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MODELING WORKFLOW FOR DISTRIBUTION OF SEISMIC WAVES VELOCITIES IN THE CENTRAL PART OF DNIEPER-DONETS BASIN

In order to provide more detailed understanding for distribution of seismic velocities in central, most prospective for petroleum exploration, part of Dnieper-Donets Basin (DDB) a velocity model incorporating well VSP and onshore seismic data was built.
Key words: velocity model, Dnieper-Donets Basin (DDB), depth model, VSP

1. INTRODUCTION

Enlargement of Ukrainian resources' base a long time ago became one of the crucial challenges for modern Ukrainian economy. Exploration of new petroleum fields and detailed research carried out at known ones are the main tasks of modern geological exploration.

Seismic exploration had taken a leading place in researching of geological structure of the fields. However, accuracy of the method to a large extend depends on our understanding of velocity properties of geologic media. Laboratory research very often turns out to be very expensive in both financial and timing terms, and thus may not be carried out if exploration company has access to Vertical Seismic Profiling (VSP) data in the field. Very often VSP is carried out only in a several wells out of hundreds on the fields, which makes building accurate depth 3D models a very challenging and risky process. Moreover, this amount of data is definitely insufficient for 3D modeling of complex reservoirs.

In order to build reliable seismic images, so to say to obtain the main result of seismic exploration work it is crucially important to determine distribution of seismic velocities in geological media. Special feature of anisotropic media, which can approximate most of geological media, is the incorrectness of determining vertical semi axes of ray velocity indicatrix based on onshore (and offshore) acquired seismic data. This is the reason for difficulties in interpretation of the velocity analysis results using onshore seismic data both for isotropic and anisotropic media.

In order to provide more detailed understanding for distribution of seismic velocities in central, most prospective for petroleum exploration, part of Dnieper-Donets Basin (DDB) a velocity model incorporating well VSP and onshore seismic data was built.

2. METHODOLOGY

First stage of the work – collection and analysis of wellbore seismic data, mainly results of VSP research. We collected the data from more than 300 wells. Most of these wells located at the area of research, while some wells are located outside the area, but in “immediate” vicinity. These wells were incorporated into model in order to control extrapolation process at the borders of the research area.

About 5 % of these data were not conditional – it was not possible neither re-interpret the data, nor even understand the readings. Therefore, we made conclusion that such oil fields may be considered as the ones without well velocity data.

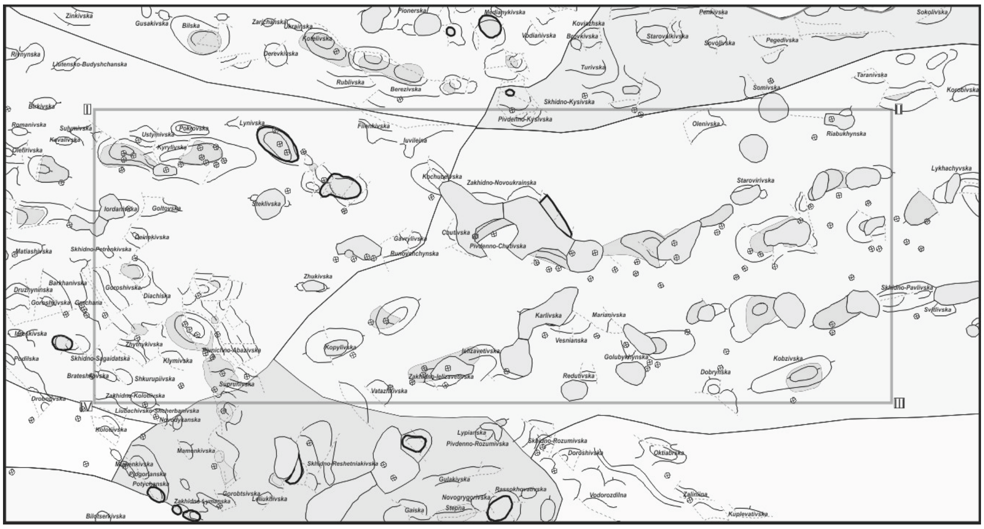

Fig. 1. The area of research, indicating main petroleum fields, geological structures and wells used for modeling

Since all the VSP surveys were conducted in different time by different methodologies, we have decided to re-interpret the data – in order to have it in one standard.

In order to have all the VSP interpretation results we have developed following workflow:

– at the first stage vertical time travel curves were referenced to absolute depth level (sea level) and correction of an a priori mistakes was made.

– at the second stage corrected time travel curve was recalculated in the time travel curve with constant increment. If input time travel curve was reordered with a step of 20 meters and more, step of an output curve was set to 20 meters. If input time travel curve was reordered with increment of 10-15 meters and more, increment in the output curve was set to 10 meters.

– at the third stage obtained data was transferred in digital and graphical form for further processing.

A section of vertical time travel curve with location of reading points is presented at figure 2. Figure 3 shows time travel curve with reading points (A) and interval velocities calculated in the well. Red arrow indicates a layer with anomalously high velocities, which corresponds to one reading point at the time travel curve and most likely is a result of measurement mistake.

Average and interval velocities based on VSP data were calculated according to the following workflow:

$$Vp\_av = \frac{H}{Tp}, \qquad (1)$$

were Vp_av – average velocity for primary wave, H – vertical depth from the reference datum, Tp – wave transit time.

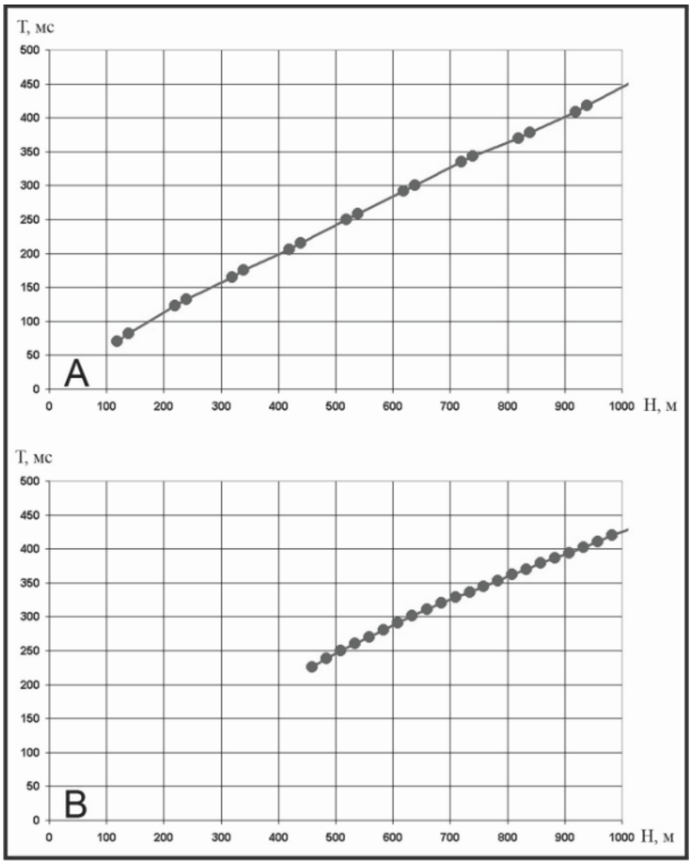

Fig. 2. Example of time travel curve with location of reading points. A and B indicate different wells

For interval velocity:

$$V\,\text{int.} = \frac{\Delta H}{\Delta Tp}, \qquad (2)$$

were $Vint$ – interval velocity of primary wave, ΔH – depth differential, ΔTp – primary wave transit time.

Calculation of layer velocity based on traditional methods (choosing breakpoints of time travel curve) is the most subjective and open to errors since interpreter's point of view is the main criteria in this approach. At the other hand, suggested methodology allows to calculate layer velocities automatically, reducing human factor.

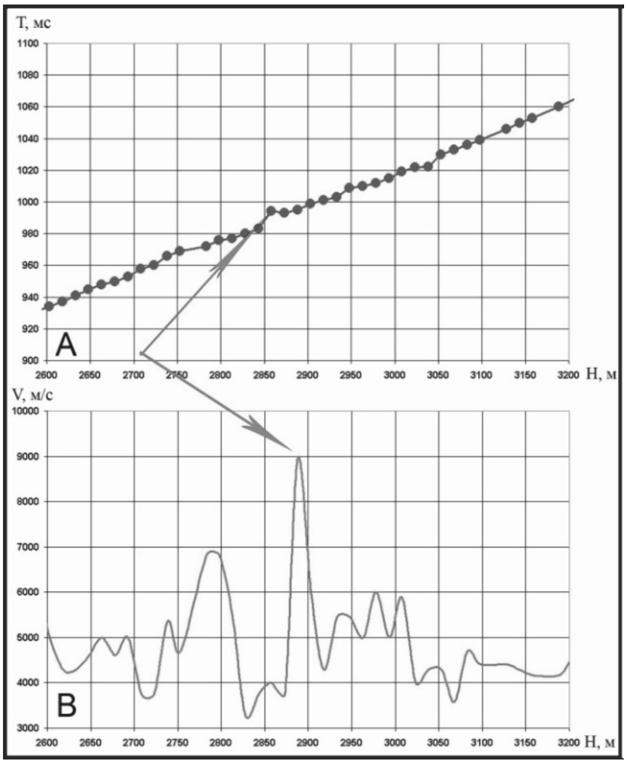

Fig. 3. Example of time travel curve (A) and interval velocities (B) before corrections. Arrows indicate errors of the first arrival readings

To calculate layer velocities authors have used not time travel curves, but interval velocities. Based on common petrophysical algorithms [2, 3] these data were converted into layers and layer velocities were calculated based on the equation (3):

$$Vp = \frac{\Delta H}{\Delta Tp} , \tag{3}$$

were Vp – layer velocity, ΔH – thickness of the layer, ΔTp – wave transit time in the layer.

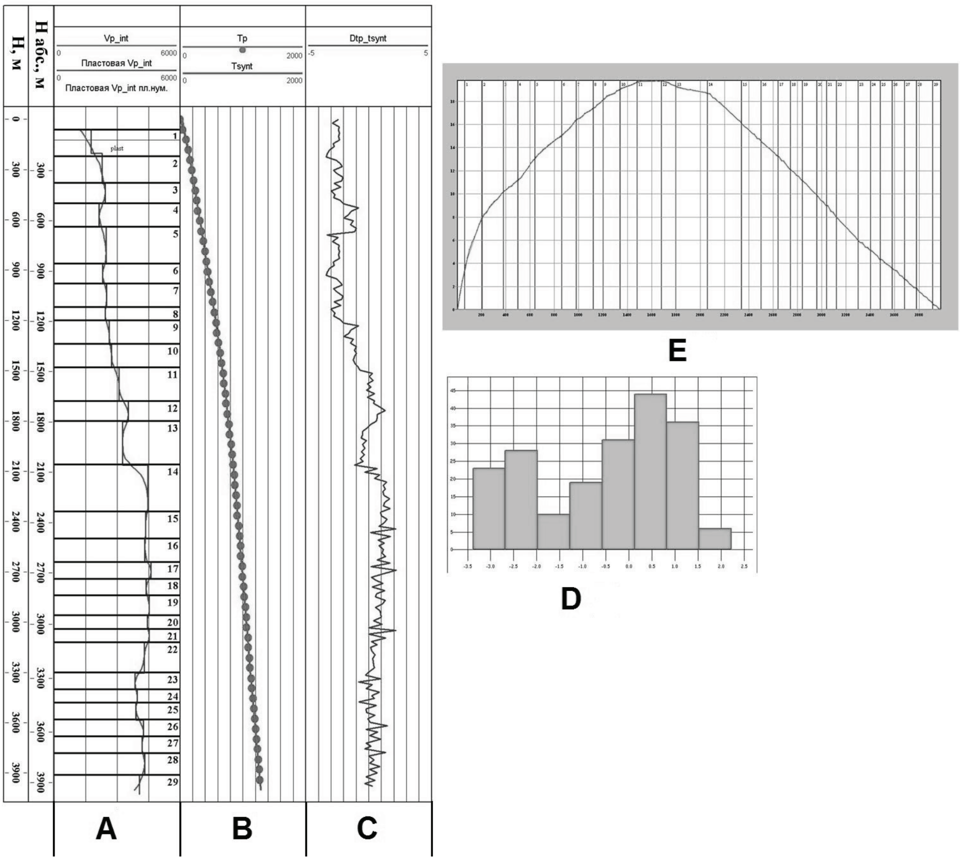

Fig. 4. An example of layer velocity modeling.
A – interval and layer velocities, B – forward modeling – calculation of vertical time travel curve, which is later compared to real time travel curve (B, C). E – correction of the model with reduced time travel curve, D – statistical control of the data.

Calculated layer velocities were used for forward geophysical modeling – calculation of time travel curves, which were compared to recorded ones. If qualitatively both curves matched, the process was finished. If qualitatively curves did not match – model was corrected solving inverse problem of reduced time travel curve with additional quality control, both visual and statistical.

3. CONCLUSIONS

Suggested workflow for modeling seismic velocities distribution allows obtaining reliable results of average, interval and layer velocities in the central part of the Dnieper-Donets Basin. An algorithm for reducing human factor while calculating layer velocities is introduced. Modeled velocity data is a valuable addition for depth modeling of petroleum prospects and leads in the central part of the DDB at every exploration stage.

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МЕТОДИКА МОДЕЛЮВАННЯ РОЗПОДІЛУ ШВИДКОСТЕЙ СЕЙСМІЧНИХ ХВИЛЬ В ЦЕНТРАЛЬНІЙ ЧАСТИНІ ДДЗ

Резюме
З метою детального вивчення розподілу швидкостей сейсмічних хвиль в центральній, найбільш перспективній частині Дніпровсько-Донецької западини було побудовано швидкісну модель з використанням даних ВСП та сейсмічних даних.
Ключові слова: моделювання швидкостей, Дніпрово-Донецька западина (ДДВ), глибинна модель, ВСП

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МЕДОДИКА МОДЕЛИРОВАНИЯ РАСПРЕДЕЛЕНИЯ СКОРОСТЕЙ СЕЙСМИЧЕСКИХ ВОЛН В ЦЕНТРАЛЬНОЙ ЧАСТИ ДДЗ

Резюме
С целью детального изучения распределения скоростей сейсмических волн в центральной, наиболее перспективной части Днепровско-Донецкой впадины была построена скоростная модель с использованием данных ВСП и сейсмических данных.
Ключевые слова: скоростная модель, Днепрово-Донецкая впадина (ДДВ), глубинная модель, ВСП