Analysis and Prediction of Seismic Characteristics of Channel Sand Body—By taking Fengle-West Yulin area as an example

Huan Jiang [a], Zhaonian Chen [b]

China University of Geosciences, Beijing 100083, China

[a]fiona_jh@163.com, [b]chen_zn@cugb.edu.cn

Abstract

It's essential to do well in the work of three stages for channel sand body identification and fine reservoir prediction: data preparation and pretreatment stage, reservoir prediction method selection, comprehensive interpretation and accuracy evaluation. First is to conduct the standardization of well logging data (environment correction and normalization) to improve the reliability of well logging data. Second is to conduct the analysis of the reservoir characteristics by combining drilling data (including drilling geological data and well logging data). Finally is to search for the geophysical methods applicable to reservoir characteristics for carrying out reservoir inversion. The reservoir spatial distribution pattern and the sand body distribution feature are predicted macroscopically by conducting the fine reservoir inversion through well-seismic fine calibration, combined with geological study of sedimentary facies.

Keywords

Channel Sand Body, Forward Model, Seismic Attributes, Sedimentary Characteristics.

1. Introduction

The study area is located in the central depression of Sanzhao in Sonliao Basin. Fengle area is located in Zhaozhou and Zhaodong County of Heilongjiang province, Northeast of Zhaozhou County, southwest of Changwu town. West Yulin area is located in Zhaodong County of Heilongjiang province. Respectively Fengle and West yulin of two blocks of 3-D cover. It has 400km^2. This paper focuses on the research of fengle – West yulin in Fuyu reservoir (Fig. 1).

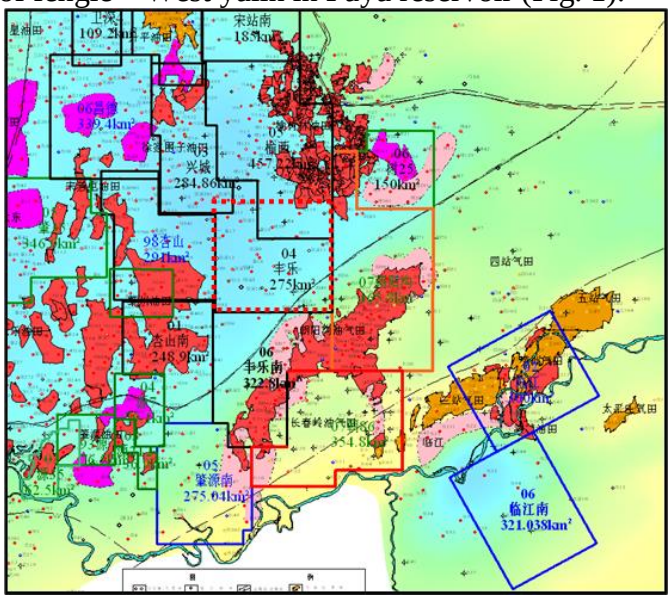

Fig. 1 Location map of study area

This study based on fine reservoir group 3D interpretation, through the method of comparative analysis optimization, formed a set of basis information on the basis of the qualitative picture of channel sand body prediction description technology. There is a good correlation between the thick

channel sand body and amplitude property in fengle-West Yulin area. Based on the amplitude preserving data, The prediction accuracy of channel sand body is higher of using the optimized time window.

2. Analysis of sedimentary reservoir characteristics

Fengle-West Yulin area is located in internal depression of Sanzhao, the layers this study are third and fourth Fuyu oil layer of Quantou group. On the whole, the third and fourth deposition of Quantou group is located in depression period of Songliao Basin, which is another significant land phase filling deposition construction with the overall depression characteristics formed between abrupt transgression at the bottom of Qingshan Mouth group after the overall lifting of end period basin at the second section deposition of Quantou group is subject to erosion. Four sections of Quantou group on the whole is purple-red, gray, gray-green mudstone and unequal thickness inter - layer deposition of sandstone.

The development of the third and fourth sections of Quantou group of Fengle-West Yulin area is with unique distinct shallow lake delta facies, which is the deposition body formed by the injection of river into the broad coastal shallow lake area. The difference from the typical delta phase model is that the environment of the shallow lake delta is shallow lake, the bottom of the lake is gentle, the water surface fluctuates greatly, and there's the larger friction force between the lake water and the lake sediment, the lake water is with weaker power and the wave function is weaker. During the formation and development of the shallow lake delta, the effect of the river is predominant, while the effect of the lake is relatively small. Therefore, the delta water, underwater distributary channel is very developed in the delta, estuary dam is without any development, and there's no deep lake phase, or half-deep lake mud. The shallow lacustrine delta can be divided into two subfacies of the delta plain and the delta front according to the deposition process and deposition environment [1].

3. Qualitative prediction of channel sand body

Through the analysis of Fengle-West Yulin area deposition and reservoir development characteristics, the channel microfacies are the effective reservoir development facies belts in this area. Therefore, it is the focus work of this study for using multi-means geophysical method to identify channel sand body based on amplitude preservation data, and implementing its developmental distribution characteristics [2].

3.1 Analysis of channel sand body seismic reflection 1 characteristics

3.1.1 Analysis of channel sand body forward model

The reservoir of Fuyu oil group in the study area is thin sandstone, and the whole target layer is characterized by sandstone interbedding with less sand but more mud. Regarding to this specific situation of the study area, whether the seismic method can reach the required accuracy, which should be studied by starting from the forward model, the design of the forward model is mainly to consider the response features of the thin sand with different thickness.

In this forward model, Zhao18 well F12 layer is taken for an example, which is used to constructed the sand wedge body model with the sand thickness changes of 0-5-10-15-20 m (Fig. 2).

Through the forward analysis, when the main frequency of seismic data is 30Hz, 20m sand layer in medium layer of FI cannot be basically separated from the seismic profile. When the sandstone thickness is 18m at 35Hz, the sand body can be identified, and its top and bottom surfaces form the reflection peak respectively. Therefore, as long as the seismic data frequency reaches 35Hz, the conventional profile can identify sand body for about 18 meters. When the seismic data is at 50Hz, the sand layer at above 13 meters can be basically identified, the thickness change for the sand layer less than 13 meters can only be judged from waveform change, reflection amplitude strength.

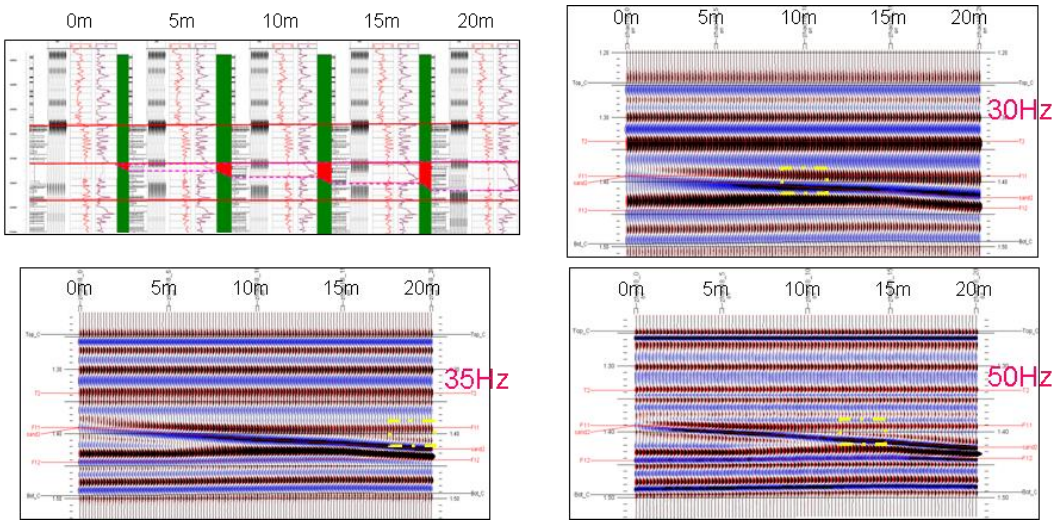

Fig. 2 Zhao18 well sand wedge forward model

3.1.2 Fine lithology calibration implements channel sand body reflection characteristics

On the basis of forward analysis, this study carries out fine lithology calibration on the wells in the work area. The sandstone velocity in the Fuyu oil layer is higher than that in the mudstone. Therefore, the top of the channel sand body corresponds to the peak, through 90° of the seismic data. The sandstone layer and seismic peak should be with better correspondence (Figure 3), the seismic trace is similar to the wave impedance profile and lateral variation of the sand layer and the extension length of the reflection phase axis has a better corresponding relation.

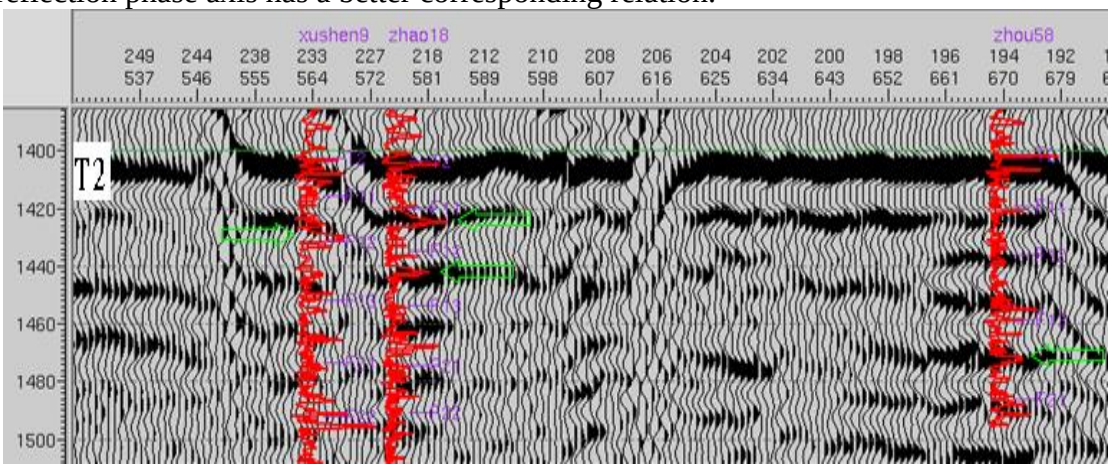

Fig. 3 Channel sand body fine calibration

3.2 Optimization of channel sand body earthquake prediction method

The application of seismic data to predict the lithofacies development is mainly to extract and analyze the waveforms or various seismic attributes within intervals of optimization time window through the analysis of corresponding relationship between different attributes and lithology based on fine calibration and interpretation, thus to qualitatively implement lithofacies plane distribution characteristics. Through the above forward analysis in this study, channel sand of the regions is with better correlation to seismic reflection, therefore, a variety of seismic prediction techniques were used in this study to make optimization of the prediction method of channel sand body of Fuyu oil group in Fengle-West Yulin area, thus to improve the prediction accuracy of channel sand body [3].

3.2.1 Seismic waveform clustering analysis

Clustering analysis is to make the classification based on the degree of affinity of sample representative indicators in the nature. Distance is statistics used to measure the similarities between the classified objects, and the samples can be classified, many ways to categorize after determining the distance between the samples, there are a lot of classified methods, of which, the most widely used is the system clustering. It first classifies each of the n samples into a single class, and then merges the

two classes with the smallest distance into one class at a time, and re-computes the distance between the classes until all samples are classified as pre-set number of categories.

In this study, the stratmagic software is used to make stratum cluster analysis. Except for F11 was with clear boundary, the boundaries of the other layers were unclear. And the coincidence rate of channel sand body larger than 3 meters is not high, the coincidence rate of channel sand body over 3 meters was not high, the coincidence of F11 small layer was about 70%, and the other small layers were lower (Fig.4).

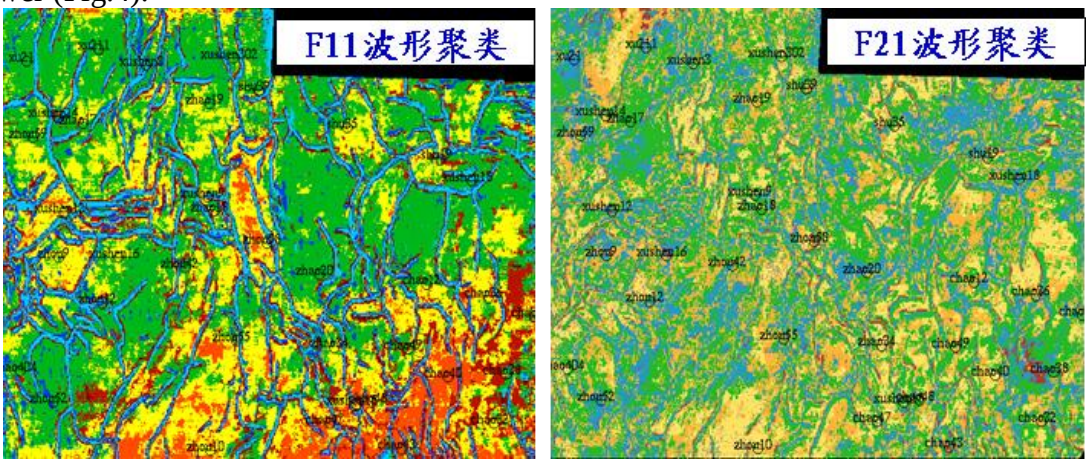

Fig. 4 Seismic phase diagram in Fengle area

3.2.2 Analysis of seismic attributes

Seismic attribute is a special measurement value of geometric, kinematic, kinematic and statistical characteristics related to seismic waves for the pre-stack or post-stack seismic data derived from mathematic transformations. These properties are indicative of subsurface lithology, oil-gas possibility, and the associated petrophysical properties, and so these attributes can be used for reservoir prediction.

Many types of seismic parameters can be extracted from seismic data such as amplitude class, frequency class, correlation class, polarity, impedance (or velocity) and others, and each class contains many parameters. (Table 1)

Table 1. Statistical tables of geological information may be reflected by some seismic attributes

Seismic attributes	Possible re1flection of reflect reservoir information
Amplitude (instantaneous + energy)	Paleogeomorphology, lithology difference, lithologic continuity, total porosity
Apparent polarity (instantaneous + energy)	Lithology, reflection polarity difference, gas possibility
Frequency (instantaneous + energy)	Rock thickness and fluid properties
Phase (instantaneous + energy)	Continuity of strata, strata structure
Amplitude min and max number ratio and position	Paleogeomorphology, lithofacies structure
Layer velocity	Lithology, porosity, pressure
Various components of spectral decomposition	Horizontal, vertical resolution, porosity, fluid, and geometry
AVO	Fluid properties in rocks
Acoustic impedance	Porosity and mud content
Curvature, boundary enhancement and so on	Faults and fracture characteristics
Inclination, azimuth and artificial lighting and other achievements	Structure, fault

Root mean square, minimum amplitude, maximum amplitude, absolute maximum amplitude, peak mean	Hydrocarbon indication
Trough mean, the average energy, amplitude sum, and sum of absolute amplitude	Lithology, physical indication
Dominant frequency, average instantaneous frequency	Hydrocarbon indication
Half the energy, the threshold value	Lithology, physical indication
Average instantaneous phase	Fluid indication
Number of zero values, arc length, bandwidth	Lithofacies horizontal and vertical variation characteristics

4. Optimization and extraction of seismic attributes

The seismic attribute has certain indication function to the lithology change, but at the same time it has many solutions, so optimization of seismic attribute and extraction method is the key to improve the qualitative prediction of channel sand body.

In this study, Emerge software was used to optimize the attribute analysis of channel sand. Through the analysis of optimized attribute of multi-wells and wellbore seismic traces, the sandstone development was positively correlated with conventional seismic amplitude attributes, but the correlation degree was low of only about 46%. (Fig.5)

At the same time, it can be seen according to the attribute analysis of main channel sand body development of each well that channel sand with different thickness or the sandstone combination of small layers has better positive correlation to amplitude properties of different frequency bands. Therefore, the attribute optimization analysis indicates that amplitude attribute is sensitive to the channel sand body. The key to improve the reservoir prediction accuracy is to select the extraction method and time window (Fig. 6).

In practice, we extracted the properties of the layers of Fuyu oil group by using the regular root - mean - square amplitude and the root - mean - square of amplitude.

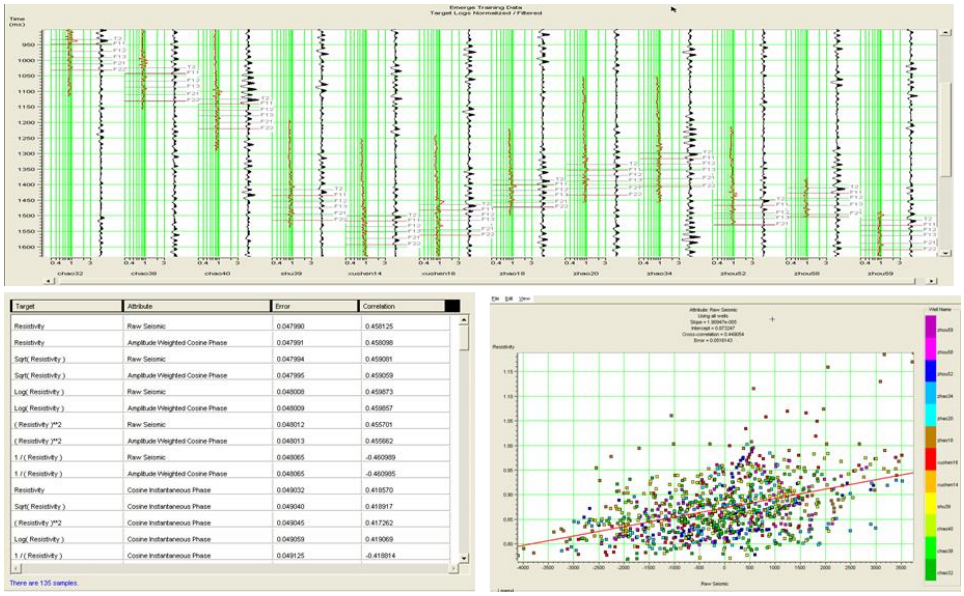

Fig.5 Seismic attribute optimization

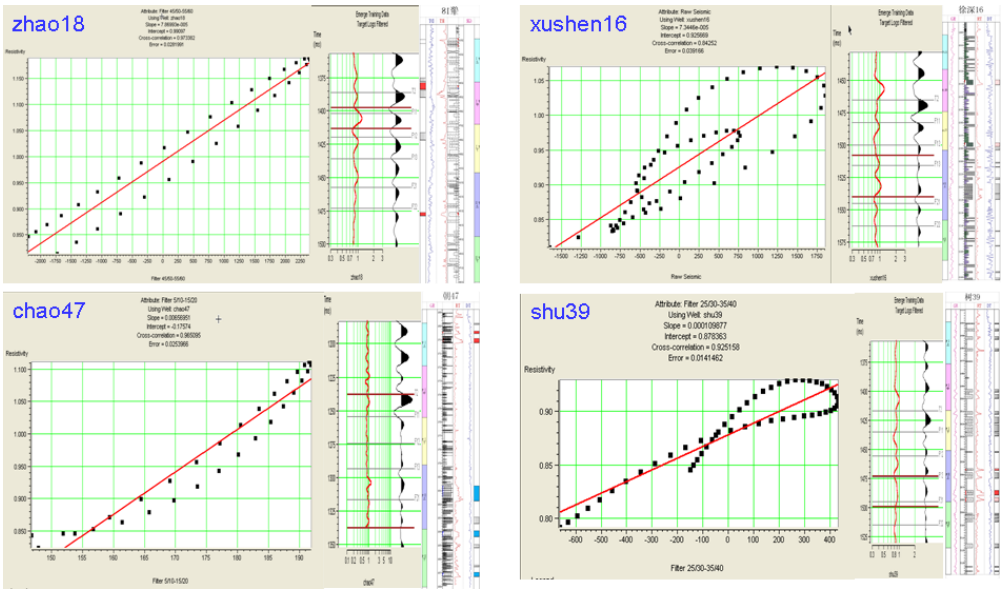

Fig. 6 Single-well seismic attribute optimization

5. Plane deposition phase analysis of Fuyu oil group

Based on above-mentioned qualitative prediction of channel sand body, the layers of deposition phase of Fuyu oil group of Fengle-West Yulin area was reanalyzed in this study.

F11 layer deposition phase development characteristics: F11 channel sand body development was more extensive, but the channel sand body thickness was smaller, and the maximum thickness was of only 7.4 meters. The main development on the plane was from diversified river of two-way source of south and north. On the whole, F11 small layer was focused on distribution nearby north and south channel.

F12 layer deposition phase development characteristics: F12 channel microfacies overall development scale was smaller, and the channel curvature was higher, channel sand body thickness was small, reflecting the deposition period of hydrodynamic conditions was weak, together with insufficient material supply. On this plane, the main development of the period was from the channel deposition of the south and southwest of the study area.

F13 layer deposition phase development characteristics: F13 layer distributary channel was mainly in north-south distribution, multi-directional channels intersect each other to form a network of channel depositional system.

F21 layer deposition phase development characteristics: when there's the deposition at F21 layer, the eastern part of the river channel development of the study area was more extensive, the diversified channel were collected from the southern, western and northern sources in Fengle-West Yulin area, river distribution direction was based on the north-south and north-east direction. The middle and eastern parts of this layer was with thicker development, and the channels from the west source are narrower and thinner, and the multi-directional channels were intertwined. The typical network was characterized by network deposition.

F21 layer deposition phase development characteristics: compared with the F21 layer, F22 layer channel was with less micro-development, and the channel was mainly in strip development of north-south and north-east direction, on the whole, F22 channel was mainly based on south source and west source channel system.

6. Conclusion

Through the integration of the distribution characteristics of the deposition facies development of each layer, the Fuyu oil group of Fengyu-West Yulin area belonged to the delta plain facies deposition and the reservoir was mainly composed of channel sandstone development. The

distributary channels from the southern, western and northern source systems were converged in this area, which was formed into the distribution characteristics similar to the reticulated river deposition. The scale of single channel development was small, which reflected the deposition characteristics of gentle terrain and relatively weak hydrodynamic conditions.

References

[1] Li Yanping et al., Depositional Characteristics of Shallow Lacustrine-Delta System in Daqing Placanticline and Fushan Oilfield, Daqing Oilfield, Daqing Petroleum Geology and Exploitation, 2005.10.

[2] Editorial Board of Petroleum Geology of Daqing Oilfield, PetroChina Geological Prospecting (Volume I) - Daqing Oilfield [M], Beijing: Petroleum Industry Press, 1993.

[3] Qin Yueshuang, Wang Yanhui, JIANG Hongzhang, et al., Reservoir Prediction Technology and Application of Channel Sand Body in Daqing Peripheral Oilfield [J], Acta Scientiae Circumstantiae, 2006, 27 (Add): 66-70.