N658: Practical Depth Conversion and Depth Imaging for the Interpreter

Format and Duration
Classroom - 5 Days

Instructor(s): Scott MacKay

Summary

Depth conversion of time interpretations is a basic skill set for interpreters. There is no single methodology that is optimal for all cases. The first part of this course emphasizes understanding the nature of velocity fields and practical approaches to velocity representation. Next, appropriate depth-conversion methods are presented in case history and exercise form. Basic and more advanced layer-based approaches are reviewed with quantitative uncertainty analysis and its impact, ranging from well-top prognoses to volumetric estimations. Depth migration should be considered an integral component of interpretation. If the results derived from depth imaging are intended to mitigate risk, the interpreter must actively guide the process. The second part of this course is an intuitive description of the theory and practical implementation of prestack depth imaging. The course focuses on the interpreter-oriented quality controls used to ensure stable velocity solutions and geologically reasonable results using the latest in imaging technology such a Full Waveform Inversion (FWI). The course concludes by outlining the flow for calibrating the depth-migration volumes to well tops and the formation of meaningful seismic attributes.

Business Impact: Participants attending this course will significantly enhance their understanding of **depth-conversion methodologies, quality control measures for method validation, and tools for accurate quantitative uncertainty estimation**. Moreover, they will acquire the skills necessary to proficiently design, guide, and quality check depth-imaging projects across diverse geologic settings.

Learning Outcomes

Participants will learn to:

1. Evaluate types of velocity data and methods for velocity definition and use.
2. Investigate the compatibility of well and seismic data.
3. Perform basic and advanced depth conversions of time data with uncertainty analysis.
4. Assess the key differences between time and depth migration.
5. Differentiate between ray and wave-equation methods.
6. Appraise the form of velocity updating (tomography/FWI) appropriate for the geology.
7. Establish a reasonable target velocity resolution for tomography.
8. Validate and correct the database via well top and seismic-interpretation ties.
9. Plan and assess QCs for iterative tomography/FWI velocity updates.
10. Appraise the methods used for determining anisotropic parameters.
11. Implement an optimal approach for calibrating well and seismic data.
12. Evaluate attributes such as inversion and (HTI) azimuthal stress and lithology estimates.
13. Review practical aspects of machine-learning classification and estimation.

Training Method

This is a 5-day instructor-led course. Each topic is introduced with a presentation followed by an exercise that allows participants to develop an understanding of the applications of the prinicples discussed.

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Who Should Attend

This course is of importance to geoscientists involved in seismic time interpretation, time-to-depth conversion, and the planning and interpretation of depth-migration projects.

Course Content

Module 1: Overview of Depth Conversion
Discuss the motivation for vertical time-to-depth conversion

- Why do we depth convert time interpretations?
- Accuracies of relative structure, well prognoses, volumetrics, and reservoir models
- Exercises: Discussions on participant experiences with time-to-depth conversion

Module 2: Sources of Velocity
Review common sources of velocity information

- Sonic logs, check shots, and VSPs
- Seismic refraction and reflection data
- Full waveform inversion
- Exercises: Analysis of various velocity source types

Module 3: Defining Velocity Types
Review definitions and characteristics of velocities

- Types of velocities
- Conversion of velocity types
- Compactional and layered geologies
- Exercises: Various problems on relating velocity types and conversions

Module 4: Representation of Velocities
Define velocities for depth conversion using vertical/spatial functions and grids

- Velocity as a function of depth
- Velocity as a function of time
- Spatial velocity variations (lateral gradients) and grids
- Exercises: Various problems defining velocity fields in various domains

Module 5: Well and Seismic Data Integration
Classify the methods for linking well and seismic information

- Establishing data polarity and phase
- Creating synthetic seismograms: “Wiggle” and P Impedance
- Correlating reflections with well tops (synthetic ties)

- Exercises: Problem sets and interactive work sessions

Module 6: Vertical Time-to-Depth Conversion (Basic)

Implement basic vertical depth conversion using T-Z functions and spatial depth corrections

- Single-layer methods (direct depth conversion)
- Handling spatial velocity variations (lateral gradients)
- QC methods
- Exercises: Problem sets and interactive work sessions

Module 7: Vertical Time-to-Depth Conversion (Advanced)

Explore vertical depth conversion with more sophisticated methods

- Multi-layer methods
- Editing velocities
- Creating velocity models (various platforms)
- Exercises: Problem sets and interactive work sessions

Module 8: Pitfalls of Vertical Depth Conversion and Uncertainty Analysis

Recognize the stability of vertical time-to-depth methods and when they fail

- The limitation of PSTM
- Complex structural regimes
- Shallow velocity anomalies and overpressure
- Uncertainty analysis (including Stochastic Modeling of uncertainty)
- Exercises: Problem sets and interactive work sessions

Module 9: Acquisition and Time Processing

Discuss the impact of acquisition and signal processing on imaging

- Acquisition considerations: Land and marine
- Processing considerations
- Exercises: Discussions on acquisition and data processing practices and experiences

Module 10: Time and Depth Migration: Comparisons

Obtain an appreciation for the differences between time and depth imaging

- Intuitive discussion of time and depth migration theory
- Exercises: Industry examples and class discussions of student experiences

Module 11: Depth Migration Algorithms: Theory and Practice

Convey an intuitive understanding of the different depth migration algorithms

- Kirchhoff, Gaussian Beam, 1-way and 2-way (Reverse Time) Wave Equation

- Offset and angle domains for Common Image Point Gathers
- Anisotropy and Multi-component
- Exercises: Case history reviews

Module 12: Depth Migration: Parameter Selection

Review the impact of parameter selection on imaging

- Kirchhoff travel times and Wave Equation imaging conditions
- Amplitudes, aliasing, and aperture
- Regularization (interpolation) and equalization (migration weighting)
- Exercises: Review key points of the module

Module 13: Tomographic Velocity Analysis and FWI

Explain the differences between various industry approaches to velocity updating

- Layer- and grid-based ray methods
- Full waveform inversion: Near-surface and deep velocity models
- FWI Imaging
- Advances in FWI (multiparameter… Q, Vp/Vs, Epsilon…)
- Exercises: Simple tomographic solution examples to demonstrate issues in stability and uniqueness

Module 14: Depth Imaging Grids

Review the different grids that need to be defined and solved for in depth imaging

- Image/Velocity: Visualization and velocity representation
- Travel times/Propagation: Summation curves and/or wavefield extrapolation
- CIP picking/Tomography: Data input to tomography and solution grid
- Exercises: Various problem sets with spreadsheets

Module 15: Well/Seismic Database Validation

Appreciate the need to review and correct the database prior to incorporating well control into PSDM

- Data exchange and QC between interpreter and processor
- Basic QCs to encounter data discrepancies
- Exercises: QCs presented with associated exercises

Module 16: Iterative Depth Imaging: Quality Control

Incorporate a set of fundamental review steps in depth imaging projects

- QCs for creating the initial velocity model
- Reviewing iterative tomographic updates and target-velocity resolution
- Setting up an intuitive review of the iterative process
- Exercises: QCs presented with associated exercises

Module 17: Anisotropy and Depth Migration

Appreciate basic concepts for imaging and defining anisotropic parameters

- Seismic anisotropy
- Parameterization (Vz, Delta, Epsilon, VTI/TTI…)
- Imaging methodologies
- Initial Vz model, velocity, and parameter updates
- Azimuthal anisotropy (HTI)
- Exercises: Review and discuss the benefits and pitfalls of attributes from isotropic and anisotropic PSDM

Module 18: Well Calibration of Depth Migration

Learn basic QCs for stable integration with well control

- Working in the time domain
- Updating the time/velocity model
- Conversion of time data to calibrated depth
- Uncertainty measures (Stochastic prognoses)
- Exercises: Review calibration flows and Stochastic Uncertainty Analysis (freeware)

Module 19: Seismic Attributes

Discuss the stability and resolution of depth imaging

- Amplitudes, curvature, coherence, Ant Tracking
- Elastic inversion, brittleness, other attributes
- AVO with Azimuth and other Horizontal Transverse Isotropy (HTI) measurements
- Practical applications of machine-learning algorithms
- Exercises: Review benefits of attributes from depth imaging