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Application of Seismic Forward Model Analysis in Reservoir Prediction of Oil Formation

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To analyze reservoirs of Zhouji oilfield qian3[2] oil group and make finite difference method get on wedge simulation forward. In the study area, the sensitivity relation between amplitude attribute and frequency attribute is confirmed by result of geological model forward and analysis of wave impedance difference of different rock types. Using the well and geological model to track constraints the amplitude of seismic stratigraphic group, make amplitude plan. And then through seismic attribute analysis and other steps, the reservoir distribution is predicted accurately and the multiple solutions of reservoir prediction are reduced.

Keywords: Seismic forward model; Attribute analysis; Reservoir prediction

1. INTRODUCTION

Using seismic attributes to predict reservoir and describe reservoir characterization has a long history [1–3]. Seismic attributes such as amplitude,wave impedance, frequency extracted from seismic data are inversed into lithologically related maps or sections [4–6]. Due to the insufficient consideration of geological situation underground and thin target layer, mainly thin interbeded formation, the predication results have multiple solutions, which poorly coincide with actual geological situation [7–8]. Using the forward model to analyze seismic response characterization of reservoirs and then operating reservoir predication can enhance the accuracy of predication [9].

We choose representative prospecting wells in the research area to analyze physical properties parameters of rock geophysics.We mainly analyzed statistic data of acoustic transit time and density, the chosen layer are generally thick and stable whose thickness are greater than 3 meters. The lithology includes salt rock, permeable sandstone and mud stone. Because the salt rock's properties are stable, its interval velocity and density remains constant. Combining with the logging data in this area (acoustic logging and density logging), we set the velocity to 4300m/s and density to 2.1g/cm^3. Except salt rock, the velocity and density increase with depth in other ithology layers.

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2. FORWARD MODELING

According to the analysis result, we divide the lithology into three types: salt rock, permeable sandstone, and mud stone. Detailed rock geophysics properties in this area are contained in table 1.

This paper uses tesseral software to operate forward modeling and adopts wave equation method. Using wave equation theory to simulate seismic wave propagation and applying finite difference method to solving the wave equations efficiently. This method not only retains the kinematics of seismic wave, but also keeps the dynamic characterizations. The target layers, mainly thin interbed, are thin in the research area.

Table 1 Rock geophysics properties

Lithology	Velocity (m/s)	Density (g/cm^3)
Permeable sandstone	4350	2.48
low depth mud stone	4450	2.6
deep depth mud stone	4500	2.61
salt rock	4300	2.1

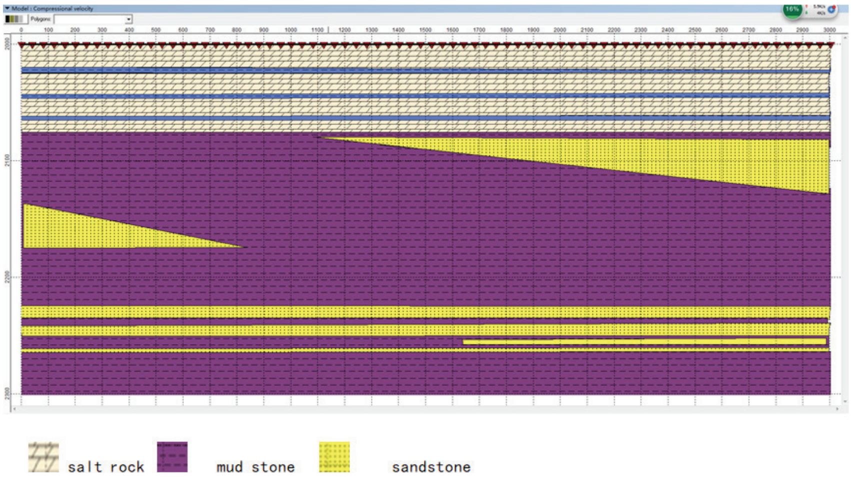

Figure 1 Wedge sand body model

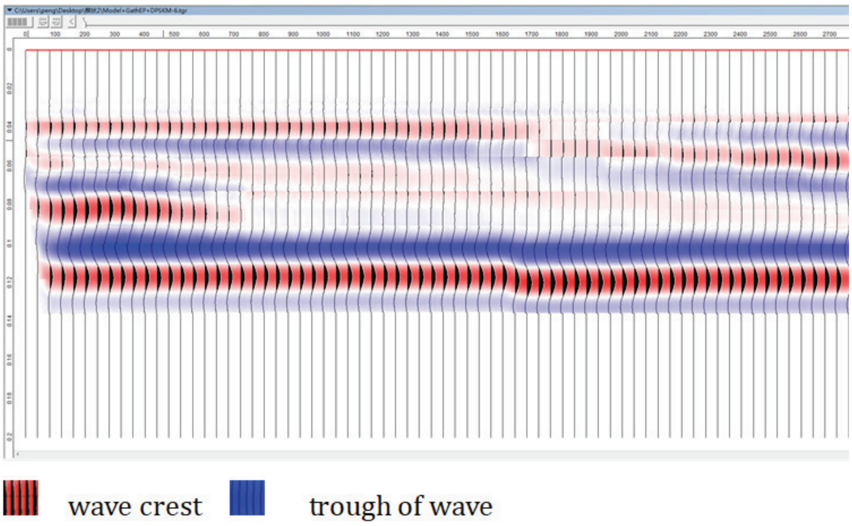

Figure 2 Seismic Responses of Wedge Sand Body

The total thickness of Eq3^2 permeable sandstone are 0–21.4m; According to the geological characterization in the area, this paper design three types geological model to operate forward calculation at first and then analyze seismic responses of different lithology combination. The rock properties parameter are contained in figure 1, the wavelet frequency is the frequency of the area with high dominant frequency, f = 30 Hz.

2.1 Wedge Sand Body Model

Above the model is the salt rhythmic layer consisting of 5 meters mud stone interbed in salt rock at different thickness. There are two wedge shaped sandstone in the middle part of mudstone. The thickness of wedge sandstone ranges from 0m to 50m. There exists 5 meters thick mudstone between one of the wedge shaped sand body and salt rhythmic layer, while another wedge sand body is farther away from the salt rhythmic layer. In the lower part, sandstone and mudstone with different thickness are interbed with each other. The thin sand layer's thickness ranges from 4m to 10m. The frequency f = 30Hz, the wave length $\lambda = V/f = 4380/30 = 146$m.

The forward modeling section is shown on Figure 2: The reflection amplitude is strong between low impedance salt rock and the underlying high impedance of clastic rocks. As the thickness of permeable sandstone increases in clastic rocks, the amplitude becomes weak. In the inner part of clastic rocks, seen from left wedge sand body, the reflection amplitude is weak between relative low impedance permeable

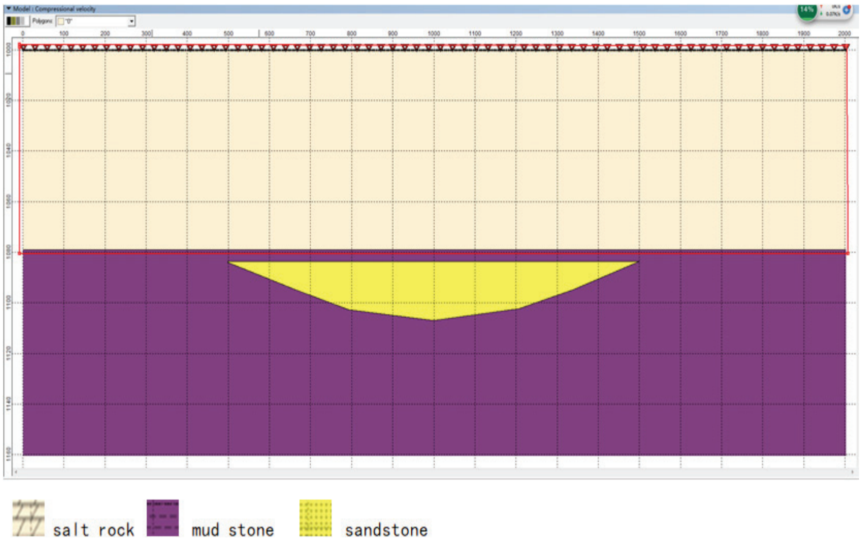

Figure 3 Lens sand model

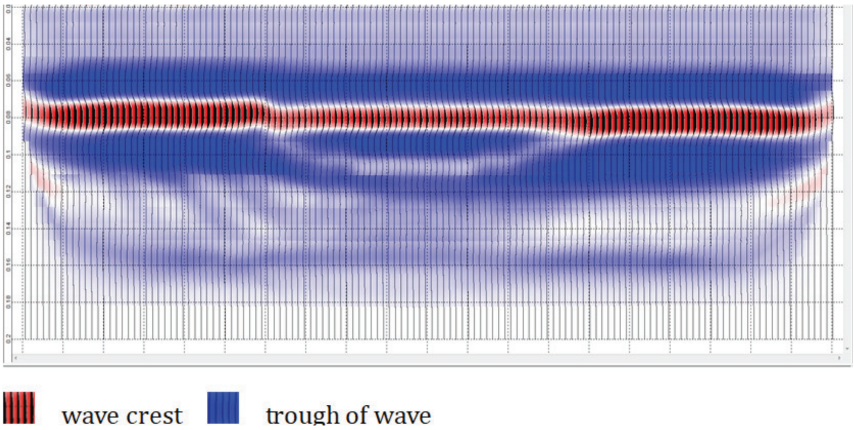

Figure 4 Sandstone lens seismic response

sandstone and high impedance mud stone. As the thickness of permeable sandstone increases, the reflection amplitude increases correspondently. The thickness of the recognizable first trace permeable sand stone in the right wedge sand body is 16m. As the thickness of permeable sand stone increases, the reflection amplitudes increases as well. The strongest amplitude appears when the thickness of permeable sandstone reaches to 31m, and then the reflection amplitude weakens and remain stable ultimately. According to the seismic resolution principles, the reflection amplitude is strongest in $\lambda/4$, which equals 36.5m. Detracting the 5meters mud layer in the middle part, the thickness of the permeable sandstone is 31.5m, basically the same with the model. In the lower mudstone area, interference occurs between different layers, showing a strong amplitude, and there are more sand layers in the right part than in the left. The amplitude also increases with the event appearing a certain degree of drop.

2.2 Lens Model

We designed a lens model based on the combination of thick layer sandstone, mudstone and salt rock. The thickness of permeable sandstone is 0m–40m.

The obtained forward modeling section after forward calculation:

The forward modeling results reveals that there is a strong reflection amplitude between salt rock and underlying clastic rock (the first wave crest in the model). When clastic rock is the pure shale (ends in the model), the reflection amplitude is strong. When permeable sandstone is interbed in clastic rock (the impedance of permeable sandstone is smaller than mud stone), the reflection amplitude weakens with the increase of thickness of permeable sandstone. On the other hand, another event appears in the inner part of clastic rock (the second wave crest), this event becomes stronger as the thickness of permeable sandstone increases and has a certain expand range, which is the reflection between permeable sandstone and mudstone in the inner part of clastic rock.

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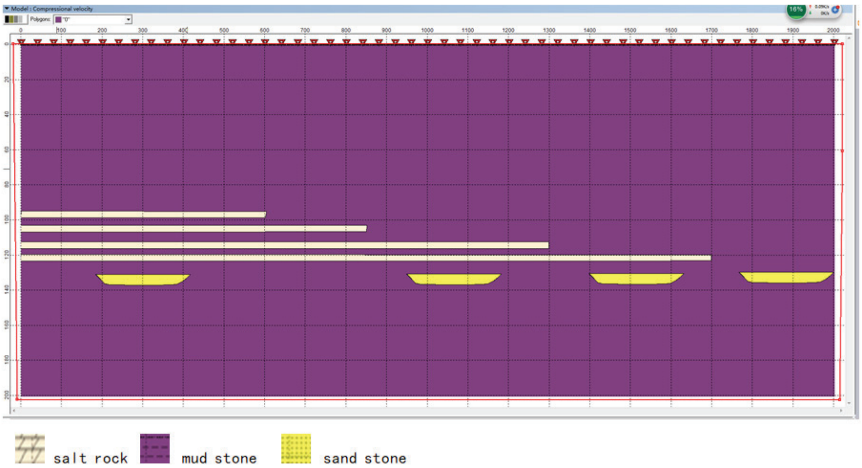

Figure 5 Salt Rhythmic layer thickness variance model

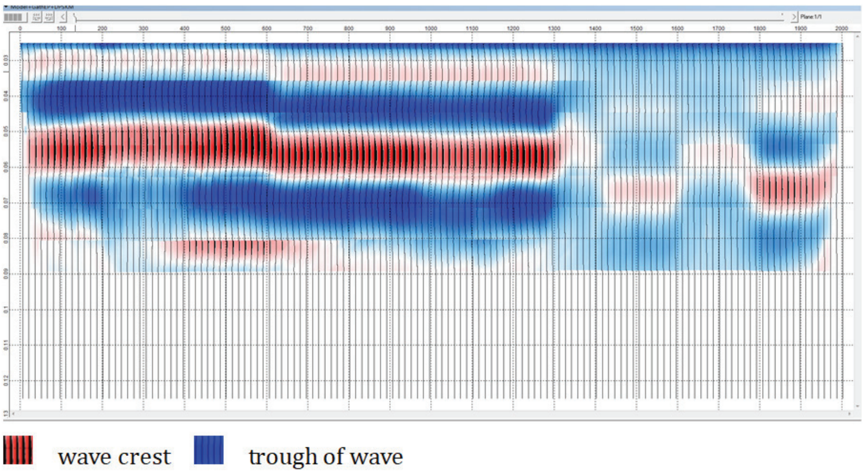

Figure 6 The seismic responses of variable thickness salt rhythm model

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2.3 The Thickness Variance Model of Salt Rhythmic Layer

Seen from logging data and synthetic record, a strong reflector is formed between sand shale and salt rhythmic layer above it in Qian3^2 oil group, the event corresponds to reflection of the Qian3^2 top boundary. The thickness of salt rhythmic layer in Qian3^2 oil group decreases and reaches to zero in the end from the northwest to the southeast. According to the geological situation in this area, a forward model was established and analyzed (Figure 5).

The seismic responses that thickness of salt rock decreases are acquired from forward modeling. Seen from figure 6, as the salt rock decreases, the correspondent wave crest amplitude also decreases. When permeable sand stone exists and there are at least two salt rhythmic layers on it, the correspondent crest wave amplitude is relatively weak. When permeable sand stone exists and there is at most one salt rhythmic layer, the correspondent wave crest amplitude increases. The frequency increases gradually as the salt rhythmic layer decreases. A scenario of sand stone prediction was developed according to the analysis result of above forward models. Combining frequency attribute with well logging data to divide salt rhythmic layers and amplitude sensitive root-mean square amplitude attribute, we characterized the area where root mean amplitude attributes decreases in thick rhythmic layers as sandstone and characterized the area where root mean amplitude attributes increases in thin salt rhythmic layer as sand stone.

3. SEISMIC ATTRIBUTES ANALYSIS AND RESERVOIR PREDICTION

3.1 Seismic Attributes Analysis of Qian3^2 Oil Group

Known from the above forward modeling analysis, for the reflector between salt rock and clastic rock, the decrease of strong reflection amplitude indicates the existence of sand stone. Therefore extracting magnitude of reflection amplitude in the time window from 8 ms above the reflector and 20ms

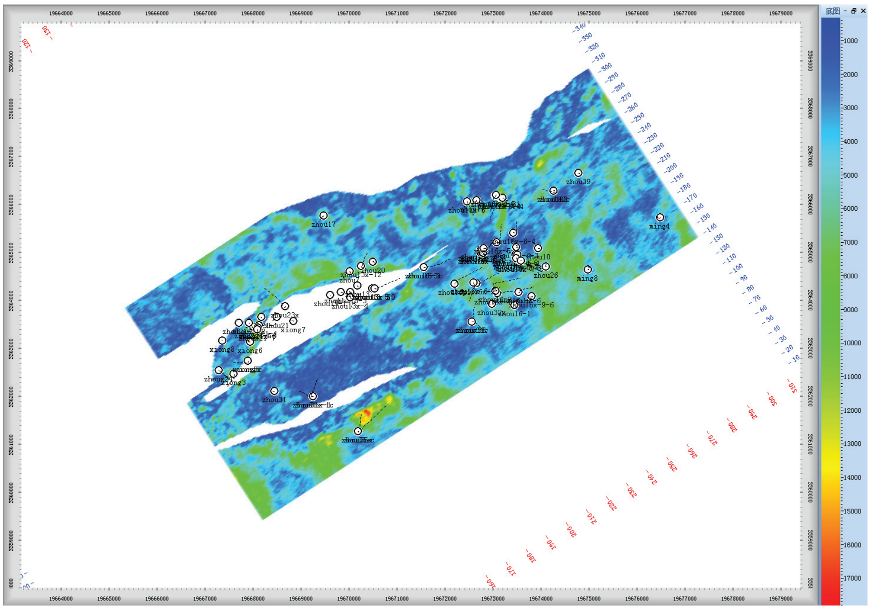

Figure 7 Root mean amplitude attribute of Qian3^2 Oil Group in Zhou 16 Well area

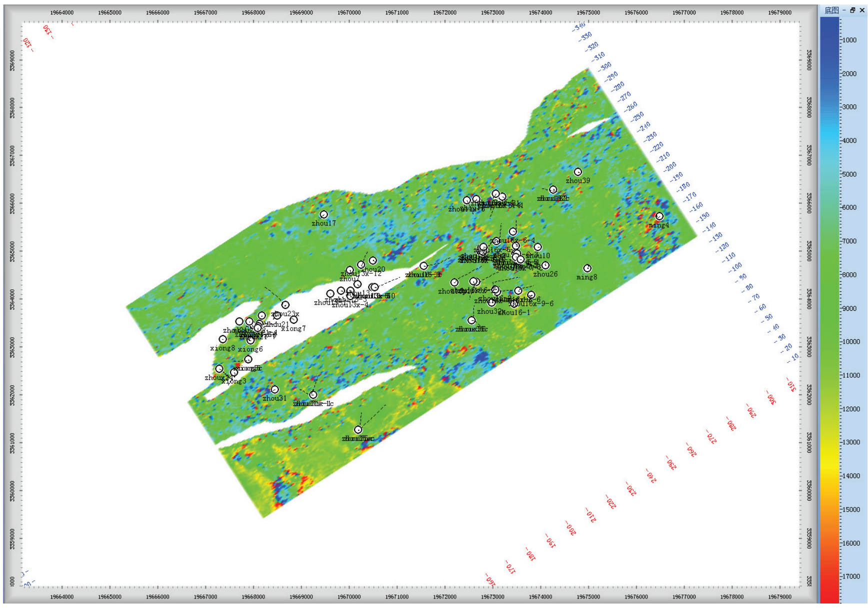

Figure 8 Qian3^2 instantaneous frequency attribute

below the reflector in Qian3^2 oil group Zhou 16 Well area can reflect sandstone's development. In forward model analysis, as the sand increase under the salt rhythmic layer, the reflection amplitude decrease clearly, the trough of wave amplitude also decreases and so does the root mean amplitude; when there is no sand, hiden reflector amplitude, the trough of wave amplitude and its root mean amplitude increase.

Seen from figure 7: Zhou 16 well areas are weak amplitude area, which coincides with actual prospecting results. Before interpreting the amplitude attribute figure of Qian3^2 Oil Group, we should analyze given wells and identify area where salt rhythmic layers are well developed. Sandstone well developed area corresponds to the area where amplitude decreases in strong reflection amplitude background. In the upper part where there is a few salt rhythmic layer or mud stone area, Sandstone well-developed area corresponds to area where amplitude becomes stronger in weak reflection amplitude background. Instantaneous frequency attribute (Figure 8) can be applied into characterization.

3.2 Reservoir Prediction

We characterized the thickness of salt rhythmic layer in this area, combining instantaneous amplitude attribute with given well data in Qian3^2 oil group. The salt rhythmic layer is generally thin in southwestern area and increases along southeast, therefore we predicted the sand body in different areas through amplitude attribute analysis. In thin salt rhythmic layers, we characterized the strong amplitude area into sand developed area, while in thick rhythmic area, we characterized the weak amplitude area into sand developed area. Besides, in the root mean amplitude attribute figure, there is an abnormally high value in southwestern area. According to the actual situation and above forward modeling analysis, this abnormal area may caused by the fact that the total thickness of salt rhythmic layer is close to tuned thickness ($\lambda/4$). This area can't be characterized as sand developed area.

4. CONCLUSIONS

According to practical geological situation in the area, we established correspondent geological forward model, based on which reservoir prediction was operated. The accuracy of reservoir prediction can be enhanced. The method achieved satisfying result in this practical application.

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