PROCEDURE OF ANISOTROPY PARAMETERS ESTIMATION IN VERTICAL TRANSVERSE ISOTROPY MEDIUM BASED ON SEISMIC DATA APPLICATION OF PROBABILISTIC OPTIMIZATION METHODS IN SEISMIC VELOCITY MODEL BUILDING

IN SEARCH OF THE NEW IDEAS TO IMPROVE HYDROCARBON RECOVERY

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Keywords: **anisotropy, velocity estimation, global optimization**

RESUMEN

Procedimiento de estimación de parámetros de anisotropía en un medio con isotropía transversal de eje vertical basado en datos sísmicos de superficie

El presente trabajo muestra la aplicación de metodologías de optimización global para la estimación de los parámetros de Thomsen ε y δ en medios con isotropía transversal de eje vertical a partir de datos sísmicos de superficie suponiendo un modelo estratificado en que la velocidad en la dirección vertical es conocida. El problema de optimización global planteado se resolvió mediante dos alternativas: algoritmos genéticos (GA) y recocido simulado o simulated annealing (SA). Se muestra en los ejemplos la capacidad de los dos métodos para llegar al mínimo global de la función costo sin resignar amplios rangos de búsqueda para los parámetros estimados.

INTRODUCTION

The velocity model is the key object of the research in the process of seismogeological subsurface imaging. It is possible after migration to determine subsurface geometry based on it. After further seismic processing, the dynamic and petrophysical features of rocks can be estimated. As a general rule sedimentary media are anisotropic. If this feature is not taken into account, the seismic processing results can give substantial differences in the positioning of the reflective interfaces (like it is shown in Banik (1984)), seismic wave field distortion (like it is shown in Kendall *et al.* (2001)), false reflexes appearance, etc. Among the main consequences of the discrepancy between an oversimplified isotropic interpretation and the reality can be the incorrect location of bore-holes or wrong decisions in the estimation of depth of the deposits. Currently, it turns out that more satisfying results of seismic processing and modelling can be achieved when proper account is made for the medium anisotropy. The solution of the problem of estimation of the anisotropy parameters is a topic of intensive research of scientists over the world (Thomsen L., 1986, Alkhalifah T. and Tsvankin I., 1995, Isaac J.H., Lawton D.C. 2004, Reshef M. i Roth. M 2006, Jervis M., Sen M.K., 1996, Tsvankin I., Thomsen L., 1994).

This research concerns the estimation of the Thomsen parameters ε and δ in anisotropic VTI (vertical transverse isotropy) medium on the basis of 2D land seismic survey data with long offsets and with assumption that the vertical velocity is known. The estimation of the anisotropy parameters was treated as optimization problem, and probabilistic global optimization methods were applied.

METHOD

This searching method of the anisotropic parameters for VTI (vertical transverse isotropy) medium is based on the traditional technology of the analysis of migration MVA (Migration Velocity Analysis) velocity. The method is based on the optimal velocity values for which the depth of imaged point of the medium as the function of the distance between the source and a receiver is invariable, which means that it is not dependent on the offset (Al-Yahya (1989); Kostecki and Półchłopek (2008)). In anisotropic medium, the so called "flatness effect" in common image gathers is possible only if anisotropy parameters ε and δ are considered. However, in this project, the estimation of the anisotropy parameters would not be based directly on the correction for the graph of the depths of imaged points giving the "flatness effect" in the common image gathers (this correction is defined with anisotropy parameters) but would use the migration with the new velocity model that takes into account the anisotropy.

Instead of parameters scanning with fixed step, as an innovation we apply the optimization approach to the problem and we will attempt to use the probabilistic methods of the global optimization: simulated annealing (SA) and genetic algorithm (GA). These methods (Sen and Stoffa (1995)) are useful especially in the solution of non-linear problems, when models contain large amount of independent variables. Its main advantages are the independence from the starting point or initial model and the possibility to "go out" from a local minima. A drawbacks are difficulties with the application of the method for the specific problem and the fact that calculations can be very time consuming.

The general workflow is the following (Figure 1):

1. Preparation of the initial model - determination of first values for parameters ε i δ and approximate model geometry.

2. Kirchhoff pre stack migration for non zero offsets.

3. Picking of the depth for offsets on common image points (CIP) panels (seven panels were used in calculation).

4. Calculation of the sensitivity function for parameters ε and δ. Difference between zero offset depth and of the depth of the imaging point for another offsets and the velocity including the parameters of the anisotropy is calculated from the formula:

$$f(\varepsilon,\delta)=\sum_{k=1}^{K}\frac{1}{N}\sum_{j=1}^{N}(z_{k,0}-z_{k,j}(\varepsilon,\delta))^2,$$

where:

$z_{k,0}$ – depth for offset zero for panel with index k, $z_{k,j}(\varepsilon, \delta)$ - depth for offset j for panel with index k, which is calculated for fixed values of ε, δ, N – number of offsets, K – number of panels.

This is the object function for optimization methods. If the values of sensitivity function for parameters ε and δ are satisfying the program stops, otherwise anisotropy parameters ε and δ are updated in accordance with optimization method (SA or GA) and sensitivity function is calculated again until stop criteria is reached.

The optimization program uses procedures from free (with respect of GNU licence) geophysical software SeismicUnix (Cohen and Stockwell (2010)).

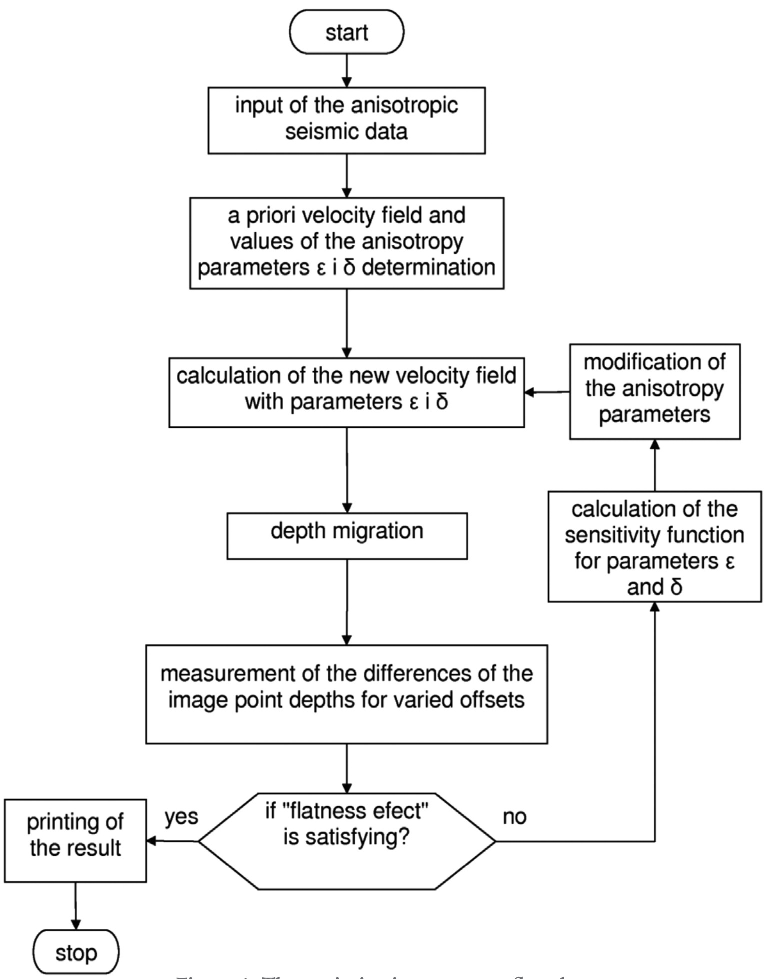

Figure 1. The optimization program flowchart.

Synthetic examples

Methodology was tested for two models presented in the Figure 2. Model I consists of one horizontal reflector, model II consists of two reflectors - one dipping and one horizontal reflector. For both models anisotropy appears in first layer. Anisotropy parameters were defined only in the first layer and have values $\varepsilon = 0.2$, $\delta = 0.05$.

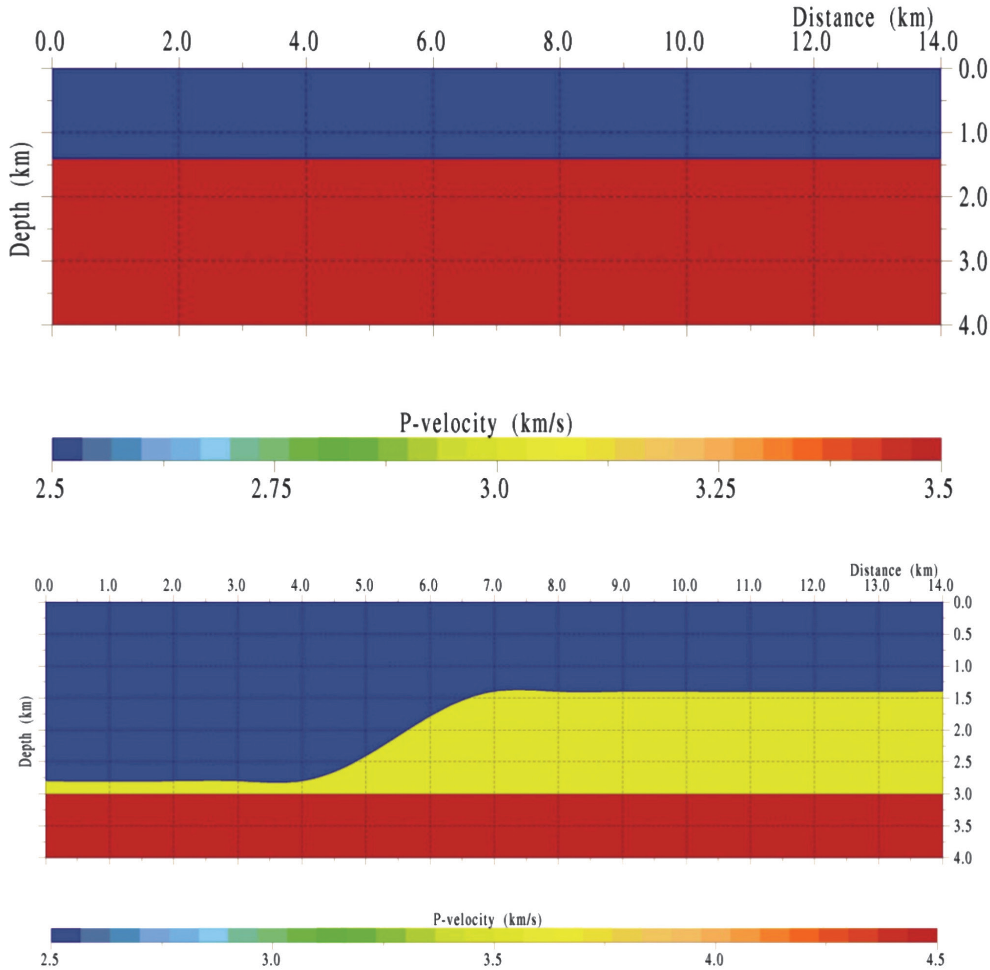

Figure 2. A. Model I consists of one horizontal reflector with depth 1400 m. Vertical velocity is constant in layer and equals 2500 m/s. Anisotropy parameters in first layer have values $\varepsilon = 0.2$, $\delta = 0.05$. B. Model II consists of two reflectors - one dipping with 250 dip in central part of model and one horizontal reflector with depth 3000m. Vertical velocity is constant and equal 2500 m/s and 3500 m/s for the first and the second layer. Anisotropy parameters in first layer have values $\varepsilon = 0.2$, $\delta = 0.05$.

Results

Calculation was carried out for 7 common image points (CIP) panels located in x = 5000, 5500, 6000, 6500, 7000, 7500, 8000 m. Vertical velocity is assumed to be known from additional data. Initial values of anisotropy parameters were fixed as 0 which gives isotropy velocity model.

The values for parameters ε and δ were sought in the interval [-0.2 ; 0.5]. For the purpose of determination of the initial geometry for model isotropic, a Kirchhoff migration was run and approximate depths were picked. Results are presented in Figures 3, 4 and 5.

		ε	δ
parameters values for model I i II		0.2	0.05
initial values for model I i II		0.0	0.0
results for model I	GA	0.256	0.003
	SA	0.233	0.007
results for modelu II	GA	0.181	0.078
	SA	0.1998	0.051

Figure 3. Values of anisotropy parameters for tested models.

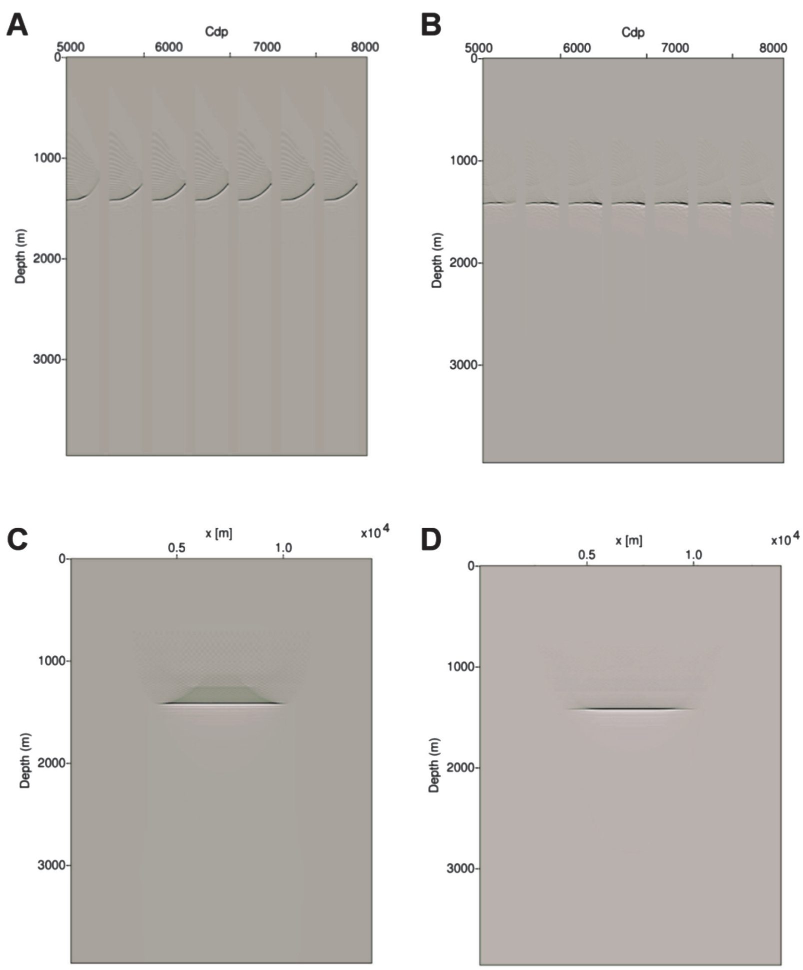

Figure 4. Results for model I. A. Selected common image panels for isotropic migration. B. Selected common image panels for anisotropic migration with parameters ε = 0.233 and δ = 0.007 obtained using SA method. C. Zero ofset isotropic migration. D. Zero offset anisotropic migration with parameters ε = 0.233 and δ = 0.007.

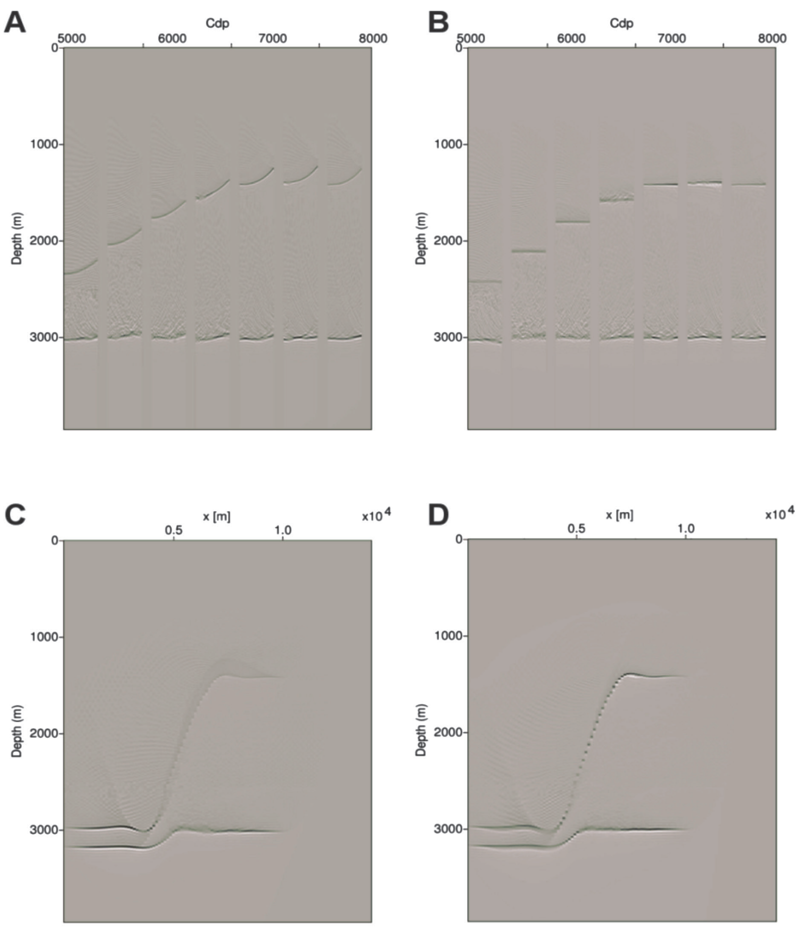

Figure 5. Results for model II. A. Selected common image panels for isotropic migration. B. Selected common image panels for anisotropic migration with parameters $\varepsilon = 0.199$ and $\delta = 0.051$ obtained using SA method. C. Zero offset isotropic migration. D. Zero offset anisotropic migration with parameters $\varepsilon = 0.199$ and $\delta = 0.051$.

CONCLUSIONS

Results are satisfying and encourage to further development of proposed methodology and examine its application conditions. First of all, possibility of using it for more complicated models must be checked. For simple models flatness effect was reached (Figures 4 and 5). Image after anisotropic migration is more accurate and correct than for migration without anisotropic parameters. Results obtained with using SA and GA are comparable for both methods.

In addition, the examples showed one of the main advantages of the global probabilistic optimization methods. It is possible to define wide values interval for seeking parameters and independence from the initial model. From the other hand, application of methods as SA and GA can be difficult because each method has its own set of control parameters. These are the parameters which characterize optimization process and adjustment of proper values can cause troubles.

ACKNOWLEDGEMENTS

This work was financed by The National Science Centre on the granted decision number DEC-2011/01/N/ST10/06963.

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