C034 REFLECTIVITY REVISITED

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Introduction

The seismic method is based on the fundamental property that downward travelling seismic source wave fields are returned to the surface by *reflection* (and/or refraction). Hence the reflectivity property of the subsurface plays a key role in seismic exploration. Structural information is generally derived from 'average' reflectivity. Lithologic information can be derived as well, provided *angle-dependent* reflectivity is taken into account.

Forward model

The essence of our forward model is that each temporal Fourier component of the seismic subsurface response is presented as a combination of matrix operators that represent surface, propagation and reflection effects. The propagation effects depend on the macro model of the subsurface and the reflection effects are determined by the detailed subsurface properties.

We discuss the situation for one reflecting depth level $z=z_m$ (Figure 1). A distinction is made between surface and subsurface effects. At the surface operator $\mathbf{D}^+(z_0)$ decomposes the input source $S(z_0)$ into a purely downgoing scalar wave field $\mathbf{S}^+(z_0)$. This primary source wave field propagates into the subsurface, the propagation being described by operator $\mathbf{W}^+(z_m,z_0)$, and reflects at the reflector at z_m. The reflection properties are contained in operator $\mathbf{R}^+(z_m)$. Next the reflected wave field propagates back to the surface, the propagation being described by operator $\mathbf{W}^-(z_0,z_m)$, and the upgoing wave field $\mathbf{P}^-(z_0)$ at the surface is recorded with some acquisition method described by operator $\mathbf{D}^-(z_0)$. However due to the free surface, energy is also reflected back into the subsurface, the reflection being described by operator $\mathbf{R}^-(z_0)$. Note that all operators are *matrix* operators and, therefore, any subsurface inhomogeneities can be taken into account.

From the angle dependent reflection coefficient to the reflectivity matrix

We start with the well-known angle dependent plane wave reflection coefficient for two acoustic half spaces separated by interface z_m (wave number formulation):

$$\tilde{R}^+(k_x,z_m,\omega) = \frac{\rho_2\sqrt{k_1^2-k_x^2} - \rho_1\sqrt{k_2^2-k_x^2}}{\rho_2\sqrt{k_1^2-k_x^2} + \rho_1\sqrt{k_2^2-k_x^2}} \tag{1}$$

It defines the relation between the incident wave field $\tilde{S}^+(k_x,z_m,\omega)$ and the reflected wave field $\tilde{P}^-(k_x,z_m,\omega)$ at interface z_m:

$$\tilde{P}^-(k_x,z_m,\omega) = \tilde{R}^+(k_x,z_m,\omega)\tilde{S}^+(k_x,z_m,\omega) \tag{2a}$$

or, in the space domain,

$$P^-(x,z_m,\omega) = R^+(x,z_m,\omega) * S(x,z_m,\omega), \tag{2b}$$

where * denotes convolution along the x coordinate. Figure 2 shows an example of $\tilde{R}^+(k_x,z_m,\omega)$ and $R^+(x,z_m,\omega)$. Note that convolution operator $R^+(x,z_m,\omega)$ contains the complete angle dependent reflection property of interface z_m.

If the reflection property of depth level z_m changes laterally, then (2b) becomes a laterally variant convolution and a matrix notation is more elegant:

$$\vec{P}^-(z_m) = R^+(z_m)\vec{S}^+(z_m). \tag{3}$$

Note that one row of matrix $R^+(z_m)$ defines the angle dependent reflection operator that need be applied to the incident wave field 'around' one grid point at z_m; one column defines the angle dependent reflection property of one grid point at z_m. The latter represents an *intrinsic* property of the related subsurface grid point; it should be the basic output of any pre-stack migration process.

Final note

During the presentation the physical significance of the rows and columns of R^+ will be explained and illustrated with acoustic and elastic examples. It will be argued that AVO effects are generated by the directivity properties of the columns of R^+. Hence, in its most advanced form AVO inversion is applied *after* elimination of the propagation operators W^+ and W^- by a proper pre-stack migration process. This is part of the DELPHI inversion scheme.

References

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Bruin, C.G.M. de, Wapenaar, C.P.A., Bèrkhout, A.J., 1990, Angle-dependent reflectivity by means of prestack migration. Geophysics, *55*, 1223 - 1235.

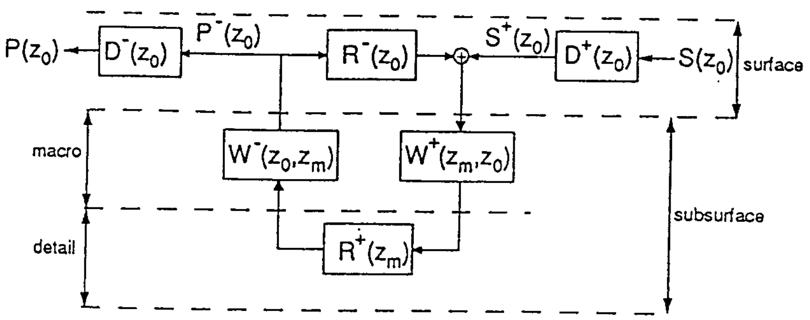

Fig.1: The reflection operator as part of the forward model (one reflection level).

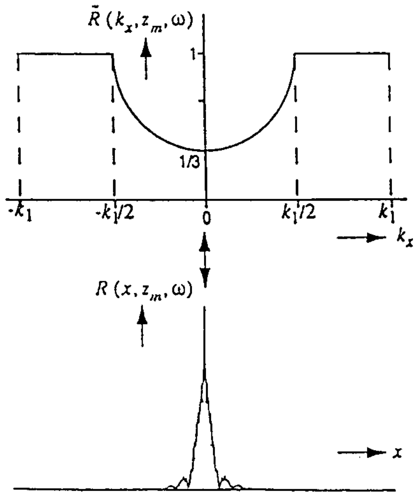

Fig.2: Angle dependent reflection operator in wave number and space domain.