Amplitude versus Angle of Incidence (AVA)

What kinds of Geophysical Data could be used?

Various kinds of geophysical data are available. They are usually separated into Seismic and Multi-Physics data, which is also called Non-Seismic data. Seismic is, without any doubt, the main method used in the oil and gas industry. But Multi-Physics data (gravity, magnetics, electrical, electromagnetics, spectral, etc.) is the main source of information in shallow subsurface applications (engineering, mapping pollution, archaeology, etc.) and at the early basin reconnaissance stage. However, seismic has its limitations and therefore also multi-physics methods are used successfully as complementary tools in subsurface evaluation. In combination with seismic data, they can significantly reduce the uncertainty of subsurface models as they measure different physical properties of the subsurface.

Seismic data and Processing

From seismic we not only need to obtain the structure that could contain hydrocarbons, but also the rock properties so we can decide on whether we are dealing with reservoir rocks (sandstone, carbonates, even shales), sealing rocks (shales, salt) or source rocks (shales, coals). To know what type of rock is present is important, but also what its porosity is and whether it is fractured, as that is important for permeability (How easy do the hydrocarbons flow through the rocks). To obtain accurate information on the rock properties we need, in principle, to consider two-way elastic wave propagation. Considering elastic propagation, which includes mode conversion, is necessary when we analyze the (pre-stack) amplitude variation with offset (AVO) or more accurately defined as amplitude variation with angle of incidence (AVA).

Amplitude versus Angle of Incidence

From pre-stack data, the amplitude variation with offset can be obtained. Using elastic modelling the variation with angle of incidence can be synthesized for different scenarios: interfaces between simple homogeneous isotropic layers, between effective media, between layers with anisotropy due to internal layering of fracture systems. Different weak anisotropy models are for the simple layering Polar anisotropy or Vertical Transfer Isotropy (VTI), for vertical fractures the Horizontal Transverse Isotropy (HTI) and more general Orthorhombic anisotropy (Ortho) of which the simplest model is a combination of vertical fractures and horizontal layering. Usually it can be assumed in that case that the fractures in both layers have the same orientation due to the maximum horizontal stress. All of these case can be modelled for weak anisotropy for PP and PS reflections.

AVA Modelling

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AVA Inversion
From the observed AVO parameters Intercept (I), Gradient (G) and Curvature (C), the changes in Vp, Vs and ρ across the interface can be obtained. This is applicable in case the AVO is azimuth independent. If full azimuth seismic data shows azimuth dependence, then a HTI or Orthorhombic medium should be included in the inversion

From Elastic to Rock Properties
From quantitative analysis of pre-stack seismic data, elastic properties of the reservoir can be derived. But these need to be translated into rock properties relevant for exploitation, that is porosity and fluid saturations. That means that a rock-physics model need to be chosen. For clastic reservoirs that is relatively easy, for carbonate reservoirs it is much more non-unique. Differential Effective medium (DEM) can be applied to build an effective medium by starting with a background model and sequentially add interparticle porosity, cracks and vugs. These effective media can then be used in AVA modelling.

The Course
The above items will be dealt with in the course; by presentations and discussions, watching videos and by doing many practical exercises. Also, each day contains a quiz which is meant to reinforce the learning. The quiz consists of multiple-choice questions. In addition, we will be using ChatGPT, a Chat Generative Pre-trained Transformer, a large language model–based query. We will investigate how accurate the answers to your questions are and learn how to build-up a conversation (Chat) with the program.