REFLECTION COEFFICIENT MAPPING IN MULTILAYER HETEROGENEOUS MEDIA

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Abstract

In this paper, the reflection coefficient mapping is obtained by applying the geometrical spreading correction to the principal component of the zero-offset primary reflection wavefield. The seismic model is assumed to be known and for tutorial reasons constituted by two-dimensional (2-D) homogeneous layers separated by arbitrary curved interfaces. The geometrical spreading factor is then expressed by a function of the so-called eigenwavefront attributes, namely the curvatures of the normal incidence point (NIP) wave and the normal (N) wave. By applying to the same set of seismic data, the proposed reflection coefficient mapping is compared with the result of the zero-offset true amplitude diffraction stack migration algorithm and also with the exact value obtained by the plane wave reflection coefficient approximation.

INTRODUCTION

One of the most important problem in the seismic method concerns for finding the amplitude anomalies - bright spot - in a true amplitude processed seismic section. This is only possible if we have a method for mapping each sample in the time domain into the corresponding reflection coefficient in the depth. In the last years, many works have addressed to this problem (Hubral et al., 1983; Bortfeld and Kiehn, 1992; Schleicher et al., 1993 and Castagna, 1997). In this paper we present a new technique for mapping the reflection coeficient at the subsurface from a zero-offset seismic section, under the assumption that the amplitude of the primary seismic reflection does not change too much with the offset. We consider the high frequency wavefield, in the seismic exploration, is very good approximated by the so-called asymptotic ray series solution. The principal component of the primary compressional wave in the zero-order approximation is generally a complex quantity. In the zero-offet configuration, the primary reflections will always have the shape of either the source pulse or of its Hilbert transform, depending on if exist or not caustic along the ray. The investigated case corresponds to zero-offset reflections, that are originated by normal rays at a curved reflector in a isotropic layered 2-D medium. The wavefield is then represented by the formula (Cerveny, 1987)

$$U = \frac{R_C}{L}\,, \tag{1}$$

where U is the amplitude of principal component of the compressional wavefield, R_C is the plane-wave reflection coefficient which could be a complex value, and L is the geometrical spreading factor, with unitary source strength and without transmission loss.

THE REFLECTION COEFFICIENT MAPPING

For determining the reflection coefficient at each normal incidence point on the reflector from the zero-offset reflected wavefield, we need only to multiply the amplitude of the principal component in equation (1) by a factor equal to the geometrical spreading. As expressed by Hubral (1983), the geometrical spreading factor in the zero-offset seismic data is expressed as function of the curvatures K_{NIP} and K_N of two eigenwavetronts of the normal ray problem, the so-called NIP (normal incidence point) wave and normal wave, respectively. The NIP wave tunes the reflection point (Figure 1a), while the normal wave tunes the reflector itself (Figure 1b). The geometrical spreading factor of the normal reflection ray is given by

$$L = \frac{\sqrt{2}}{\sqrt{K_{NIP} - K_N}}\,. \tag{2}$$

If the macromodel is a priori known, the two eigenwavefront curvatures can be forwards calculated by formulas that depends on the normal ray parameters and the velocity model (Hubral and Krey, 1980). In the case that we does not know the macromodel, these two curvatures could be obtained as solution of some inverse problem as presented by Muller et al. (1998). The zero-offset section, that is used as input data, can be simulated from a set of common-offset seismic sections by an optimized stack process. In this paper, for didatic reason, we only consider the situation where the macromodel is totally known. After determining these curvatures by using the assumed known macromodel, we apply the obtained zero-offset geometrical spreading factor to the picked amplitude of the principal component of the primary reflection wavefield, resulting in the reflection coefficients through the reflector.

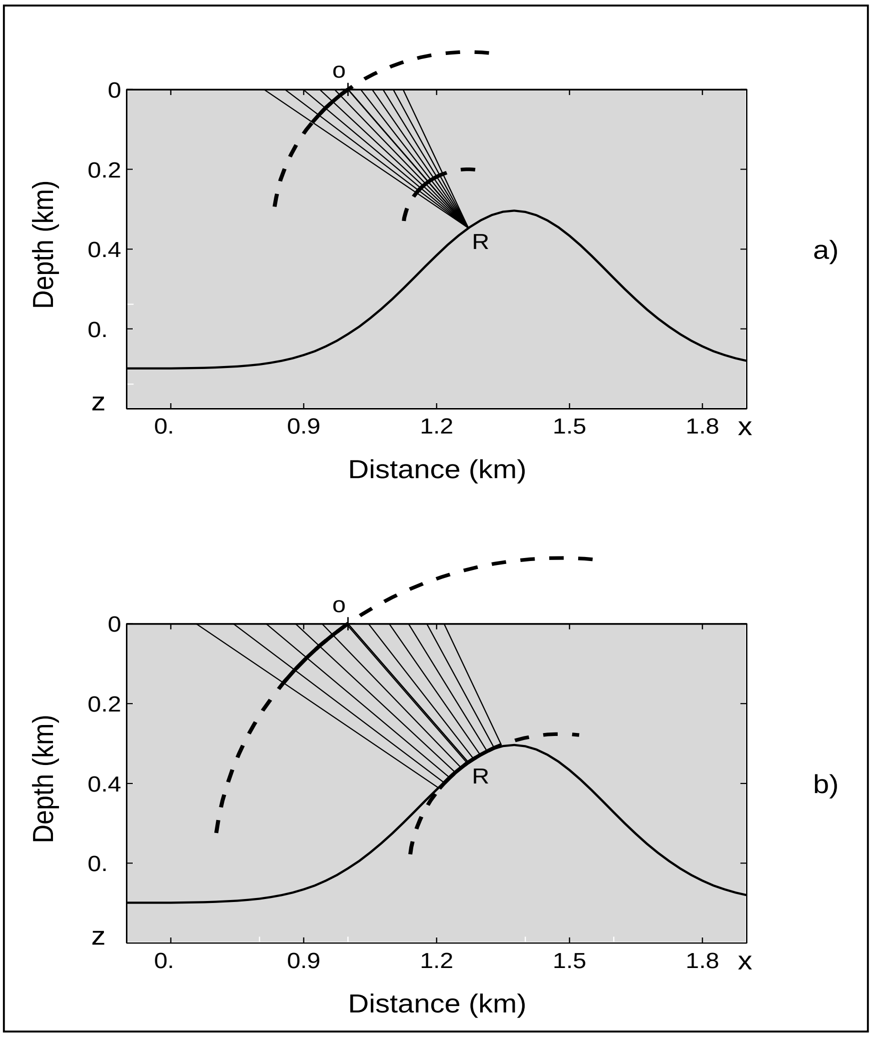

Figure 1- Homogeneous model: a) rays defining the NIP wave that start at reflection point R. b) normal rays defining the N wave that start on the reflector.

APPLICATION

In order to measure the accuracy of the proposed reflection coefficient mapping using the eigenwavefront attributes, we have applied it to a set of seismic traces generated by the ray tracing algorithm SEIS88, within a zero-offset configuration. We consider the macromodel constituted by the interval velocities 2500 m/s, 3000 m/s and the half-space velocity 3500 m/s, separated by two arbitrary curved interfaces (Figure 2). We have also apllied to the same set of seismic data, by considering the same macromodel, the well known true amplitude diffraction stack migration. The true amplitude depth migrated seismic section is presented in the Figure 3. Both results are showed in comparison to the exact values of the reflection coefficients in Figure 4, where we have the picked reflection coefficients as given by the true amplitude migrated data and the result obtained by the eigenwavefront reflection coefficient mapping.

CONCLUSIONS

The presented reflection coefficient mapping procedure is called here **eigenwavefront reflection coefficient mapping method,** because in order to determine the reflection coefficient we need to calculate the attributes of two eigenwaves - NIP and Normal Waves. In practical point of view when the macromodel is not known a priori, these wavefront parameters can be well determined by some inversion technique based on the seismic stack processing. In contrast with the true amplitude Kirchhoff migration, the eigenwavefront mapping method does not use any integral operator for obtaining the reflection coefficient. When compared with the true amplitude diffraction stack migration result, we can see that both methods have the same accuracy in the central part of the model, but the last one suffer from border effect (apperture) while the former does not present any problem of this nature.

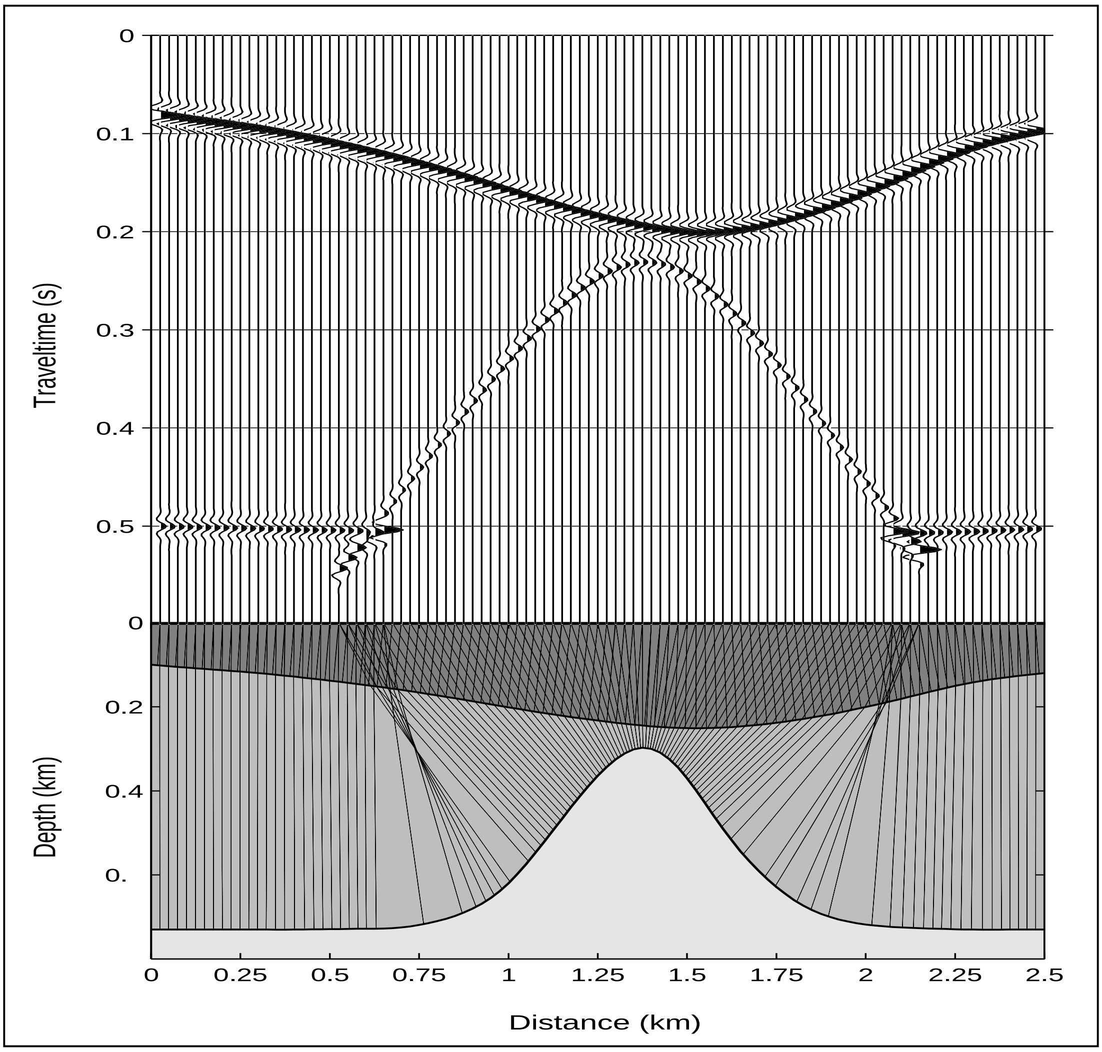

Figure 2 – Seismic Model and seismogram. *Lower half*: Heterogeneous model with curved interfaces and with zero-offset normal incidence rays. *Upper part*: Zero-offset seismogram. The wavefield corresponds to the principal component of P-P reflected wave.

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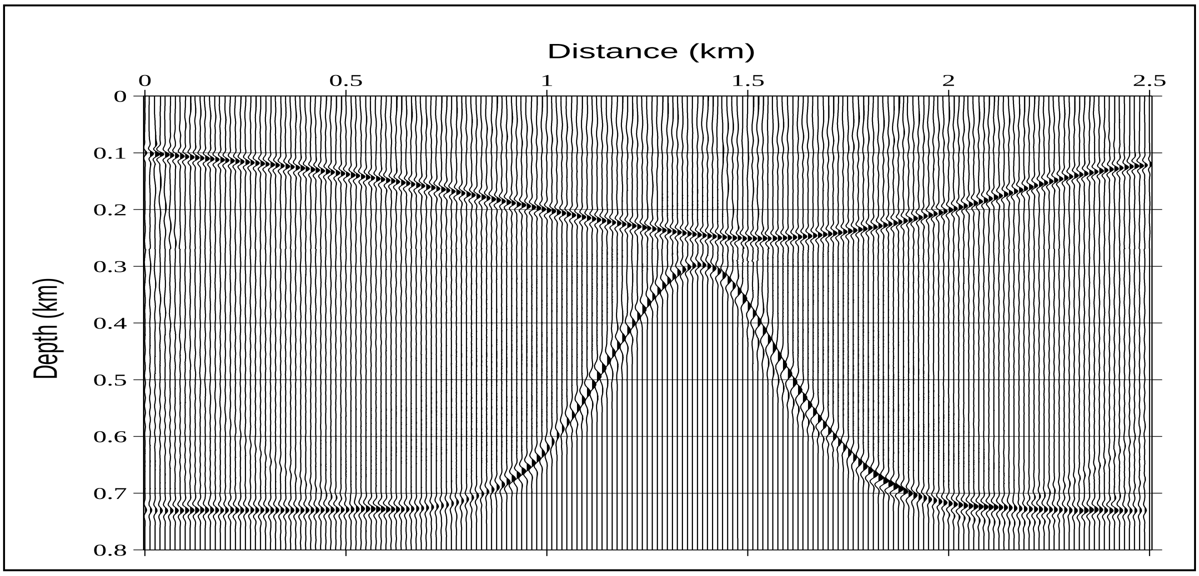

Figure 3 – True amplitude depth migrated section obtained by the modified diffraction stack migration.

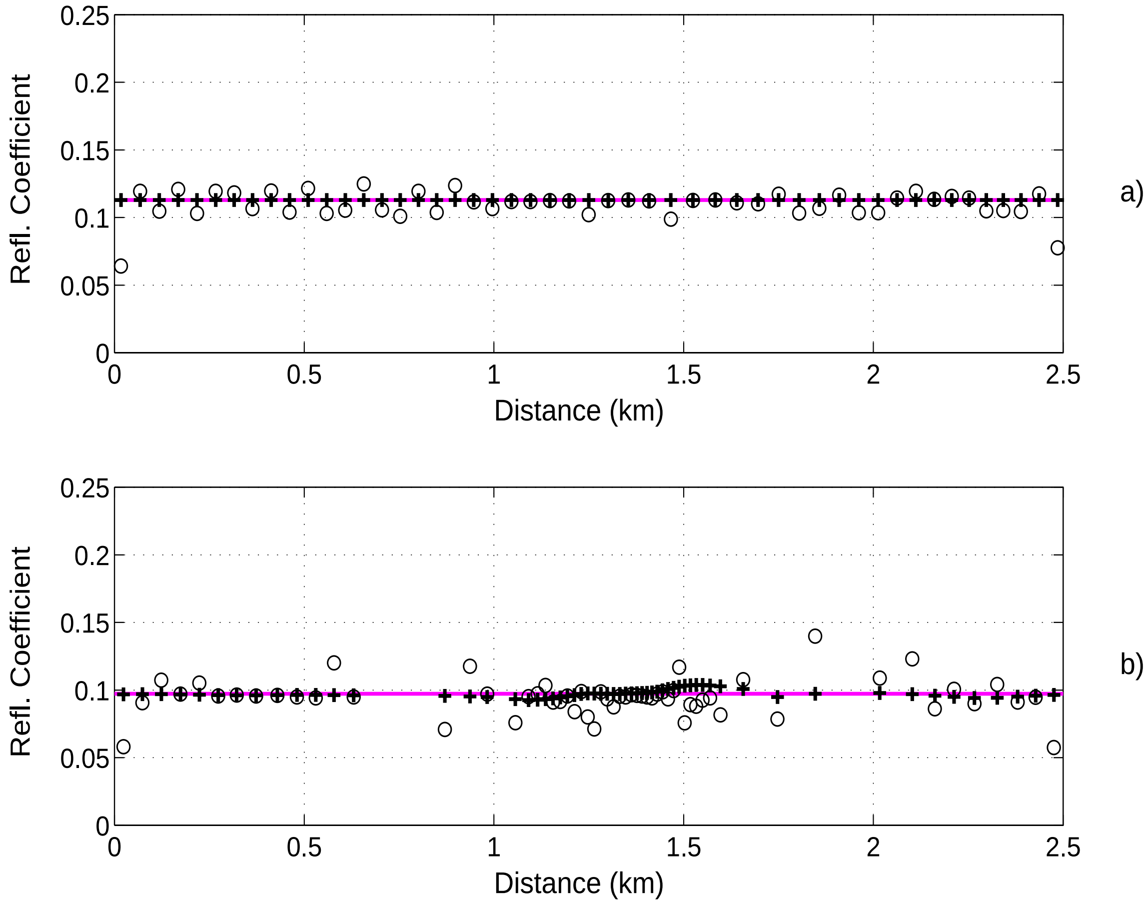

Figure 4 – Reflection coefficient at each normal incidence point on the reflectors a) first reflector and b) second reflector. The gray solid line corresponds to the exact reflection coefficients. The black cross line is obtained by using the eigenwavefront attributes and the circles line results from the true amplitude diffraction stack migration.