ORIGINAL ARTICLE

Analysis of Sensitivity of Delta Facies Seismic Attributes Through Forward Modeling

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Abstract: The sand bodies of the underwater divergent channels in the delta subfacies in the delta are distributed in narrow strips, and the thin inter-layer characteristics are significant. This type of sand body has low control degree, and the prediction between wells mainly relies on seismic methods. It is affected by the quality of seismic data. The prediction accuracy is low. In this paper, taking the No.1 reservoir of Gaotaizi Oilfield Research Area as the research object, the forward model is used to describe the relationship between seismic attributes and channel sand body thickness.

Keywords: Forward simulation; Geological model; Channel sand body; Seismic attribute; Sensitivity

Gaotaizi Oilfield is located in the south of Daqing Changyuan, a tertiary structure in the south of the Daqing Changyuan secondary structural belt. Gaotaizi Oilfield is a heterogeneous oilfield with continental sedimentary river-delta deposits. Straight shunts are mainly sand bodies. This type of sand body has a small development scale, a low drilling encounter rate, a strong heterogeneity on the plane, and a low degree of well pattern control. This paper studies the thickness of the river sand body with a forward model for the grape flower reservoir in Gaotaizi area. The relationship with seismic attributes and sensitive seismic attributes are preferred.

Seismic attributes are a measure of the geometric, kinematic, dynamic, and statistical characteristics of seismic data. This definition is basically a purely mathematical definition[1]. Landmark's definition of seismic attributes is: "Earthquake attributes are a kind of characteristics that describe and quantify seismic data. The determination is to decompose the seismic data, and each seismic attribute is a subset of the seismic data." Le Youxi used forward modeling technology to study the seismic wave propagation velocity (the relationship between density and depth and seismic attributes[4]. Wang Yonggang *et al*. Studied the correlation between seismic attributes and reservoir characteristics through forward modeling[5].

1. Seismic attribute classification

The purpose of seismic attribute classification is to reduce the redundancy of seismic attributes, reduce the blindness of attribute analysis, and improve the efficiency of attribute prediction calculation. At present, a recognized, complete and unified classification of seismic attributes has not been established. Many scholars have done classification research. There are four popular classification methods. One is proposed by Taner *et al*. In the early 1990s. Starting from the basic definition of seismic attributes, the seismic attributes are divided into geometric attributes and physical attributes[3]. The second was proposed by Brown *et al*. In 1996, which divided seismic attributes into pre-stack attributes and post-stack attributes according to different data volume sources[2]. The third is the classification by Chen attribute function proposed by Chen in 1997, that is, the seismic attributes are divided into bright and dark points,

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unconformity traps and fault block uplifts, anomalous hydrocarbon orientation, thin reservoirs, formation discontinuities, and limestone reservoir Layers are related to clastic rocks, tectonic disconnection, and lithologic annihilation[1] . Fourth, by the end of the 1990s, some people classified seismic attributes into four categories: geometric attributes, kinematic attributes, dynamic attributes, and statistical attributes.

Non-linear attributes are unique in terms of reaction lithology, oil and gas, etc. This research mainly uses the PAL attributes of landmarks. Seismic attributes are divided into amplitude, instantaneous, frequency spectrum, sequence, and related five categories of attributes.

2. Selection of model parameters

The study area is the Putaohua oil layer in Gaotaizi area. The amplitude, phase, frequency, and number of peaks of the seismic profile are analyzed. Aiming at these characteristics appearing on the seismic profile, a forward model is designed to explore the relationship between seismic attributes and thin mud-sandstone interlayer structure, and further to find a method of using seismic attributes to predict thin reservoirs in thin mud-sandstone interlayer[6].

The parameters such as speed, density, and main frequency in the model are designed according to the actual data in the work area. The upper and lower green pure mudstone velocities are 2700 m/s (density of 2264.49 kg/m^3) and 3000 m/s (density of 2285.91 kg/m^3). The velocity of the middle silt mudstone is 3400 m/s (the density is 2385.57 kg/m^3), the channel sand velocity is 3700 m/s (the density is 2408.96 kg/m^3), and the main frequency of the seismic wave is 40Hz.

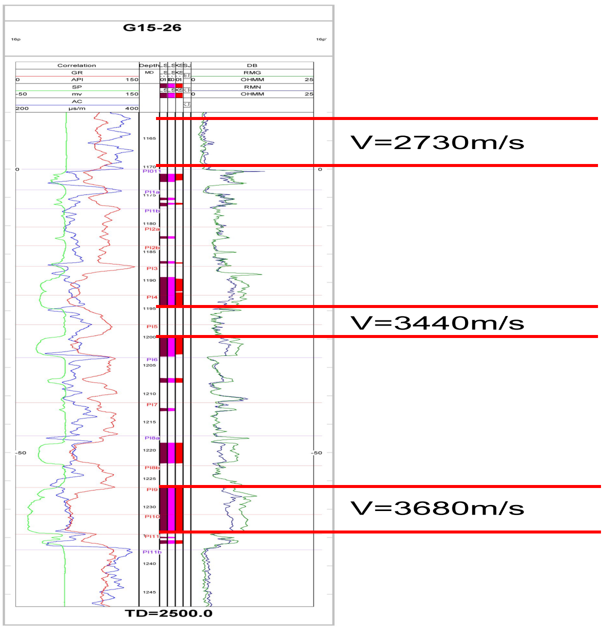

Figure 2-1. Speed selection

3. Basic ideas for sensitivity analysis of seismic attributes

In order to further determine the relationship between the properties and the thickness of the sandstone, according to the actual interpretation results in this study area, their physical property parameters were obtained from the AC data in the logging data[8]. Synthesized seismic records obtained from forward modeling, use forward seismic data to extract various attributes, analyze the sensitivity of attributes to sandstone, and analyze the correlation of seismic attributes to optimize seismic attributes[7].

This time, the Rick wavelet is selected. Its advantages are that the peak frequency is obvious, the wavelet shape is simple, and the wavelet continuity is short. The most basic and common one-dimensional model of seismic traces is the convolution model. It is considered that seismic traces are formation reflection The coefficient and wavelet convolution plus noise composition can be expressed as follows:

$$S(t) = R(t) * W(t) + n(t) \tag{1}$$

In the formula: S (t) -synthetic seismic record, R (t) -reflection coefficient sequence, n (t) -noise.

The actual seismic wave is affected by the low-pass filtering of the earth during the formation process. The seismic wave changes from a sharp pulse to a pulse waveform with a certain length. The spherical divergence of the seismic wave, absorption attenuation, and transmission loss all cause changes in the seismic reflection profile. At the same time, the effect of noise on the actual profile cannot be ignored. These changes must be taken into account when conducting seismic forward modeling[9].

On the synthetic seismic record, the above five types of attributes are extracted along the target horizon, and then the Spearman correlation coefficient of the statistical relationship between the thickness of the river sand body and the seismic attribute is calculated based on the thickness change characteristics of the geological model to analyze the river sand body and earthquake Relevance and sensitivity of attributes. The calculation formula of Pearson product moment correlation coefficient is as follows:

$$\rho_S = 1 - \frac{6\sum d_i^2}{n\left(n^2 - 1\right)} \tag{2}$$

In the formula: n-the number of samples, and d-the rank difference of two-paired variables.

4. Sensitivity analysis of seismic properties of forward model

In this study, the discovery software forward module GMAplus Struct is used. This module is a forward modeling system based on ray tracing theory and wave equation theory. It can use accurate synthetic record calibration to determine complex velocity distributions. Use gradient gradients in the vertical and horizontal directions to ensure that the model is more in line with the actual underground conditions. This module is based on the above principles, referring to drilling information, seismic waveform changes, reservoir prediction and inversion results, establishing a geological model, extracting wavelets from the side of the well, and finally applying the principle of normal incidence to self-excitation and self-receiving, taking into account a certain degree of noise Interference, simulate the seismic reflection wave, and get the synthetic record. By comparing with the waveforms and occurrences of the actual seismic traces, the correctness of the geological understanding is verified[10].

Model 1: Assuming that no sandstone develops in the interior, design a geological model such as (**Figure 2-1**) according to the above velocity and density, and its thickness should be the thickness of layer PI9. This model is a synthetic seismic record profile without sand bodies.

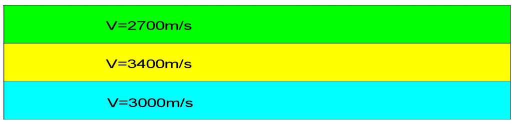

Figure 4-1. Geological model

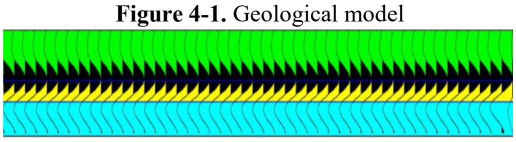

Figure 4-2. Synthetic seismic record

According to the actual sandstone thickness of the well profile, see Figure 4-3, and design the geological model shown in **Figure 4-4**.

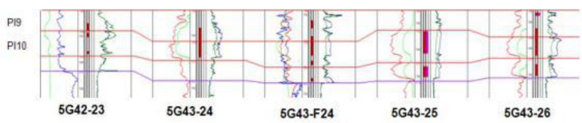

Figure 4-3. Actual well profile

Model 2: Sand body PI9 develops, the thickness of the single sand body varies, and the stacking relationship is different. According to the actual thickness of the sandstone, the thickness of the sand body is 0-5 m. Obtain the synthetic record as shown in **Figure 4-5**.

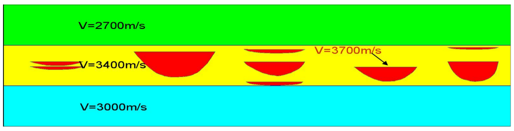

Figure 4-4. Geological model

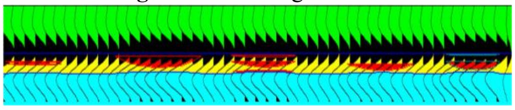

Figure 4-5. Synthetic seismic record

With the target layer as the window, 38 attributes in 5 major categories are extracted and normalized. The correlation between the seismic attribute dimension and the thickness of the sandstone is analyzed to analyze the correlation.

$$y = (x - MinValue)/(MaxValue - MinValue)$$

In the formula: x, y are the values before and after the conversion, MaxValue-sample maximum, MinValue-sample minimum.

Spirman correlation analysis is performed on the above various attributes and sandstone thickness. Theoretical analysis shows that when it is 0-0.19, it is polar correlation, 0.2-0.39 is low correlation, 0.4-0.69 is moderate correlation, and 0.7-0.89 is highly correlated. , 0.9-1 is extremely high correlation.

5. Conclusion

Through the characteristic analysis of the attribute change map and the sandstone thickness map, it can be obtained that the amplitude-type attributes have a good similarity with the reservoir thickness. Therefore, when predicting the channel sand body, multiple amplitude-type attributes can be used for prediction.

The average reflection intensity of the instantaneous attributes is very similar to the thickness of the sandstone, but other attributes are similar to the thickness of the sandstone, so the instantaneous attributes are not good at recognizing fluvial sand bodies.

Among the spectrum-type attributes, the arc-length attribute is very similar to the sandstone thickness, but other attributes are very similar to the sandstone thickness, so the spectrum-type attributes are not good at recognizing fluvial sand bodies.

The sequence-type attributes only have a certain similarity between the number of wave peaks and the thickness of the sandstone, but other attributes are very similar to the sandstone. Therefore, the sequence-type attributes have a good recognition ability for river-phase sand bodies.

References

1. Chen Q, Steve S. Seismic attribute technology for reservoir forecasting and monitoring. The Leading Edge 1997; 16(5):445. doi: 10.1190/1.1437657.
2. Brown AR. Seismic attributes and their classification. The Leading Edge 1996; 15(10):1090-1090. doi: 10.1190/1.1437208.
3. Gao L, Yang QY. New advances in seismic attribute technology (in Chinese). Geophysical Prospecting for Petroleum (Supplement) 2004; 43.
4. Yue YX. The application of model technology to studying geological research geological significance of seismic attributions. Geophysical and Geochemical Exploration 2001; 25(3): 191-197. doi: 10.3969/j.issn.1000-8918.2001.03.006.
5. Wang YG, Yue YX, Liu W, *et al*. Relativity between seismic attributes and reservoir characters. Journal of the University of Petroleum,China (Edition Of Natural Science) 2004; 28(1): 26-30+35. doi: 10.3321/j.issn:1000-5870.2004.01.008.
6. Xie D, Wang YG, Yue YX, *et al*. Application of seismic attribute analysis technology in the production of Ziyin Oilfield. Geophysical Prospecting for Petroleum 2003; 42(1): 72-76. doi: 10.3969/j.issn.1000-1441.2003.01.016.
7. Liu ZF. Key techniques of integrated seismic reservoir characterization for tight oil &gas sands. Progress in Geophysics 2014; 29(1): 182-190. doi: 10.6038/pg20140125.
8. Yuan BH, Xu LG, Kang NC, *et al.* Related technical advances in petroleum seismogeology. Acta Petrolei Sinica 2013; 34(3): 580-590. doi: 10.7623/syxb201303025.

9. Liang HW, Mu LX, Fan ZF, *et al.* The AHP study of architecture pattern of meandering reservoir on the basis of forward simulation. Journal of China University of Mining & Technology 2014; 43(6): 1063-1069+1086.
10. Zhang Y, Qiu LW, Li J, *et al.* Sedimentary facies analysis based on cluster of seismic attributes by fuzzy C-means algorithm. Journal of China University of Petroleum (Edition of Natural Science) 2015; 39(4): 53-61. doi: 10.3969/j.issn.1673-5005.2015.04.007.