Introduction E-Advanced Seismic Data Acquisition & Processing

Dear Participants

Introduction

My name is Jaap Mondt and I am the teacher for the "*Advanced Seismic Data Acquisition & Processing"* e-learning course. This course will introduce the main aspects of acquisition & processing of Seismic Geophysical Data using a book and many exercises / assignments. The course starts four time a year and if you enroll you are expected to finish it within the 3 months. In this note I will explain my role and what is expected of you and how we can get the most out of your time spent on it.

My role

My main activity will consist of giving feedback to your questions based on studying certain chapters of the book and your submitted solutions to the exercises. The exercise feedback will either consist of additional questions, which aim to increase your understanding and which you are kindly asked to answer or remarks that parts of the answers are in error and need to be redone, in which case I will ask you to resubmit updated solutions (adding v2 or v3 to the filename). My feedback will mainly be personal, then it will only be seen by you, or if it would be of interest to all then I will put it in the 'Discussion Forum" or "News Forum".

Your role

You should within the 3 months given solve the exercises, react to the feedback and if the next version of your answer is better I will increase the score. After 2 re-submissions, I will provide and explain the solution, so that you do understand the issue dealt with in the exercise.
As another part of your activity would be interactions with other participants. For that you put questions and or remarks on the "Discussion Forum" and see if any of the other participants have an enlightening answer. Of course, I will also monitor it and might make comments on the answers or give an answer myself. The questions and comments could include your name or not. In addition, you could contribute to the exercises by indicating errors or unclear statements, improve exercises or describe your own experience.

What kinds of Geophysical Data could be used?

Various kinds of geophysical data are available. They are usually separated into Seismic and Non-Seismic data. Seismic is, without any doubt, the main method used in the oil and gas industry (see below). But Non-Seismic 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 oil-and-gas exploration stage. However, seismic has its limitations and therefore also non-seismic 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. Controlled Source EM for example responds to reservoir resistivity and can thus be used to differentiate between hydrocarbons and brine.

Why Seismic data and why Processing?

Seismic data is one of the main sources of information on the subsurface. 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 (mainly shales). Not only what type of rock is important to know 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 the best image of the subsurface we first need optimum acquisition. Optimum means fit for purpose. Designing a survey is a science by itself. There are several criteria that need to be satisfied. First of all, the area covered during acquisition should be the prospect area extended sufficiently to provide fold-fold and fully migrated data. An acquisition principle that should be adhered to as much as possible is symmetric sampling, which means equal shot and receiver spacing and equal in-line and cross-line distances (for a 3D). A noise spread (trial acquisition with closely spaced receivers and shots) is acquired in each new area to determine the needed shot and receiver intervals, the bandwidth, etc. The shot and receiver station spacing should be such that no spatial aliasing of the data occurs. Surface and subsurface diagrams are useful to see what CMP spacing and offsets in each CMP gather result from the surface geometry of shots and receivers. The data recorded is the ground motion which gives a continuous (analogue) signal in time which needs to be digitized for the processing. This digitization needs to be done so that neither temporal nor spatial aliasing occurs. Namely by aliasing information will be lost. Hence, the complete wave-field which arrives at the surface must be faithfully represented by the discrete/digital data.

Although all the information is present in the so-called shot or field records, processing is needed to make them accessible for interpretation. In interpretation, we try to obtain a true image of the "geology" of the subsurface. Processing can be divided into a) signal processing steps and b) wave propagation based processing steps. Signal processing steps are, for example, static corrections, removal of shot-generated noise by velocity filtering, shortening the wavelet by de-convolution, NMO correction, etc. The wave-propagation part consists of migration or imaging. For wave propagation we need, in principle, to use equations describing full elastic wave propagation in an inhomogeneous, anisotropic, visco-elastic earth (as that is what really happens in the subsurface). However, these equations would lead to very complicated and computer intensive processing algorithms. So, we need to simplify our description of the wave propagation. What we do is to use, as phrased by Ian Jones, *appropriate approximations*. This means that we use simplifications that will still solve the problem at hand, that are still appropriate. The one most commonly used is the one-way acoustic wave equation which describes only a single reflection per reflection ray-path, ignores density, only uses a velocity depth model and only considers P-wave propagation. This will provide us, for example, with migration algorithms/operators (for time- as well as depth migration) that will still do a correct summation of acquired data. This will give a migration output that still contains all the effects of anisotropy, attenuation, wave conversions, shear velocities, etc. For example, acoustic ray-tracing uses Snell's law which doesn't consider density or we mention that a velocity-depth model is needed for migration (we don't mention a velocity & density depth model). Despite the use of this acoustic approximation in our processing, amplitudes can be used (can they?) to determine pore-fluids and pre-stack migrated data can be used in AVA analysis for deriving shear wave properties. But note that if we model a synthetic geophysical quantity, say related to amplitudes, such as the reflection coefficient we need (do we?) to include densities across the interface and for AVA we need to include density and shear velocity in order to interpret the pre-stack seismic amplitudes (as the effect of these properties is contained in the observed data).

Conventional Processing
As mentioned before the aim of processing is to obtain an image of the subsurface which depicts as faithfully as possible the geology. Some people would say that processing basically consists of "imaging" and the rest of the processing is pre- and post-processing. Whether you see it like that or not is not that important.
In practice, we have split up the processing into a sequence of small steps, which can be done in any sequence needed, hence endless permutations are possible. All of these operations need optimal parameter choices specific for each project. Also during processing, it is important to

prevent aliasing from occurring when going from one domain to another (un-aliased data in shot gathers can turn into aliased data in common midpoint (CMP) panels).
The objective of processing can be subdivided into three sub-objectives: 1) Improving signal-to-noise (S/N) ratio by static corrections and filtering, 2) Improving vertical resolution by de-convolution and 3) Improving horizontal resolution by migration. Sub-objectives 1 and 2 make use of signal processing, whereas sub-objective 3 makes use of wave propagation. In addition, we will obtain rock properties in so-called Quantitative Interpretation for which specific pre-processing is needed.

E-learning Course

The above items will to various degrees be dealt with in the course; by studying chapters in a text book and by making many exercises. In addition, you will benefit from Moodle facilitated interactions with other participants and with the instructor (that is me).

For more information on courses go to www.epts.org

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