: Integrating 4D data in single well models and the “Seismic PLT”
- Working with Geomechanics Experts on stress models
- Working with CO2 monitoring: Using 4D seismic to monitor CO2 injection (sequestration)

Managing 4D Studies

- Business Case
- Feasibility Studies
- PRM engineering feasibility studies
- Depletion Planning
- Surveillance Plans
- Business Case: frequency of seismic surveys; Long term seismic planning; Impact on reservoir decisions; Impact on reserves and recovery; Evaluating as part of the depletion plan;

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4D Case Histories

- Forties (4D, North Sea)
- Schiehallion (4D North Sea)
- Baobab (4D, Ivory Coast)
- Peace River (Seismovie)
- Valhall (PRM, North Sea)
- Mars (Nodes, Gulf of Mexico)