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Identification of non-structural traps based on AVO-analysis and Elastic Inversion within the northern edge of the Dnieper-Donets Depression

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SUMMARY

Non-structural traps in the sedimentary stratum of the northern edge of the Dnieper-Donets Depression had not explored sufficiently by seismic methods. In this work, the authors demonstrate research and analysis of seismic data elastic characteristics using methods of AVO-analysis and elastic inversion with identification of lithologically trapped gas-saturated object. Alongside with the positive experience of acoustic contrast objects on seismic data identification, the authors present the generalized limitations of using AVO-analysis and elastic seismic inversion, in particular, within the northern edge and the whole Dnieper-Donets Depression.

Introduction

Non-structural traps in the sedimentary stratum of the northern edge of the Dnieper-Donets Depression not studied sufficiently by seismic methods. Investigation of the dynamic characteristics of seismic data, especially in case of the common-depth point pre-stack gathers, represents the effective tool to identify the potential hydrocarbon saturation of the various type perspective objects, including lithological ones. One of the tools are AVO-analysis and elastic seismic inversion. The authors of this work would like to share the positive experience of studying elastic parameters on pre-stack seismic data and identification of a lithologically trapped gas-saturated object, based on results of AVO-analysis and elastic inversion. Alongside with the positive experience of seismic contrast objects in the seismic data identification, the authors present the generalized limitations of using AVO-analysis and elastic seismic inversion, in particular, within the northern edge and the whole Dnieper-Donets Depression.

Generalized limitations of using AVO analysis within the northern edge of the Dnieper-Donets Depression (DDD)

- Quality of the input data: taking into consideration the influence of LVL and nonidentity of source and receiver conditions, seismic data processing without amplitude controlling, bad quality of old well logging data;
- Thin net pays of gas saturates formations beyond seismic data resolution, and as a rule, its provide seismic interference with other reflectors;
- Considerate depths of bedding and thin net pays (approximately less than 10 meters) represent one of the main restrictions for applying AVO-analysis;
- Low-porosity gas-saturated sandstones are not contrast on seismic and on the contrary: high-porosity thick water-saturated sandstones with residual gas saturation can create abnormal seismic amplitudes;
- Non-contrast acoustic impedance of low-porosity gas-saturated sandstones and shales or other enclosing rocks creates the AVO-anomalies of the II class;
- Based on the investigation that were carried out, AVO-analysis and pre-stack elastic inversion give clear results in the Moscovian deposits;
- As a rule, gas-saturated net pays are lays within the range of Vp/Vs: 1.4 – 1.64. However, other variant also possible, that needed to be analyzed separately.

We would like to note once again that the above is not a complete list of restrictions for AVO and elastic methods for the DDD. Every case needed to be investigated deeply and separately.

Figure 1 shows cross plots of acoustic impedance and Vp/Vs ratios: a) based on literature sources *(Brian Russell, 2013*); b) based on the real well data that contain registered curves of cross-dipole acoustic logs (S-wave) for the hydrocarbon fields in the north edge of the DDD.

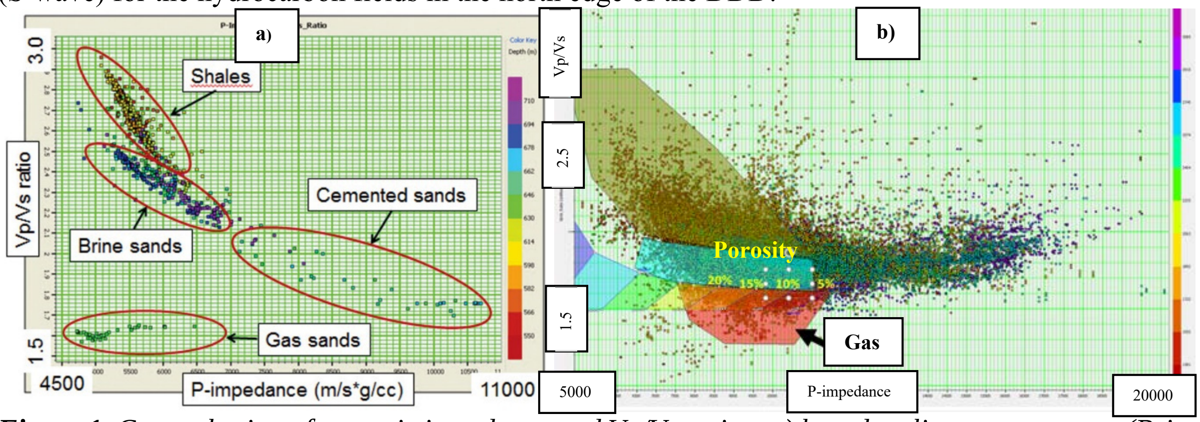

Figure 1*. Cross plotting of acoustic impedance and Vp/Vs ratios: a) based on literature sources (Brian Russell, 2013); b) based on the real well data that contain registered curves of cross-dipole acoustic logs (S-wave) for the fields in the north edge of the DDD*

AVO-study on the gas field within the producing horizons M-2 offers the positive answer to the question "can AVO-analysis work correctly on the gas condensate fields of the northern edge of the DDD?"

The materials of 3D seismic data processes with amplitudes controlling used as input data. This approach allowed ensure studying the amplitude relation and obtain the results presented below.

As it noted above, the authors used the wells with real cross-dipole acoustic (S-wave) that is critically important when using the seismic pre-stack analysis. However, there exist wells without S-waves, and in such wells, S-waves generated with fluid substitution based on the Biot-Gassman equation *(Brian Russell, 2013*). Figure 2 demonstrates such case with generation of the S-wave, synthetic seismic angles gathers modelling and its comparing to the real one within the boundaries of confirmed gas-saturated interval in Moscovian deposits. Seismic response represents the AVO-anomaly of II class. Fig.2 demonstrates that based on cross plotting results of the P-impedance versus Vp/Vs, gas saturated zone can be clearly identified on the logs curves (see Fig. 3). Fig. 3 shows seismic section with the anomaly «bright spot» in the Moscovian deposits that drilled and produced stable gas inflow. This deposit is tectonically trapped and lithologically restricted.

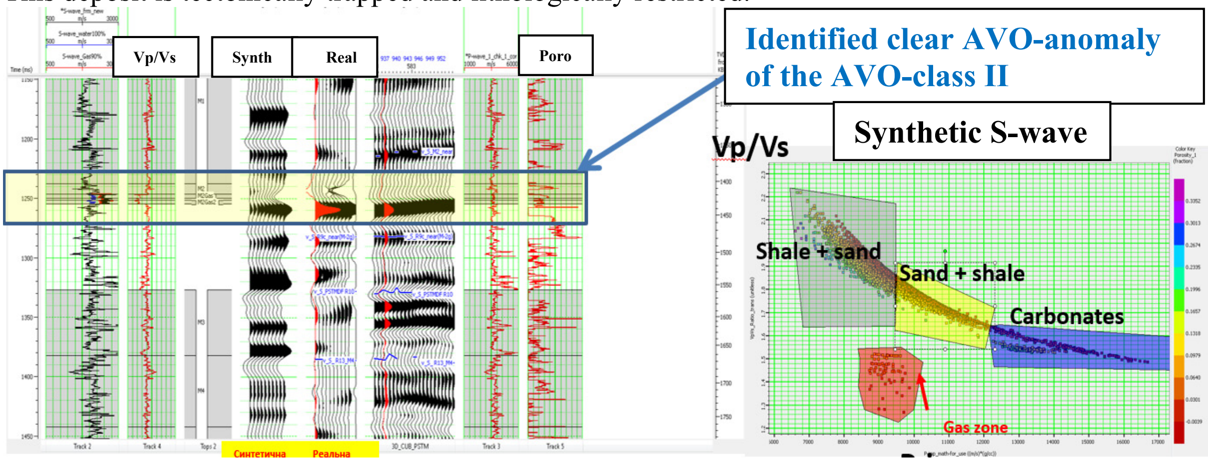

Figure 2. *Synthetically modelled seismic angles gather and its comparison to the to the real one within the boundaries of confirmed gas-saturated interval in Moscovian deposits (left) based on cross plotting results of the P-impedance vs Vp/Vs*

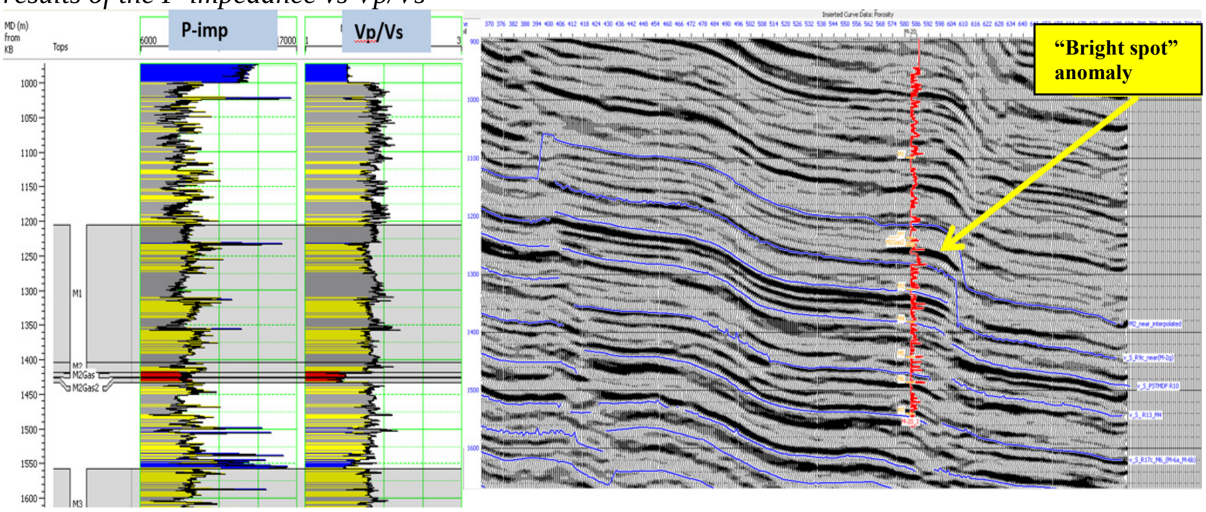

Figure 3. *Color-coded values cross plot curves (left) and seismic section with "bright spot" anomaly of the II class (right).*

Next step was to perform the cross plotting (Fig. 4) in accordance with: (*Zijian Zhang, Daniel R. McConnell1,De-hua Han, 2012 and Castagna, J. P., and H. W. Swan, 1997)* based on intercept and gradient volumes, which confirms that the anomalous seismic amplitude is the AVO-anomaly of the II class in accordance with the classification (*Rutherford, S. R., and R. H. Williams, 1989)*. Plotting the Poisson's ratio section (this AVO-attribute is useful specifically for the AVO-anomalies of the II class), Intercept/Gradient section and the result of pre-stack elastic inversion – Vp/Vs ratio cube are ones of the classical tools for studying the seismic anomalies based on the pre-stack data. Fig. 5 shows these results and the map of AVO-attribute distribution over the horizon within the thickness of the producing Moscovian horizon M-2.

Obtained results provide clear understanding of the perspectives for applying the AVO-analysis and elastic inversion for prospecting and exploring the hydrocarbon fields of non-structural type.

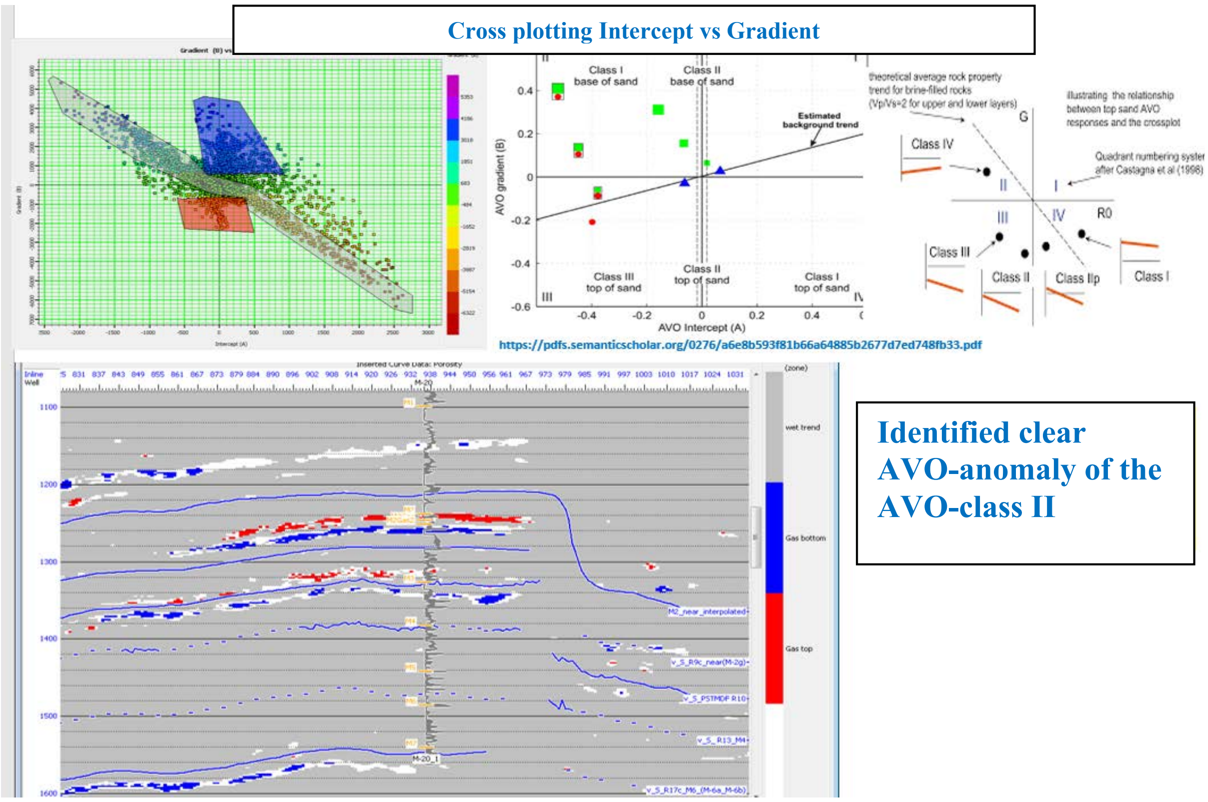

Figure 4. *Cross plotting of AVO-anomalies provides additional confirmation that the anomaly «bright spot» is the AVO-anomaly of the II class.*

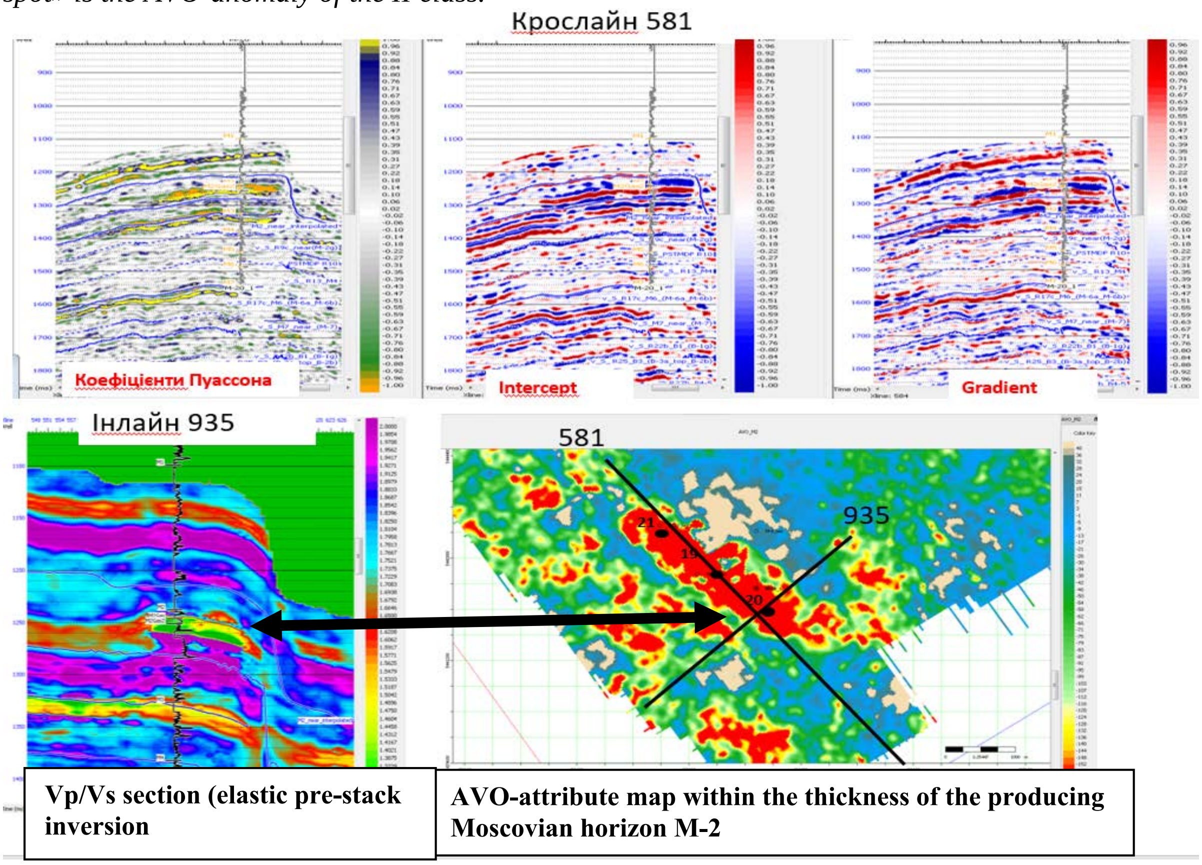

Figure 5. *Sections of Poisson's ratio, Intercept and Gradient, Vp/Vs ratio. Map of AVO-attribute distribution over the horizon within the producing interval.*

Conclusions

We provided analysis included cross plotting of acoustic and elastic properties in the wells for both cases with crossdipole real S-wave and with modelled S-wave. We investigate the Vp/Vs ratio and acoustic impedance: gas-saturated intervals are within Vp/Vs 1.4 – 1.64 units can be clearly identified. Acoustic impedance needed to be investigated for every separate case.
The AVO-study within the gas-condensate field in the northern edge of the DDD within the pay of producing horizons of Moscovian deposits offers the positive answer to the question "can AVO-analysis work correctly on the gas condensate fields of the northern edge of the DDD?"
The key parameters for AVO-analysis of the majority of gas-condensate fields at the northern edge of the DDD are net pays, bedding depths, lithology, porosity and quality of the input seismic data and well logs. Due to this, most gas-saturated intervals can't be identified in the seismic data and in such case, the structural factor must be decisive factor for hydrocarbons trapping.
II class AVO-anomalies can be modelled within the northern edge of the DDD.
The obtained results provide clear understanding of the perspectives for applying AVO-analysis and elastic seismic inversion for prospecting the hydrocarbon fields of non-structural type. Also, other crucial factor affecting amplitudes such a correct seismic data processing, especially anisotropy influence on seismic image can be taken into account as shown by Prodayvoda and Kuzmenko, 2019 but it is restricted by 3D seismic acquisitions. According to this 3D seismic must be long offset and wide-azimuth.

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