SEISMIC WAVES IN RESERVOIRS ROCKS

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This short course presents the fundamentals of wave propagation in sedimentary formations, e.g., siliclastic rocks, shales, carbonates, requiring a realistic description based on poro-viscoelasticity and anisotropy, in view of the presence of different fluids (oil, gas, brine) and fractures and cracks. The emphasis is on geophysical applications, but researchers in the fields of material science, – including many branches of acoustics of fluids and solids (acoustics of materials, non-destructive testing, etc.) – may also find the course useful. Moreover, I illustrate the use of seismic and ultrasonic modeling, with a brief account of the numerical algorithms for computing the synthetic seismograms.

Use of modeling and inversion for the interpretation of the seismic response of reservoir rocks requires the understanding of the relationship between the seismic attributes and the rock properties. In particular, in the exploration of oil and gas reservoirs, it is important to predict the rock porosity, the presence of fluids (type and saturation), the preferential directions of fluid flow (anisotropy), the presence of abnormal pore-pressures (overpressure), etc. Applications include unconventional sources (oil shale), evaluation of methane hydrate content, upscaling techniques, detection of overpressure, propagation in permafrost, exploration of the Earth's deep crust, and time-lapse for monitoring of CO_2 sequestration .

In order to solve the wave equation, the model (the geological layers in exploration geophysics) is approximated by a numerical mesh. The solution by direct methods (FD, pseudospectral, FEM) implicitly gives the full wave or diffusion field, and do not have restrictions on the material variability. Finite-differences and pseudospectral methods are studied. Their accuracy and stability. The main aspects of the modeling are introduced as follows: (a) time integration, (b) calculation of spatial derivatives, (c) source implementation, (d) boundary conditions, and (e) absorbing boundaries.

Summary of the subjects:

Theory:

- Theory for porous media. Jacketed and unjacketed compressibility tests.
- Gassmann and Backus equations for sandstones and shales.
- Overpressure physics and methods.
- Anisotropic (fractured) media.

Numerical methods

- The finite-difference method. Accuracy and stability.
- Wave equation. Introduction of attenuation.
- Computation of synthetic seismograms.
- Diffusion equation. EM fields.

Applications

- Characterization of fractured media.
- 4D seismic methods
- Rock-physics of unconventional resources. Oil shales.
- Detection of gas hydrates and monitoring of CO2.
- Cross-well seismic and EM methods. CSEM method

Requirements:
Attendants should download a Fortran compiler to run the forward modeling codes.
A free version for Windows is available at:
http://force.lepsch.com/2009/05/downloads.html
Download and install: Force209GFortranSetup.exe

Duration: 3 days, 6 hours per day.

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The theory and numerical techniques can be found in the following book: Carcione, J. M., 2007, Wave fields in real media: Wave propagation in anisotropic, anelastic, porous and electromagnetic media: Handbook of Geophysical Exploration, vol. 38, Elsevier (Second edition, extended and revised).

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