Synthetic Seismic Models Construction for Detailed Geological Outcrop Description

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Synthetic Seismic Models Construction for Detailed Geological Outcrop Description

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SUMMARY

The purpose of this study is to examine the seismic response of fluvial deposits by using the method of forward seismic modelling. The studied outcrop is located in Kemerovo Region, 250 km from Tomsk and is about 500 m in length and about 30 m height. The exposure deposits belong to the fluvial depositional environment and the age of sediments is Lower Cretaceous.
In this work the synthetic model construction was provided with the help of simple convolution-based method. Modeling was performed in two software products Petrel and Madagascar. To construct the impedance cube, petrophysical properties were taken from the analogue field, which formed in similar depositional environment.
The sensitivity analysis of detailed seismic pictures on the frequency change was carried out. Thus, 8 models were built in a frequency range of 25 to 200 Hz in steps of 25 Hz. Attribute analysis was provided to estimate the ability of Net to Gross ratio of fluvial reservoir forecasting by using seismic attributes.
Furthermore, an analysis of the effect of fluid saturation on seismic image of fluvial deposits was conducted.

Introduction

Reservoirs of fluvial depositional environment have a rather complicated structure. Drilling wells to clarify the geological heterogeneities rather expensive process, so the seismic is a relatively inexpensive source of information about the internal structure of such reservoirs. To improve understanding of seismic image the forward seismic modelling is a valuable tool. This allows us to test the relationship between geology and seismic response. The ability of comparing the seismic response and known geology allow to improve understanding of seismic features.

The subject of the project is to analyze how different scale and type of heterogeneity of fluvial type reservoir can be recognized on seismic. During the study the following tasks were considered:

- different frequencies synthetic seismic models construction;
- net to Gross prediction by using the seismic attributes;
- the analysis of how different fluid saturation can influence seismic response.

Geological settings

The studied Shestakovo outcrop is located in Kemerovo Region, 250 km from Tomsk and is about 500 m in length and about 30 m height. The exposure deposits belong to the fluvial depositional environment and the age of sediments is Lower Cretaceous. Units of the second and third levels elements of Miall's (1985) architectural analysis can be clearly distinguished on photopanel (figure 1). The second hierarchical level is represented by fining upward sand units, whose stacking forms the third hierarchical level performed by thick single-storey sand bodies.

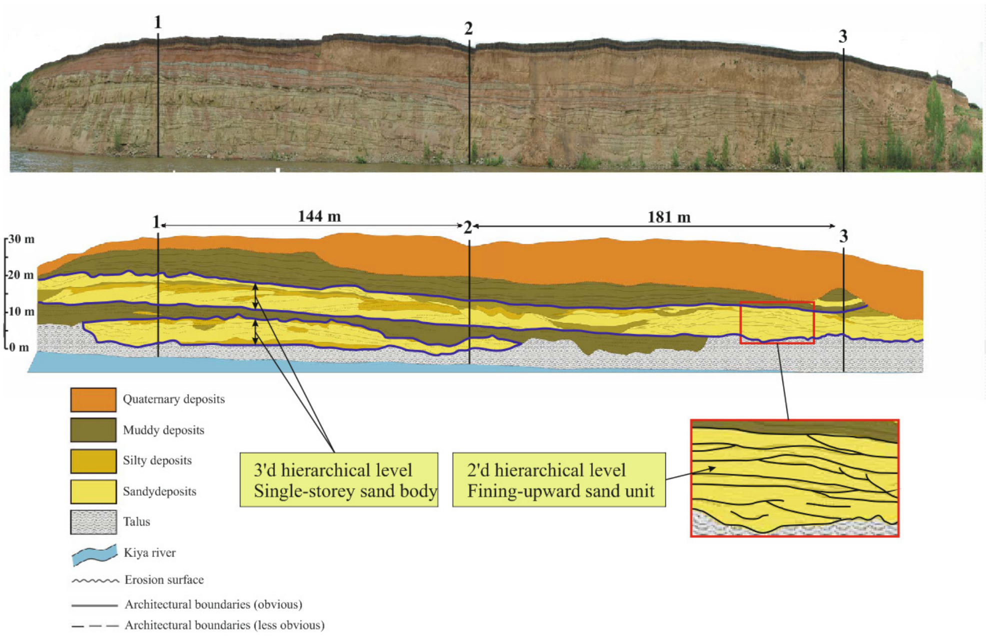

Figure 1 *Photopanel of Shestakovo outcrop and architectural interpretation (modified from Podboronov, 2004).*

Modelling process

In this work the synthetic model construction was provided with the help of simple convolution-based method. The modeling process can be divided into two stages. The first is performed in Petrel and impedance cube is obtained as a result. The second stage is modeled by using Madagascar and seismic traces are obtained at the output. To construct the impedance cube, petrophysical properties were taken from the analogue field, which formed in similar depositional environment.

During the work 2D and 3D models were produced by using the software Petrel. The first one is to analyze the different scale heterogeneities within the fluvial reservoir, which can be detected by seismic and second one is to provide the attributes and fluid saturation analysis.

The input data for 2D modelling were the interpretation panel of the outcrop and 3 topographically positioned pseudo wells, which are sedimentary logs. Firstly the image were tied to the wells and the different facies boundaries were depicted by polygons. Then, the manual assigning of facies values to each cell were provided. Vertical size of cell was chosen equal to 0.2 m taking into account the minimum thickness. Horizontal size of cell is 5 m. During 3D modelling the facies were modelled by using Sequential Indicator Simulation. Variogram parameters were taken from Podboronov's study (2004).

Seismic response analysis

To estimate the sensitivity of the seismic resolution, depending on the frequency, the eight 2D synthetic models at frequencies from 25 Hz to 200 Hz in steps of 25 Hz were constructed. The study was performed starting with the maximum resolution in order to measure at which frequencies the identification of various levels heterogeneities can be seen clearly or contrary interpretation becomes complex and ambiguous.

Considering the seismic frequency range from 200 to 125 Hz it can be seen that the boundary separating the thick sand and clay intervals can be traced quite well and expressed as continuous reflections (figure 2). At that time, the chaotic reflections indicating the structure of upward fining sand units are attenuated with decreasing frequency and practically not noticeable at a frequency of 125 Hz.

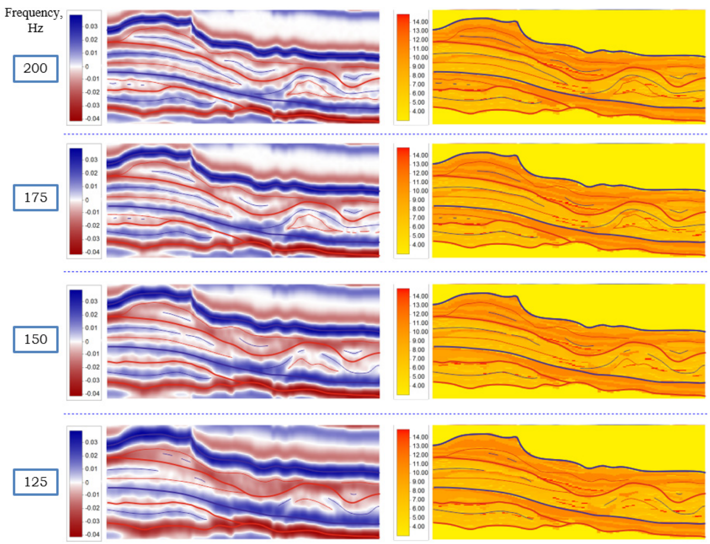

Figure 2 *Seismic cross-section with range of frequency from 200 to 125 Hz and acoustic impedance images.*

Figure 3 shows that at frequency of 100 Hz the boundary separating the lower sand layer having an average thickness of about 8 meters, and the overlying clay layer are barely noticeable, and at 75 Hz it is entirely absent. At 50 Hz frequency the top and bottom of the upper sand body are discontinuous and smooth. At frequency of 25 Hz any reflectors corresponding to internal structure of total interval are not detected, moreover the top and bottom reflectors do not accurately reproduce the actual boundaries. In the frequency range from 100 to 25 Hz the internal structure of the sand bodies is not reflected.

According to the results, it can be concluded, that with decreasing frequency the seismic resolution decreases. Reflectors relate to third hierarchical level of the fluvial system (single-storey sandbodies) degrades as frequency decreases and completely disappears at frequency 25 Hz. The boundaries of the second hierarchical level of the fluvial system (upward fining sand units) cannot be detected at the frequency lower than 125 Hz.

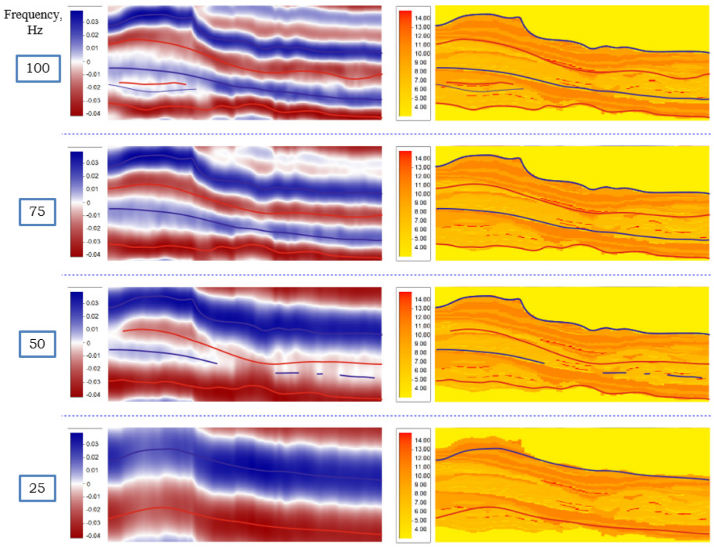

Figure 3 *Seismic cross-section with range of frequency from 100 to 25 Hz and acoustic impedance images.*

Attribute analysis

Attribute analysis was performed to assess the ability to forecast Net to Gross ratio of fluvial reservoir with the help of seismic attributes. Figure 4 shows that RMS (root mean square) amplitude has the best correlation at the medium frequencies of considered range, namely from 75 to 100 Hz. It can be assumed that this is the optimal frequency, at which sand bodies are identified accurately. At frequencies below 75 Hz, the correlation coefficient is low, due to the fact, that the resolution is not sufficient to separate clay and sand body with sufficient precision. In addition, at frequencies above 100 Hz, the coefficient of correlation reduces. This effect probably can be explained by the influence of wave interferences. With regard to the relative acoustic impedance, its correlation with the Net to Gross ratio gradually increases with frequency increasing.

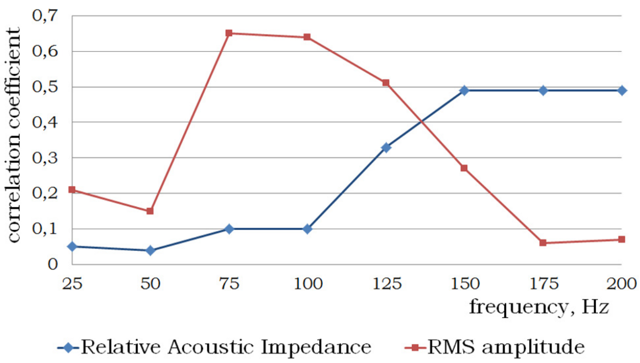

Figure 4 *Correlation coefficient versus seismic frequency plot.*

Fluid saturation sensitivity

This chapter of work is devoted to analysis of seismic sensitivity to a change of fluid from water to gas. Fluid substitution equations were applied to predict how gas-water contact can be displayed on the seismic in the fluvial system deposits. For modelling of replacement of one fluid by another, the Gassmann's substitution equation was used.

By comparing the seismic response of water saturated cube and gas-contact cube (figure 5), only in the area, where the contact is further away from the different lithology boundaries, at a distance of 4 meters, the weak reflection can be detected. It can be concluded, that identification of the gas-water contact in such thin-bedded fluvial reservoir is difficult, even with such a high frequency.

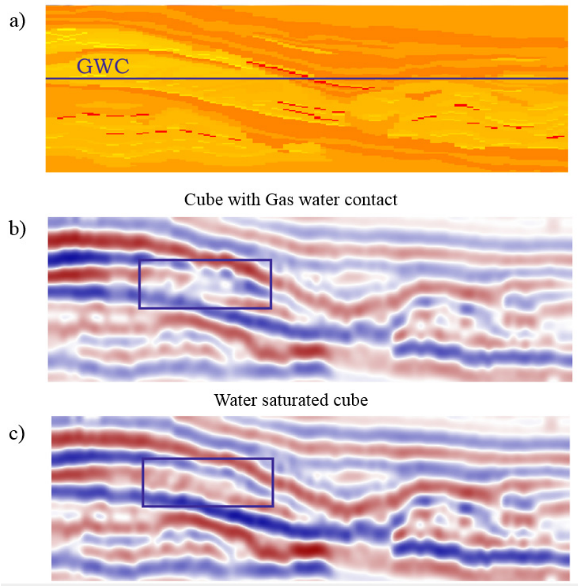

Figure 5 *a) Impedance cube with GWC; b) Seismic image with gas water contact; c) Seismic image of water saturated cube.*

Conclusion

- As expected, the seismic expression of fluvial system degrades from the highest seismic resolution to the lowest.
- It is believed that the single-storey sand bodies are distinguished fairly well, even at relatively low frequencies, while fining-upward sand units have chaotic seismic response even at high frequencies.
- The maximum correlation coefficients between the RMS amplitude and Net to Gross occur within frequency spectrum from 75 to 100 Hz, while between the Relative acoustic impedance and Net to Gross correlation gradually increases from lower to high frequency.
- It is found that GWC contact has certain features in the seismic, but it is quite difficult to distinguish from the geological reservoir heterogeneities, due to the complex architecture and thin-layered structure of fluvial system.

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