VELOCITY ANALYSIS BY HOMEOMORPHIC IMAGE FOCUSING

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ABSTRACT

In the conventional seismic processing the image of the seismic reflector is obtained by applying a depth migration method to the input seismic data. This is reached by assuming a known macrovelocity model and using a diffraction stack process on the observed seismic data. In this paper a new kind of image of the seismic reflector is defined by considering only the kinematic aspects, within a seismic model consituted by homogeneous multilayers separated by curved interfaces. The referred new image process is performed as solution of the inverse reflection normal ray problem, having as input data a zero-offset seismic section and as searched-for parameters the radius of curvature (R_{NIP}) of the Normal Incidence Point (NIP) wave, the emergence angle (β_0) and the emergence point x_0 of the reflection normal ray . The cited three parameters are then determined for each normal reflection ray by applying the Double Diffraction Stack Technique (DDSI), and the image itself is builted by putting the amplitude of the diffraction stacked data into the center of curvature of the NIP wave, the so-called *homeomorphic image*. By using three different macrovelocity models, we provide a measure of the sensibility of the proposed imaging process on varying the bottom layer velocity of the target zone.

INTRODUCTION

It is well known from the geophysicists that to obtain a true image of the seismic reflectors it is necessary to have a very good information about the macrovelocity model above the target reflector. Several works in the past years have interested for velocity inversion problems. A complete discussion about a lot of these works can be found in Hubral and Krey (1980) and Hubral (1993). Recently, Tygel et al. (1993) presented a new inversion technique, the so-called Double Diffraction Stack, through which it is possible to estimate several parameters on the trajectory of a selected ray between the source and geophone for any arbitrary configuration. This inversion technique is based on the weighted diffraction stack migration algorithm as presented by Schleicher et al. (1993), that in this paper is taylored in order to determine the NIP wave attributes, which are used for building the homemorphic image of the target seismic reflector.

DETERMINATION OF NIP WAVE ATTRIBUTES

For determining the NIP wave attributes it is used the double diffraction stack inversion technique having as input a simulated zero-offset section. This is reached with help of a Kirchhoff type diffraction stack algorithm, where the weight function is defined by the radius of curvature, or the emergence angle or else the point of emergence of the so-called NIP wave. In two-dimensional case the weighted diffraction stack migration is mathematically described by the one-dimensional integral

$$V(M,t) = \frac{1}{\sqrt{2\pi}} \int_A d\xi w(\xi,M) \partial_{t-}^{1/2} U(\xi, t+\tau_D(\xi,M))$$

In this integral formalism we have that the symbol $\partial_{t-}^{1/2}$ means the half-time anticausal derivative. The ξ parameter determines each source and geophone position on the earth surface and $w(\xi,M)$ is the weight function used to stack. The function $U(\xi,M)$ represents the vertical component of the primary reflection wave. Thus, by choosing the appropriate weight function and making use of the correct stack trajectory given by the $\tau_D(\xi,M)$ diffraction curve for a diffraction point M, we may obtain a result proportional to the reflection coefficient at the reflection point in the subsurface, i.e. the so-called true-amplitude depth migration. Otherwise if the weight function equals the unit, the result is a non preserved amplitude (or kinematic) seismic migration.

As a consequence of the above definition we have that the result of the integral (1) depends basically on the used macrovelocity model and of the selected weight function. If we consider that the velocity function is known and, we write $V(M,t) = V_\omega(M,t)$, where ω is the index for specifying the used weight to stack the set of data. The double diffraction stack inversion technique is then defined by a double stack which one with a different weight function $\omega = 1$ and

$\omega = 2$, being the result obtained as the ratio between the two stacks given by

$$V_{DDS}(M,t) = \frac{V_1(M,t)}{V_2(M,t)}$$

By the asymptotic analysis of the integral (1), if for the first stack we choose as weight function a ray parameter specified by the trajectory that starts at the diffraction point M and ends at the surface of the earth, and for the second stack the unit, the double diffraction stack inversion will result at the value of the selected ray parameter.

In this paper, we have used the above definitions in order to determine the following normal reflection ray parameters: (1) The emergence position coordinate x_0 at the earth surface; (2) the emergence angle β_0 at the earth surface; and (3) the radius of curvature R_{NIP} of the so-called NIP wave associated with the normal incidence point.

In the homeomorphic image space each reflection point in the earth subsurface is then related with a center of curvature given by the coordinate trio (x_0, R_{NIP}, β_0). Thus, the signal amplitude of the depth migrated seismic section when put into the corresponding center of curvature will perform what we call the homeomorphic image. This homemorphic image will be true only if the diffraction stack process is done with the true macrovelocity model, in contrast we will have an estimated homeomorphic image. In order to define the best velocity model we should combine the DDSI results with the one derived from others macrovelocity independent optimization methods that also provide the estimate of the NIP wave attributes (Muller et al, 1998).

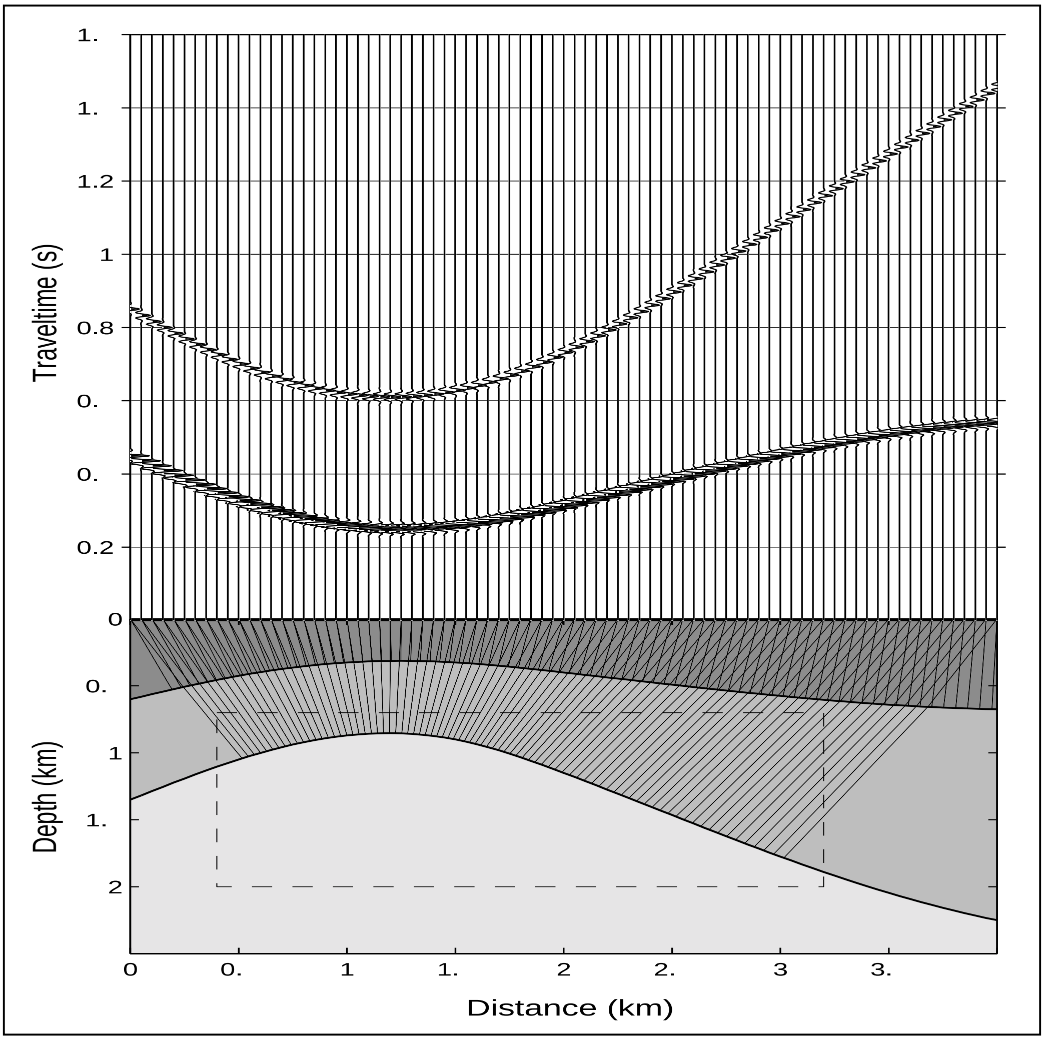

Figure 1- *Lowerpart*: Synthetic model with curved interfaces and zero-offset normal incidence rays. The dashed line indicates the target zone for migration. *Upper part*: Zero-offset synthetic seismogram.

EXAMPLES

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In order to do a numerical experiment we have generated a set of synthetic seismic traces by using the ray theoretical modeling algorithm SEIS88. We have used a seismic model (Figure 1) constituted by two layers above a half-space and two reflectors. The P-wave velocities are $2500\, m/s$ and $3000\, m/s$ for the first and second layer, respectively. By using a Gabor wavelet with frequency of 60 Hz, a sample interval of $\Delta t = 1ms$ and a space interval on the x axis $\Delta x = 25m$, we have obtained an ensemble of zero-offset seismograms (Figure 1) used as input in the imaging process. In this seismic experiment we consider only primary $P-P$ reflections.

The final products are obtained by considering three different possible p-wave velocities within the bottom layer of the seismic model (Figure 1): ($2700m/s, 3000m/s, 3300m/s$). Thus we have : (1) The depth migrated seismic images of the target reflector (Figure 2); (2) The homeomorphic images of the target reflector (Figure 3); (3) the radiusgrams of the NIP wave associated with the target reflector (Figure 3); (4) the anglegrams of the NIP wave associated with the target reflector (Figure 4); (5) the coordinate of the emergence points of the reflection normal rays at the target reflector (Figure 5). It is important to observe that in this experiment the first velocity and the geometry of the above interface is considered a priori known.

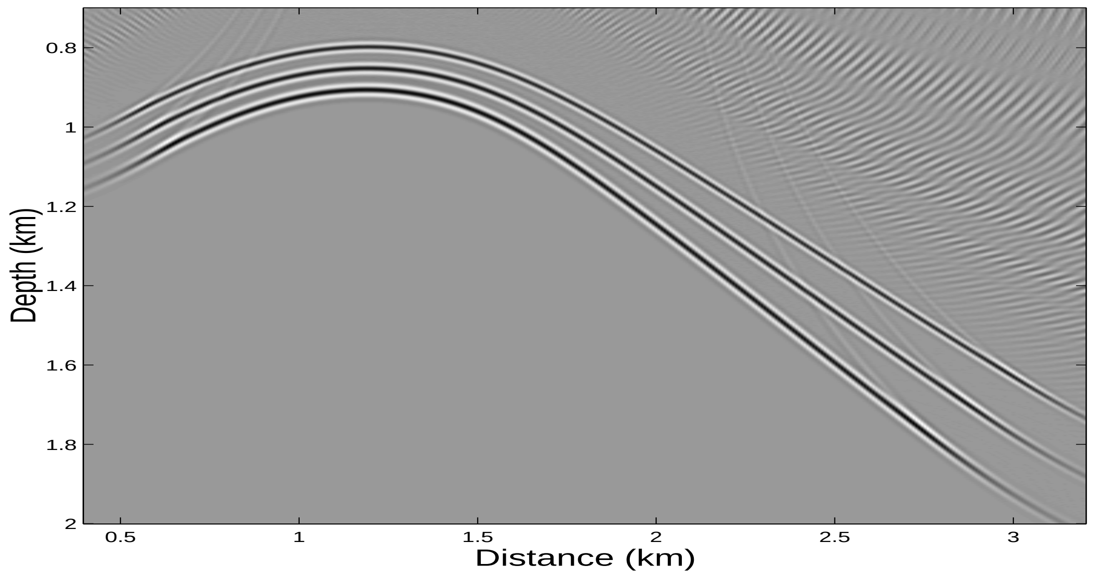

Figure 2 - Depth migrated images corresponding to the target zone showed in Figure 1, for the three different possible P-wave velocities within the bottom layer.

CONCLUSIONS

By using the NIP wave parameters (R_{NIP}, β_0, x_0) obtained as products of the DDSI technique, it was built the homeomorphic image of the selected seismic reflector, by considering three possible P-wave velocities within the bottom layer. In order to estimate the best layer velocity, we should combine the results of the DDSI and the NIP wave attributes obtained by other macrovelocity independent optimization procedures, making possible to estimate into an optimal sense the best macrovelocity model.

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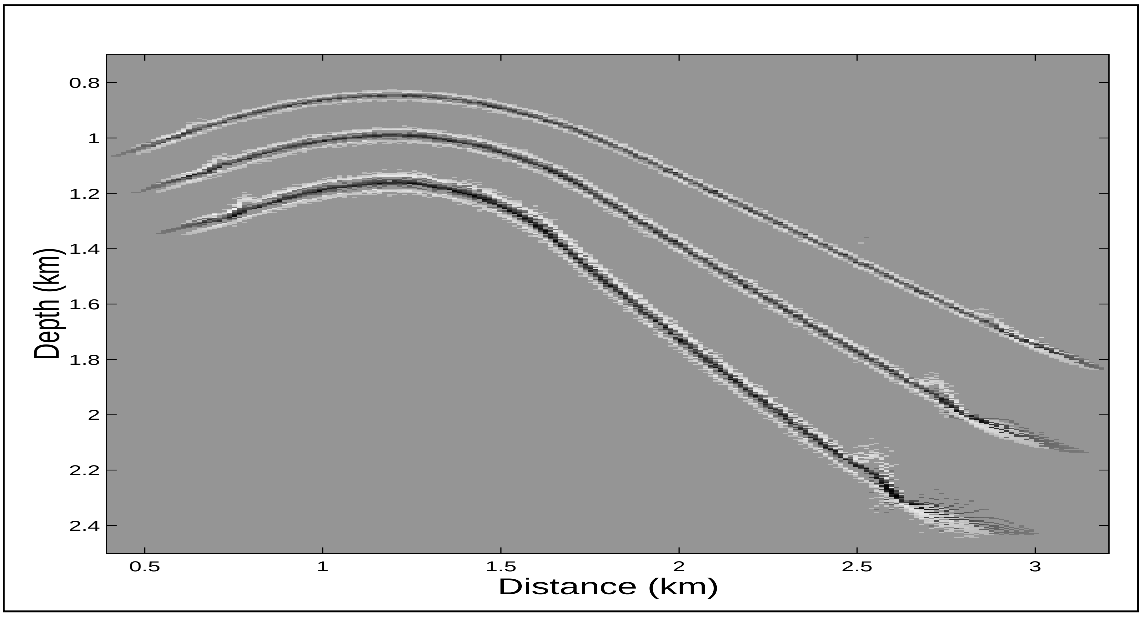

Figure 3 – Homeomorphic images corresponding to the target zone in Figure 1, for the three P-wave velocities within the botton layer (2.7 km/s, 3.0 km/s and 3.3 km/s).

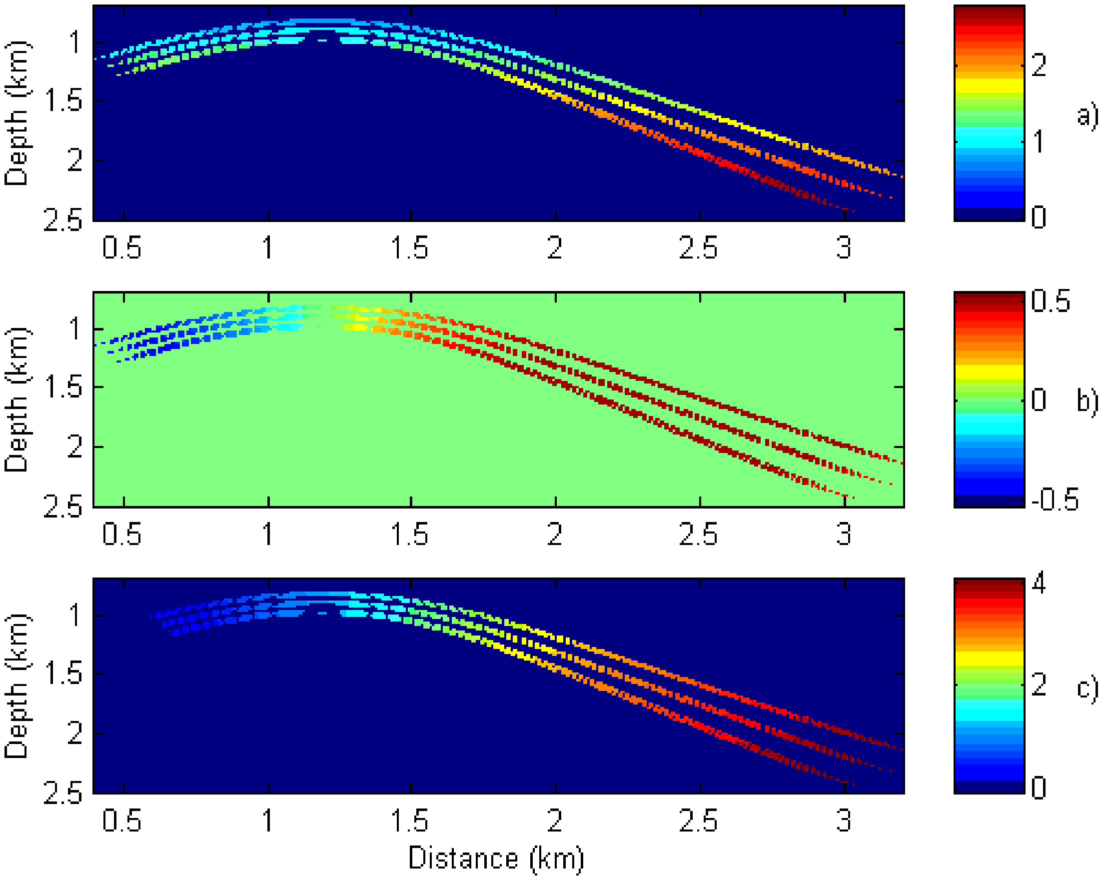

Figure 4 - NIP wave atributes correspondig to the three P-wave velocities within the bottom layer (2.7 km/s, 3.0 km/s and 3.3 km/s): a) radiusgrams b) anglegrams and c) emergence point coordinates of the reflection normal rays.