Department of Geophysics

Instructor: Prof. Ilya Tsvankin

COURSE NUMBER AND NAME

GPGN651: Advanced Seismology. Offered in the Fall semester.

COURSE OBJECTIVES

To introduce students to modern seismology of anisotropic, heterogeneous media.

CATALOG DESCRIPTION

In-depth discussion of wave propagation and seismic processing for anisotropic, heterogeneous media. Topics include the influence of anisotropy on plane-wave properties and point-source radiation, seismic signatures for transversely isotropic (TI) and orthorhombic models, anisotropic moveout analysis of 2D and wide-azimuth reflection data, parameter-estimation and imaging methods for TI media, joint processing and inversion of PP- and PS-waves, and anisotropic amplitude-variation-with-offset (AVO) analysis.

Prerequisites: GPGN552 and GPGN553 or consent of instructor.

Credits: 3 hours lecture; 3 semester hours.

Texts: "Seismic signatures and analysis of reflection data in anisotropic media" by I. Tsvankin (main textbook), "Seismology of azimuthally anisotropic media and seismic fracture characterization" by I. Tsvankin and V. Grechka, "Quantitative seismology" by K. Aki and P. G. Richards, and "Crystal acoustics" by M. J. P. Musgrave.

COURSE SYLLABUS

Wave propagation in homogeneous anisotropic media – 2 weeks

- Anisotropic wave equation, generalized Hooke's law, stiffness tensor for various symmetries
- Plane waves, Christoffel equation for arbitrary anisotropy, polarization vectors
- Phase and group velocities, relation between slowness surface and wavefront
- Basic properties of point-source radiation

Seismic signatures for transversely isotropic (TI) models – 3 weeks

- Solutions of Christoffel equation for P-, SV-, and SH-waves
- Thomsen notation and its application for weak and strong anisotropy
- Analytic description of body-wave velocities and polarizations
- Anisotropy parameters of sedimentary rocks

Anisotropic moveout analysis of reflection data – 3 weeks

- Normal-moveout (NMO) velocity for TI media with vertical (VTI) and tilted (TTI) symmetry axis
- Generalized Dix equation for NMO velocity
- 3D description of normal moveout, NMO ellipse
- Quartic moveout coefficient and nonhyperbolic moveout analysis
- P-wave moveout equation for layered VTI models

Velocity analysis and processing of P-waves for VTI media – 2 weeks

- Two-parameter description of time-domain processing
- Estimation of parameter η from nonhyperbolic and dip moveout
- Basics of migration velocity analysis and depth imaging
- Case studies of time and depth processing

Converted waves and joint processing of PP and PS data – 1.5 weeks

- Properties of mode-converted waves and PP + PS = SS method
- Joint NMO-velocity inversion of PP- and PS-waves for VTI and TTI media
- Case studies of velocity analysis and imaging of multicomponent data

Notation and signatures for azimuthally anisotropic media – 1.5 weeks

- Thomsen-style notation for orthorhombic and HTI (TI with horizontal symmetry axis) models
- Adaptation of VTI equations in symmetry planes

- NMO ellipses and nonhyperbolic moveout in orthorhombic/HTI media

Amplitude analysis for anisotropic media – 2 weeks

- Reflection/transmission coefficients of plane waves
- Amplitude-variaton-with-offset (AVO) analysis of P-, SV-, and SH-waves for VTI media
- Moveout-based geometrical-spreading correction
- Principles of azimuthal AVO analysis for orthorhombic/HTI media