TETRA TECH RPS ENERGY | TRAINING

N004: The Essentials of Rock Physics and Seismic Amplitude Interpretation

Instructor(s): Rob Simm or Eleanor Oldham

Format and Duration

Classroom - 4 Days
Virtual - 8 Sessions

Summary

This course presents the physical basis for quantitative seismic interpretation within the context of hydrocarbon exploration and production. Key technologies are explained in a straightforward manner; with topics including rock physics analysis of log data, well ties, 1D and 2D seismic modelling, amplitude and AVO analysis, seismic inversion to rock properties and the use of seismic amplitude information in prospect risking. Practical exercises utilise Excel based applets to aid understanding and the lessons learnt are of general application.

Business Impact: Rock physics has numerous applications for adding reserves and growing production within the business cycle; from recognition of diagnostic seismic signatures in prospect identification to reservoir characterisation and volumetric uncertainty estimation in field evaluation as well as enhanced oil recovery through time lapse techniques in field development. Moreover, a cross discipline understanding of rock physics is central to the effective integration of geology, petrophysics, geophysics, engineering.

Learning Outcomes

Participants will learn to:

1. Make a basic AVO model and use it to determine expectations in seismic interpretation in a variety of AVO scenarios.
2. Understand the principal characteristics of seismic wavelets and appreciate how the interference phenomenon can be used in the thickness prediction problem.
3. Tie a well using the well seismic matching and adaptive techniques and appreciate the importance of well tie information in the construction of forward models and seismic inversions.
4. Understand Gassmann fluid substitution and how rock physics models in general can be used in log conditioning and interpretation.
5. Understand different approaches to AVO analysis, how AVO projections work and the importance of data quality in the successful application of AVO analysis.
6. Understand bandlimited impedance and how it can be used in an AVO context for interpretation of net pay thickness.
7. Appreciate the differences between classical 'best estimate' seismic inversion and modern rock physics based techniques such as JiFi and ODiSI.
8. Understand the basics of Bayes theorem and how it can be applied in probabilistic approaches to seismic inversion and prospect risking.

Training Method

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

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Who Should Attend

The course is designed to be an introduction to practical rock physics application in seismic interpretation and would be of interest to all working Geoscientists, Petrophysicists, and Reservoir Engineers. For experienced Geophysicists who are regularly involved in seismic modelling, the course can be used as a refresher.

Course Content

Course content is evenly split between lectures that review the basics of how seismic relates to rock properties and PC-based practicals utilizing real data. Through the use of commercially available PC-based software, the basics of rock physics interpretation of seismic data are understood. By the end of the course, students will not only be able to create first order reflectivity models and understand the basics behind the buzzwords (AVO, EI etc), but also be able to ask pertinent questions that relate to the use of seismic data in prospect risking.

Session 1

- Seismic basics
  - Seismic geometry (source-receiver separation, incidence angle)
  - The gather and the stack
- How AVA works (*Exercise*)
  - Aki Richards approximation (a first order model utilizing isotropy and elasticity)
  - The convolutional model
  - Polarity definitions (and the importance of zero phase)
  - 3 term vs 2 term approximation (AVO plot and AVO crossplot)
  - Rock property controls on Intercept and Gradient
  - Elastic parameters (isotropic and elastic)
  - Angle vs offset
- Offset vs angle
  - The role of the velocity model
  - Intercept and gradient from seismic
  - Angle stacks
- Far angle effects
  - Critical angle and mode conversion in high contrast rocks
  - Offset dependent attenuation and layered anisotropy effects
- Siliciclastic case study (*Exercise*)
  - Variation of AVA signatures with depth
  - AVO classes
  - Effect of hydrocarbon on elastic parameters
  - AVA siliciclastic model

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Session 2

- AVO scenarios overview
- Examples: porosity, fluid, pressure, layering, thick vs thin bedded, carbonates, contacts
- Class II/III prospect failure (*Exercise*)
- Class IV overpressure example (*Exercise*)
- Class IIp oil sand example
- DHIs
- Resolution (*Exercise*)
    - (Temporal or vertical) resolution and detectability
    - The thickness prediction problem
    - Lateral resolution (maps vs sections)

Session 3

- Characteristics of seismic wavelets
- Well ties
    - Log calibration (Drift evaluation and correction) (*Exercise*)
    - Well tie example (Well-seismic matching ,Adaptive technique)
    - Well tie issues (Character and phase ambiguity, Possible model issues – e.g. VTI)

Session 4

- Gassmann's equations (*Exercise*)
    - Key equations presented
    - Mixing models (Voight, Reuss, Hill average)
- Fluid Substitution and AVA case study, considering:
    - Minerals
    - Fluid
    - Porosity and Densit
    - Velocitie
    - Dry rock QC (sands)
- Log QC and Conditioning
    - Log data integrity: Log registration, bad hole, invasion, Vp/Vs artefact
    - Tools: Crossplots, log transforms, neural nets, drift analysis

Session 5

- Fizz gas (Low Saturation Gas) (*Exercise*)
- Introduction to Rock Physics Models
    - Diagenesis context
    - Key trends (mechanical and chemical diagenesis)

  - General functions (e.g. Vernik's variable stiffness model)
  - Contact models
  - Inclusion models
- Palaeocene sands example (*Exercise*)
- Fluid substitution in sand/shale sequences
  - Types of sand/shale mixtures
  - Modifications and pitfalls of Gassmann
- Effect of pore shape on velocity (inclusion models) (*Exercise*)
- Case study - Sand stiffness effect on AVO

Session 6

- AVO analysis
  - Discrimination methods – colour coded crossplots & projections
  - 2 term Coordinate Rotation/Projection/Weighted stack method
  - Real world issues
  - Factors influencing data quality
  - Data conditioning (post processing)
- AVO Interpretation Example (*Exercise*)

Session 7

- AVO and Impedance (*Exercise*)
- Bandlimited Impedance (Coloured Inversion)
- Simple Net Pay estimation (using BLI) (*Exercise*)
  - Connolly's technique and Simm's simplification
- Calibration and uncertainty
- The problem of seismic trace inversion
- Classical 'Best Estimate' trace inversion
  - Sparse spike (direct Rc estimation)
  - Model based Inversion (match and update method)
  - Pre stack simultaneous inversion (AI, SI and Rho)

Session 8

- Issues with Best Estimate Inversion
- Best Estimate Inversion and Probability
- Introduction to application of Bayes (facies probability)
- JiFi (Joint Impedance and Facies Inversion)
- Stochastic/Probabilistic Inversion
  - Application to reservoir modelling
  - ODiSI (trace matching)

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- Role of prospect specific DHIs in risking
- Use of Bayesian update (*Exercise*)