O3-3	SIMULTANEOUS DETERMINATION OF VELOCITY AND INTERFACE DEPTH IN REFLECTION TOMOGRAPHY

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Abstract

Seismic traveltime tomography is used to reconstruct a velocity model of the Earth's subsurface using propagation times of wavefields that have passed through the region of interest. Reflection tomography incorporates the traveltimes of seismic waves that have propagated through the medium of interest before and after reflection from an interface. It is used typically in surface seismic reflection data (e.g., Bishop et al., 1985, Williamson, 1990). In reflection tomography we can parameterize the reflector and velocity field in some suitable fashion and simultaneously inverting them. This approach is very "attractive" since it treats both inversion parameters on the same basis (Bishop et al., 1985; Farra and Madariaga, 1988). However, because of the trade-off between media velocity and reflector depth (the velocity-depth ambiguity- Stork and Clayton, 1986; Bickel, 1990; Lines, 1993; Ross, 1994; and Tieman, 1994) the reflector interfaces and velocity cannot be uniquely determined without a priori information on reflector location.

In this work we present a method for velocity and interface depth determination based on tomography of reflection traveltimes. The standard practice of dividing the medium into a grid of square cells with values of slowness assigned at the grid points has been followed. A continuous reflector is also given as function of horizontal offset. Rays are traced backward in time, through the reference model to compute the predicted traveltimes for arrivals from the given reflector (*forward model*). The velocity and reflector depth of the reference model is then adjusted to minimize the difference between the predicted traveltimes and the actual traveltimes of the prestack time data (*inversion*). For the two-parameter model consisting of a slowness variation ds and reflector depth variation ds the traveltime deviation of a ray is given as:

$$\mathbf{A*dx=dt}$$

where matrix **A** consists of slowness and depth derivatives weighting by the expected variance of each parameter, vector **dx** contains information about new velocity and reflector model and **dt** is the difference between calculated and observed data.

We solved the forward problem by using a finite-difference algorithm for calculating reflection traveltimes in complex 3D velocity models with complex 3D reflector geometry (Hole and Zelt 1995). Snell's law for reflections is used in the vicinity of the reflecting interface. The reflector model is allowed to vary smoothly in depth. The advantage of this method is that traveltimes are computed simultaneously for all receivers. The raypaths and the depth derivatives are stored in order to construct the matrix **A**.

The inverse problem is solved by weighted least squares. The resulting system is written as

$$\mathbf{(A^T*C_D^{-1}*A+C_M^{-1})*dx=A^TC_D^{-1}*dt}$$

where C_D is the data covariance matrix containing the variance of the data and C_M is the a priori parameter covariance matrix.

The solution of this problem is quite difficult since reflection seismic data contain a long wavelength ambiguity making difficult to separate traveltime information into velocity and reflector depth components. It is also known from the literature that in reflection tomography the ambiguity in

velocity for a given reflector is dependent on the offset of the recording spread and the picking accuracy (Bickel, 1990).

We have tested our method on three cases:

a) We assume that reflector is completely defined by a priori information i.e. a depth and shape are specified.
b) Parameterize the reflector and include it in the inversion assuming that the velocity field is known by a priori information (velocity analysis or applying refraction methods)
c) Inverting both parameters (depth reflector-velocity) at the same time.

Unfortunately a standard application of an optimization method “suffers” from a trade-off between reflector depth and near-reflector velocities and the uncertainty in the selection of the appropriate weighting factor for each parameter and factors for the regularization of our inverse problem (Soupios et al., submitted, 1999).

Finally, the tests confirm that the short-wavelength velocity-depth trade-off at the reflector is unresovable without the incorporation of further a priori information.

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