P252 AVO-INVERSION OF COMPRESSIONAL AND CONVERTED REFLECTIONS IN THE NEAR-CASPIAN TROUGH

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Abstract

The paper presents an application of the AVO-inversion algorithm with respect to compressional and converted reflections for multicomponent seismic AVO-data that were acquired in the Near-Caspian trough at the one of the oil-and-gas deposits. The algorithm provides stable nonbiased estimates of three elastic parameters of the medium V_p, V_s and ρ (Nefedkina et al., 1999). Possibilities of more accurate determining these parameters taking into account medium geometry structure, thin layers and anisotropy were studied. The obtained results coordinate with drilling data and correspond to the theoretical conceptions about the elastic parameters behavior at the gas deposits.

Introduction

Traditional approach to the AVO-inversion problem solution using precritical reflections provides stable determining only relative variations of the compressional wave impedance $\frac{\Delta\rho V_p}{\rho V_p}$ and less reliable determining relative variations of modulus of rigidity $\frac{\Delta\mu}{\mu}$. Complexing of compressional and converted waves permits us to obtain stable estimates of relative variations of three elastic parameters $\frac{\Delta V_p}{V_p}$, $\frac{\Delta V_s}{V_s}$ and $\frac{\Delta\rho}{\rho}$ (Nefedkina et al., 1999; Jin et al., 2000).

This paper presents the results of AVO-inversion of multicomponent seismic data that were acquired in the Near-Caspian trough at the oil-and-gas deposit Matin. Three “bright spots” were found at the PP-wave stack section (Fig. 1). Previous works with these seismic data (absence of such anomalies at the SS-wave stack section) permitted to connect two anomalies with gas deposits and later on it was confirmed by drilling results. AVO-analysis carried out for these two anomalies showed that reflection coefficients behavior corresponds to the gas deposit. In this paper parameters V_p, V_s and ρ of the gas reservoirs are determined using the AVO-inversion algorithm with respect to compressional and converted reflections (AVO(PP+PS) algorithm) (Nefedkina et al., 1999) and then possibilities of more accurate determining these parameters taking into account medium complex structure, thin layers and anisotropy are studied.

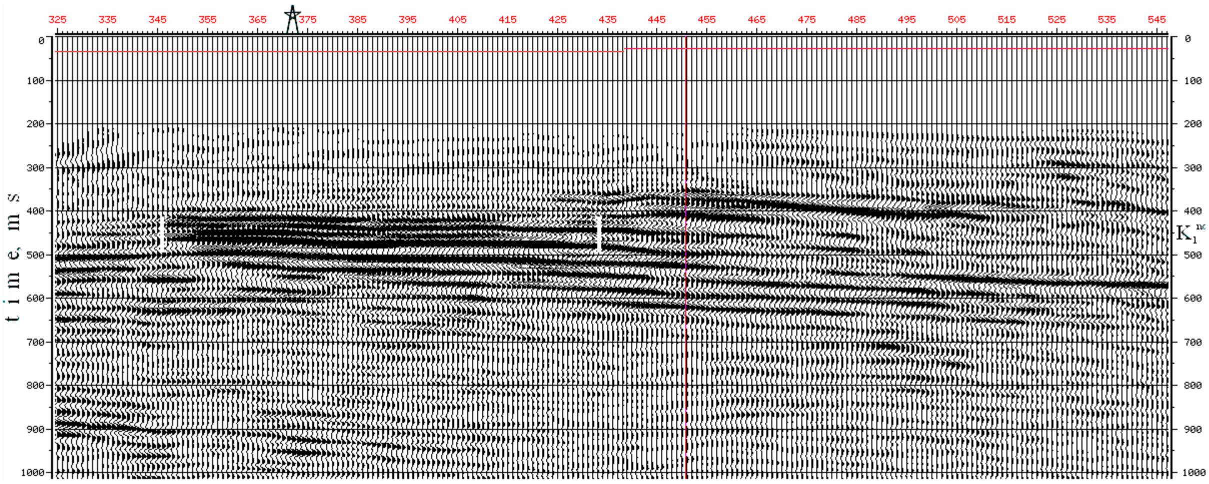

Figure 1. PP-wave stack section.

Methodology

AVO(PP+PS) algorithm is based on the principle that dependencies between the reflection coefficients of compressional and converted waves and the incidence angle are expressed in the polynomial form. The problem is considered in linearized variant on the assumption that variations in elastic parameters at the boundary that separates two isotropic half-spaces are small:

$$R^{pp}(i) \approx r_0^{pp} + r_1^{pp}\sin^2 i + r_2^{pp}\sin^4 i + \ldots,$$

$R^{ps}(i) \approx -\sin i[r_0^{ps} - r_1^{ps}\sin^2 i - r_2^{ps}\sin^4 i + \ldots]$, where i is the P-wave angle of incidence.

Relative variations of the elastic parameters at the boundary are determined from formula:

$$\begin{cases} \dfrac{\Delta V_p}{V_p} = 2\left[r_0^{pp} - \dfrac{1+2\gamma}{(1+\gamma)^2} r_0^{ps} + \dfrac{2}{(1+\gamma)^2} r_1^{ps}\right] \\ \dfrac{\Delta V_s}{V_s} = \dfrac{1+2\gamma}{\gamma(1+\gamma)^2} r_1^{ps} - \dfrac{2+3\gamma}{2(1+\gamma)^2} r_0^{ps} \\ \dfrac{\Delta \rho}{\rho} = \dfrac{2}{(1+\gamma)^2}\left[(1+2\gamma) r_0^{ps} - 2 r_1^{ps}\right] \end{cases}$$

The data were processed to preserve amplitudes and several gathers with high S/N ratio at which we had succeeded in identifying coherent lineups of PP- and PS-waves were selected for further investigations. AVO responses for compressional and converted reflections were defined and their parameters (r_0^{pp}, r_0^{ps} и r_1^{ps}) were determined (Fig. 2). For PS-waves AVO-analysis was performed using x-component, linear approximation was carried out for the function $-R^{ps}/\sin i$. Then the relative variations of elastic parameters at the boundary were determined and also the elastic parameters of gas reservoirs were determined using the model.

Medium that covers the gas reservoirs at the Matin deposit is anisotropic. It is followed from existing of significant y-component and time delay between x- and y-components. Shear-wave splitting takes place in the anisotropic medium and, therefore, we observe the interference impulse of PS_1- and PS_2-waves at the converted wave gathers. So, the effect of shear-wave splitting was investigated by rotation analysis of the multicomponent data (Obolentcheva, Gorshkalev, 1986). This analysis is able to find the principal axes of anisotropy and the time delay of splitting. The compensation for overburden anisotropy is then achieved by applying the estimated time shift, amplitude and rotation corrections, which simulate the reverse of the shear-wave splitting effect of the overburden. After this procedure AVO-inversion was carried out again.

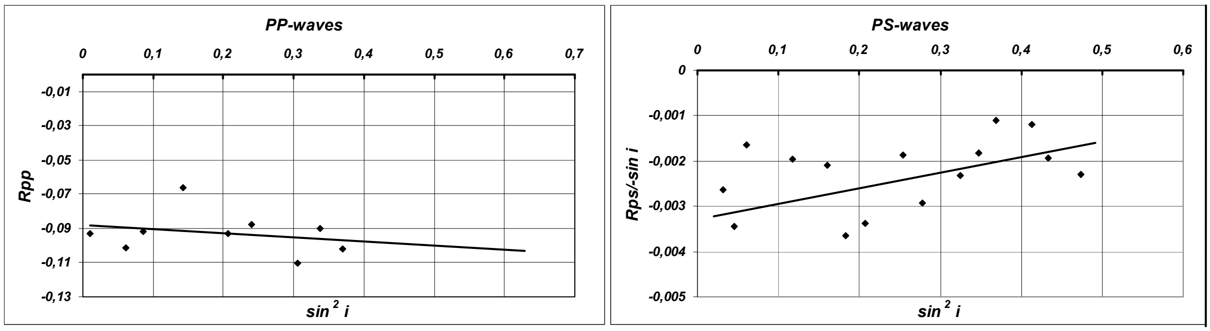

Figure 2. Observed reflection coefficients of the PP- and PS-waves approximated by linear polinom.

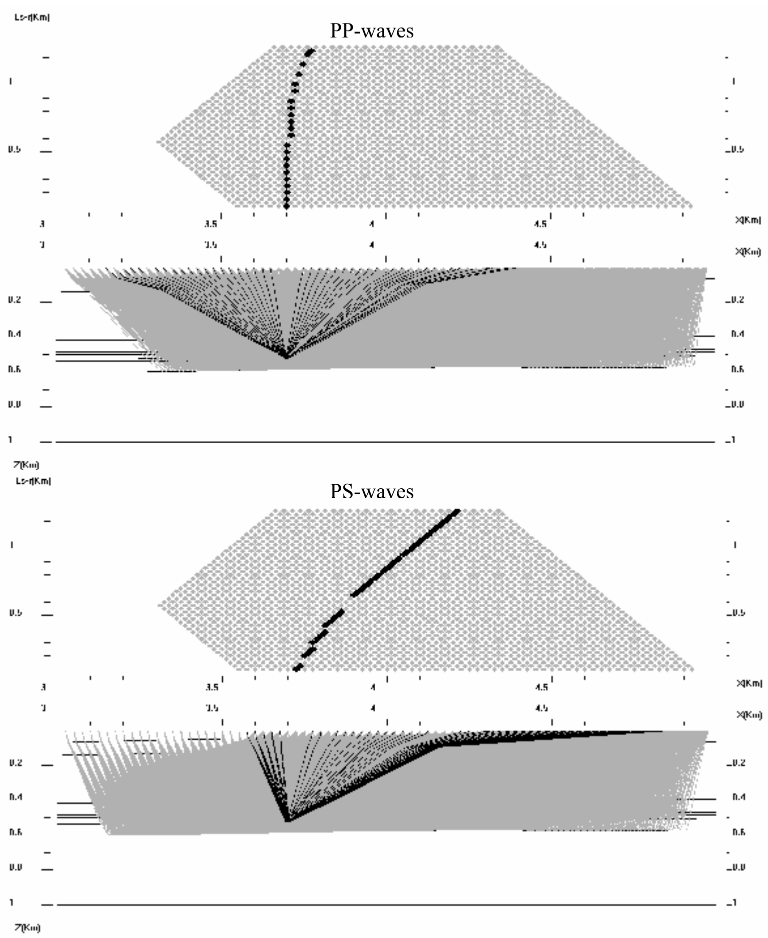

Figure 3. Results of ray tracing algorithm work. Selection of traces that correspond to the reflection from the specified part of boundary is shown at the observation scheme.

Thickness of the gas layers is 7 and 16 m, so we applied corrections to the amplitudes using the method that had been proposed by Bakke and Ursin (1998). The authors of this method insist that during the reflecting from thin layer the impulse form is changed on its derivative and the reflection coefficient from the thin layer is the reflection coefficient from one boundary normalized by

$$C(x) = \frac{T(0)}{T(x)}\left[1 + \frac{V_{\mathrm{RMS}}^2 - V^2}{2V_{\mathrm{RMS}}^4 T^2(0)}\right].$$

So, the corrections applied to the observed amplitudes are: $d(t,x) = R(x)\Delta T(0)C(x)p'(t)$, where p – impulse, $R(x)$ – signal amplitude. After this procedure AVO-inversion was carried out again.

The algorithm of ray tracing also was applied to raise the accuracy of elastic parameters determining. The rays from the all boundaries were computed using this algorithm and selection of rays reflected from area with specified length at the top of gas reservoir was performed (Fig. 3). CDP gathers of PP- and PS-waves were formed in such a way and AVO-inversion was carried out again.

Results

Results of the AVO-inversion problem solution using AVO(PP+PS) algorithm are shown in Figure 4. Clear P-wave velocity decreasing is noted within the bounds of the dynamic anomalies. The values of S-wave velocity change a little. The values of density are determined less stable than the P- and S-wave velocities but density decreasing is observed at the gas reservoir location anyway.

The P-wave velocity values coordinate with drilling data. Approximate corrections applied for the complex structure, thin layers and anisotropy raised the accuracy of elastic parameters determining by some percents.

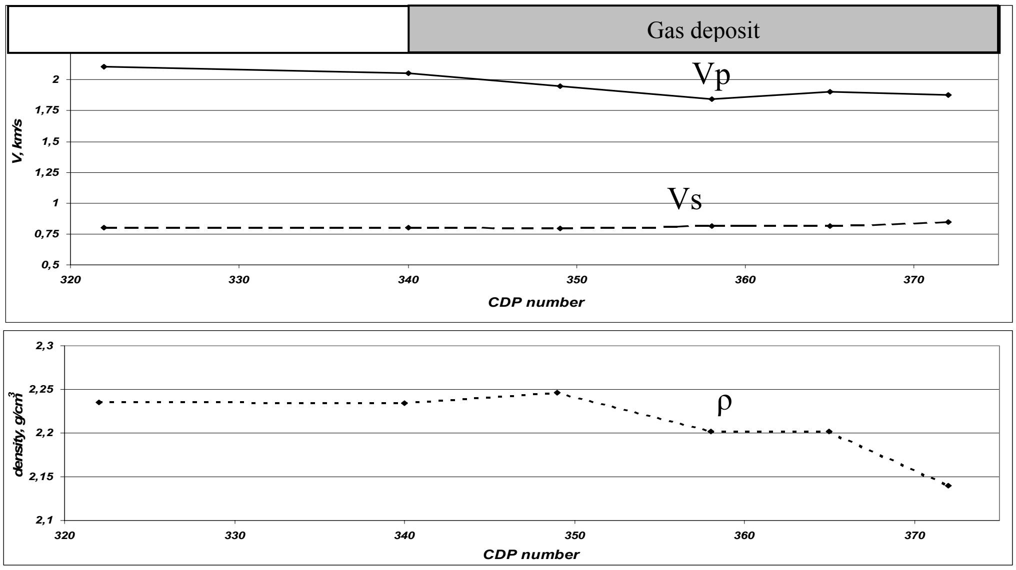

Figure 4. Results of the AVO-inversion problem solution.

Conclusion

AVO(PP+PS) algorithm provides stable determining V_p, V_s and ρ at the lower bed. The obtained results coordinate with drilling data and correspond to the theoretical conceptions about the elastic parameters behavior at the gas deposits. Studied possibilities of more accurate determining these parameters taking into account medium complex structure, thin layers and anisotropy showed that the used algorithms result in the refinement of elastic parameters by some percents.

Reference

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