PL04 – Mi.,10.3.,08:30-09:30 Uhr · H0104

Mann, J. (U Karlsruhe)

Seismic Reflection Imaging - from Time to Depth

A frequently used way of obtaining information about the Earth's interior is to investigate the propagation of elastic energy in the form of seismic waves. These have, for instance, been of help in gathering knowledge about geological structures from the Earth's crust down to the core. In particular, reflection seismic methods are applied when information about targets of only several kilometers (up to about 50 km) in depth is of interest. For that purpose, seismic energy is released from controlled sources, such as explosions or vibrators, reflects at discontinuities of the elastic properties in the subsurface, and is finally recorded at a number of receiver positions. Reflection seismic measurements are widely applied in the exploration for hydrocarbon reservoirs, where a detailed image of the subsurface geology typically up to 5 km depth is required. In the following, I focus on seismic reflection modeling, imaging, and inversion techniques required to transform the recorded data in the time domain into a structural image in the depth domain. It is assumed that the acquired multicoverage prestack data are preprocessed such that unwanted wave types (including multiple reflections), incoherent noise, source and receiver signatures etc. have already been reduced as far as possible.

With the strong increase of computing power during the last ten years, new, computationally more expensive and sophisticated processing methods have become feasible. One of these methods in seismic reflection imaging is the Common-Reflection-Surface (CRS) stack (e.g., Jäger et al., 1999; Mann et al., 2001). The CRS stack is based on a generalized multi-dimensional multi-parameter high-density stacking velocity analysis. It suppresses incoherent noise and enhances coherent reflection events, produces a stack section in the time domain, i.e., a simulated zero-offset section which may be used for a first interpretation, and finally provides so-called kinematic wavefield attributes. The latter are a key to connect time-domain seismic data with a depth image of the subsurface. Mathematically, the CRS stack is based on zero-order ray theory (geometrical optics). In contrast to many other seismic imaging methods, no information (e.g., a rough idea about the subsurface elastic properties) other than the data itself is required for the CRS stack. It is therefore classified as a data-driven seismic time-domain imaging method. The basic concept of the CRS stack is to locally describe reflection events in the time domain by means of a traveltime approximation of second order with respect to source and receiver locations.

The parameters of the CRS stack operator, the kinematic wavefield attributes, are related to wavefronts of hypothetical experiments. The attributes are suited for various purposes, the most important one being the determination of a velocity model required to produce a structural image in the depth domain. Different inversion schemes are available, either based on the back propagation of the hypothetical wavefronts (generalized Dix-type inversion) or on iterative forward modeling of these wavefronts followed by an update of the velocity model and the reflection points associated with the picked input data to minimize the misfit between forward-modeled and data-derived attributes (tomographic inversion). Due to the use of the wavefield attributes instead of traveltimes only, the tomographic approach (Duveneck, 2004) requires minimum picking effort. It provides a smooth macro-velocity model which is kinematically consistent with the recorded data.

The application of both, the CRS stack and the tomographic inversion based on the CRS stack results, allows to set up an entire seismic reflection imaging workflow: with the macro-velocity model obtained from the inversion, a depth migration finally provides the structural image of the subsurface in the depth domain. This step can be performed as a poststack migration of the CRS-stacked section and/or as a prestack migration using the entire prestack data. In the latter case, the kinematic consistence of model and data can be directly evaluated by investigating the flatness of reflector images in common-image gathers. Furthermore, the prestack migration can be performed in a true-amplitude manner such that the amplitudes of reflector images are directly related to the reflection coefficient. This allows further analyses of the subsurface properties such as, e.g., amplitude variation with angle (AVA) analyses.

Synthetic data examples demonstrated the potential of the CRS-based imaging workflow (e.g., Mann et al., 2003). Real data examples indicate a similar performance: a detailed structural image in the depth domain can be obtained in a highly automated manner by means of a CRS-based imaging workflow.

References:

Duveneck, E. (2004). Velocity model estimation with data-derived wavefront attributes, Geophysics 69(1). In print.

Mann, J., Jäger, R., Müller, T., Höcht, G., and Hubral, P. (1999). Common-reflection-surface stack - a real data example. J. Appl. Geoph., 42(3,4):301-318.

Mann, J., Duveneck, E., Hertweck, T., and Jäger, C. (2003). A seismic reflection imaging workflow based on the Common-Reflection-Surface stack, J. Seis. Expl., 12:283-295.

Jäger, R., Mann, J., Höcht, G., and Hubral, P. (2001). Common-reflection-surface stack: Image and attributes, Geophysics, 66(1):97-109.