Gas Saturated Reservoirs Characterization in Case of Coal Beds Presence  
(South Tambeyskoye Field Case Study)

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Introduction

In recent years seismic inversion becomes an indispensable part of reservoir characterization process. But there are some key points for getting acceptable results. Relationships in domain of elastic and petrophysical properties from well logs should allow to get reliable separation between reservoirs and non-reservoirs. In order to get this detailed well log interpretation, petrophysical analysis and rock physics modeling as for reservoirs as well as for non-reservoirs should be done accurately. Seismic data should correspond geological situation, what could be checked by modeling seismic gathers at well locations and comparing them with obtained seismic data. This conditions seem to be quite simple, but each dataset is characterized by its own features and consequently, each case needs its own methods to consider.

In this paper some problems which can occur during the implementation of seismic inversion on an example of the dataset from the South-Tambeyskoye field are reviewed. The South-Tambeyskoye field is located in Arctic region in the north-eastern part of the Yamal Peninsula. The target interval is elastic formations dated to the Cretaceous system. Reservoirs are presented as sandstones and siltstones with clay, coal and tight interlayers.

Rock Physics Modeling

Well log data are used in such complex project for solving following objectives:

a) performing of rock physics feasibility study for appropriate inversion type definition,
b) justifying the required seismic inversion parameterization based on well log interpretation results in the range of reservoir and non-reservoir

The petrophysical basis for seismic inversion is the data of the rock elastic properties resulting from empirical and theoretical modeling (Rock Physics).

Due to measurement conditions (wash-outs, etc.) and applied logging tools well log data often can be considerably distorted. Therefore log measurements require empirical correction. Empirical modeling procedure is as follows: 1) quality estimation of acoustic and density data which is performed using core data or reference based layers with known characteristics; 2) measurements correction using empirical equations. Such equations have local restriction and can be used only for those conditions and input data set on which they were received. The correction of sonic and density logs in the intervals of poor quality distorted by the influence of well conditions, and the synthesis of these curves in the intervals of DTP and RHOB absence, are performed using different empirical modeling methods.

Theoretical modeling of elastic properties (Rock Physics Modeling) is based on theoretical approaches and was done in target interval to achieve a reliable seismic response and estimate elastic properties in undisturbed by borehole conditions. The input data for elastic properties modeling are as following: the information about the formation pressure and temperature, fluid properties and bulk volumes obtained from the well log data interpretation. The components of the bulk volume model are: clay volume; bulk volumes of the solid rock minerals – sand/silt fraction; effective porosity was estimated according to the neutron-density methods, the influence of gas condensate in pay zones was considered; saturation evaluation was done by the Archie equation. Special attention was paid to assessing the volume content of clay minerals. According to the core studies there are up to 38% of feldspars in mineral composition of rocks. Based on the bulk volume model and elastic properties results investigated deposits were divided into several lithotypes: gas saturated sandstone, brine sandstone, shaly non-reservoir, coal and tight rocks. Additional attention is required to the presence of coal in the gas saturated target interval due to their significant impact on the petrophysical
interpretation and elastic modeling results, especially if there are no reliable measured elastic properties of coal. After testing of several algorithms during the Rock Physics modeling the best elastic properties reconstruction was achieved with a widely used “self-consistent model”. Modeled density and acoustic (P-Sonic and S-Sonic) curves delivered from Rock Physics modeling presented on a Figure 1. Thus, the accuracy of reservoir and pay zones definition based on seismic inversion results in the target interval was achieved by the presence of good separation of lithotypes in domain of several elastic parameters. It was clear that areas of gas saturated sandstones, non-reservoirs with brine sandstones, tight and coals have a reliable separation in elastic properties domain according to rock physics modeling results (Figure 2). These results were the basis for a choice of simultaneous AVO/AVA inversion for reservoir characterization.

Figure 1 Log plot with empirical and theoretical modeling results of density (RHOB) and acoustic (DTP, DTS) logs: *_ini – initial logs, *_cor – corrected logs, *_mod –modelled logs.

Figure 2 Vp/Vs-AI crossplots coloured lithology flag (left) and saturation flag (right)
Seismic modeling

Gas saturated reservoirs have a huge impact to AVO effects, even a small gas content at the pore fluid produces a significant anomaly. Consequently in such situations this is impossible to use full stacked seismic volume even for horizon interpretation. The near stack formed from the traces, where AVO is not observed, is more reliable for picking. In this case reservoir characterization should be based on pre-stack interpretation technics.

Geological section of studied area is represented by thin-bedded reservoirs (the layer thickness is often about 2-4 meters) in a shale matrix with high coal content. Coals are also thin beds and quantity of them could reach 10% of whole rocks volume within some geological sections. The final AVO effect is composed by interference of AVO effects generated by thin layers. The greatest contribution is formed by high-contrast lithotypes: gas saturated reservoirs and coals.

Coals and gas saturated reservoirs refer to the lowest P-impedance values. They could be separated only by using additional elastic parameter, for example Vp/Vs ratio. Gas saturated reservoirs are characterized by lower Vp/Vs ratio then coals. Figure 3 shows the influence of detailed coal description to the AVO modeling. AVO effects are shown on the pseudogathers where each trace represents one stack. We worked with five offset stacks and it is obvious from the real seismic data that amplitude variations from stack to stack could be up to 20-30%. We compared three different ways of coal elastic properties modelling, for other lithotypes all parameters were similar. The first way was to reconstruct coal properties by rock physics modelling, the second option was usage of Vs as constant value. The last one was setting Vp/Vs ratio up as constant value. Cross-correlation between seismic and synthetic data is colour-coded. The highest correlation coefficients in this case were achived by using constant Vp/Vs ratio for coals. Estimated wavelets are also sensitive to differences at rock physics modelling. Deterministic AVO wavelets estimation could be succeed only for the third variant of rock physics modelling.

![Seismic data comparison](image)

**Figure 3** Comparison of real seismic data and pseudo gathers modeling with different parameters: 1) seismic data; 2) Variant 1.RPM; 3) Variant 2. Vp/Vs ratio for coals is a constant value; 4) Variant 3. Vs for coals is a constant value; 5) well logs: lithology and P-impedance (blue curve)

Reservoir characterization

Reservoir characterisation was performed by using results of simultaneous deterministic partial stack inversion which is based on Constrained Sparse Spike inversion algorithm. The inversion was utilized at P-impedance, Vp/Vs ratio and Density parametrization. Seismic section contains a lot of bright spots (blue circles on figure 4), but not all of them correspond to gas saturated reservoirs. During
volume interpretation of inversion results bodies of gas saturated reservoirs were captured (purple bodies on the figure 4). Below there are sections of acoustic properties overlaid by these bodies. The lowest values on the P-impedance section do not match to gas bodies, they mostly coincide with coal layers. Using the Vp/Vs data allows to identify bodies of gas saturated reservoirs accurately, the lowest values on the section match with the captured bodies very well.

**Figure 4** Bodies of gas saturated reservoirs (purple shapes) in comparison with sections of inverted Vp/Vs (a), P-impedance (b) and near seismic stack (c).

**Conclusions**

Analysis of elastic properties modeling leads to the conclusion that quantitative reservoir characterization and prediction of saturation and lithology in the target interval are possible only with S-wave velocity data involvement, and therefore utilizing of Simultaneous AVO/AVA inversion.

2D seismic modelling is very sensitive to the rock physics modelling results. So detailed petrophysical analysis and rock physics modelling for reservoirs and also non-reservoirs is essential to get the theoretical AVO response which will be corresponded to the real AVO effect. In the geological situations when gas saturated reservoirs occur in association with coals Vp/Vs volume is a quite useful indicator for target reservoirs definition. Therefore pre-stack inversion methods should be used for reservoir characterization.

**References**