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2019 Distinguished Instructor Short Course | Manika Prasad

Physics and Mechanics of Rocks: A Practical Approach

Course Duration
One day

Intended Audience
- Seismic imagers and interpreters who want to learn how fluids, stress, and other environmental effects change seismic signatures;
- Geophysicists who wish to derive rock properties and constrain well-to-seismic ties;
- Geologists and sedimentologists looking to develop predictive models of sedimentary environments and stratigraphic events;
- Reservoir engineers to build porosity, permeability and fluid coverage models for reservoir simulations using 3D and 4D seismic data;
- Basin modelers and completions engineers to evaluate stresses from well log and seismic data;
- Geoscientists performing formation evaluation and well logging interpretations; and
- Basin managers and team leaders who wish to evaluate accuracy of predictions and understand risk and errors in models.

Prerequisites (Knowledge/Experience/Education Required)
Attendees should have an understanding of basic rock properties, such as porosity, permeability, sediment compositions and depositions, and structural geology. It will be helpful to have familiarity, but not necessarily expertise in seismic properties. The accompanying textbook will include mathematical details, data, and problem solutions for mineral modulus calculations, rock stiffness calculations for textural symmetries, velocity binning in flow zones, pore stiffness, and Gassmann fluid substitution. The lecture will focus on fundamental rock physics principles, applications, and analysis of results.

Course Outline
The course is organized into two main sections: Section I. Rock Physics Fundamentals (introductory section) and II. Advanced Topics in Rock Physics (application section):

I. Rock physics fundamentals: In this section, I will

a. review fundamental principles underlying rock physics, and rock properties;
b. investigate the effects of fluids on rock properties;
c. derive basic rock physics correlations and explain why and how they work;
d. review rock properties that can be mapped with remote sensing.

II. Advanced Topics in Rock Physics: In this section, the student is introduced to

a. poroelasticity;
b. attenuation and dispersion;
c. geomechanics;
d. complex electrical conductivity and permeability;
e. investigate the causes for complications and deviations from basic correlations;
f. examine existing empirical and theoretical models;
g. discuss selected case studies in rock physics.

Learner Outcomes
On completion of the course, the learner should be able to:
- Describe and explain the applications of rock physics for reservoir characterization, formation evaluation, and field monitoring.
- Identify and evaluate existing and potential technologies applicable to rocks physics and rock mechanics for reservoir/formation studies.
- Identify, list, and describe physical properties of rock, and relate these properties to the mechanical behavior of the rocks.
- Interpret and predict the effect of mineral properties (e.g. clay minerals) on load-bearing capacity and strength of rocks.
- Integrate and model elastic wave propagation, electrical conductivity and fluid flow in rocks.
- Evaluate and assess errors in experimental data, the uncertainty, and the value of theoretical models.
- Develop expertise in rock physics interpretations of seismic and electrical conductivity to identify fluids and quantify saturations.
- Gather key strengths in rock physics interpretations by developing a broad understanding of existing or potential technology transfers between engineering and earth science fields that relate rock physics to reservoir geophysics and reservoir engineering.
- Gain knowledge and expertise to understand physical and mechanical behavior of rocks through examples of stress dependent changes in strains, seismic velocity, electrical conductivity, and pore structure.
- Interpret rock physics and rock mechanics data and model elastic wave propagation, electrical conductivity, and fluid flow in rocks.
- Assess errors in experimental data; assess the uncertainty and the value of rock physics models.

These learning objectives will allow geoscientists and engineers to:

- Distinguish major trends in and control factors for velocity and impedance changes in the subsurface.
- Describe and evaluate velocity and impedance data for changes in fluids and stresses.
- Apply basic rock physics techniques to evaluate reservoirs.
- Identify and select the best practice workflows when using rock physics for seismic interpretations.
- Analyze complex conductivity data to interpret reservoir properties.

Abstract

Rock physics is an interdisciplinary branch of geophysics that explains geophysical remote sensing data, such as seismic wave velocities or electrical conductivity in the context of mineralogy, fluid content, and environmental conditions. Thus, rock physics interpretations often require input from physics, geology, chemistry, chemical engineering, and other fields. For example, seismic waves in cemented rocks travel faster than in loose sediments. Since the physical behavior of rocks controls their seismic response, rock physics brings a key knowledge that helps with the interpretation of rock properties, such as porosity, permeability, texture, and pressure. Rock physics employs indirect geophysical data, such as seismic impedance, sonic log velocities, laboratory measurements, and petrophysical information about porosity, fluid type, and saturation in reservoir characterization, evaluation, and monitoring. Typically, rock physics is used by anyone doing a monitoring survey to map fluids from 4D seismic; petroleum engineers doing reservoir simulations; geologists evaluating over-pressures and making basin models. For all such purposes, an understanding of wave propagation is required to relate seismic properties (e.g. velocity and attenuation) to physical properties of rocks and to evaluate seismic data in terms of subsurface petrophysical parameters. For example, an application of rock physics is seen in 4D seismic data (i.e. repeated seismic data acquired from the same field), where fluid saturation changes are evaluated from the changes in velocity using fluid-substitution models. Another rock physics application is for example to understand and predict the effect of clay minerals on load-bearing capacity and strength of rocks using fundamental knowledge about the properties of clay minerals (e.g. CEC, surface area, dispersibility, charge, sorption, plasticity, etc.), the clay water content, as well as the effects of their distribution within the rock. Thus, an effective prediction of rock properties from indirect measurements requires a solid understanding of the physical behavior of rocks under in situ conditions of pore and confining pressures and fluids saturations.

During this one-day short course, I will provide the earth scientist and engineer with the fundamental basis of rock physics to describe the physical processes that govern the response of rocks to external stresses that are essential for reservoir characterization. The course will also offer practical guidance to better analyze existing data. A major goal of this course is to offer practical instruction and provide working knowledge in the areas of rock physics and rock mechanics for rock characterization.

Mature fields can be reborn. Overlooked deeper and shallower objectives as well as new play concepts reinvigorate oil fields where the acerage is held and the infrastructure is in place. 5D interpolation reinvigorates legacy seismic surveys. In North America, technical innovations including horizontal drilling and hydraulic fracturing may directly target the source rock, or drill tight or highly heterogeneous parts of the reservoir too expensive to produce from vertical wells. Our analysis becomes more statistical, where the experience obtained from tens if not hundreds of wells can be correlated to volumetric attributes. Using core to generate reservoir-specific templates, seismic attributes can be statitically correlated to brittleness, total organic carbon, rate of penetration, and expected ultimate recovery.

In this one day short course, I will illustrate these concepts by example, showing modern workflows based on interactive interpretation and display as well as those aided by
machine learning.

Instructor Biography

Manika Prasad has been at Colorado School of Mines (CSM) for the past 14 years, and previously at Stanford University, and University of Hawai'i. She received her BS from Bombay University and MS and PhD from Kiel University in Germany. Prasad's main interests lie in understanding microstructural controls on geophysical data. She is the recipient of the Virgil Kauffman Gold Medal in 2017, Outstanding Educator Award (2015), and the AAPG-SEG Distinguished Lecturer Award (2012). Known as the "mud queen" among her peers and students, she pioneered the integral research in source rich rock and fluid properties using tools and techniques from geoscience and engineering domains. In addition to teaching and research duties at CSM, Prasad serves as Associate Editor for Geophysics and is Second Vice President of SEG.