The application of reservoir prediction method based on seismic low frequency properties in Xishanyao Formation in SN58 well area

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Abstract. In order to eliminate the shielding effect of the coal seam on the sand body, better predict the sand body, comprehensively apply the seismic forward modeling method and frequency division technology to extract the low frequency signal in the suitable frequency range, the seismic information of the coal seam can be filtered out, and the sand body is retained. There is a school signal, and then according to the matching relationship between the low frequency signal and the sand body, the distribution range of the sand body can be well predicted, and then the seismic inversion method and the logging data of the new drilling are used to verify whether the sand body distribution is reasonable. The results show that the sand body interpretation conclusion of single well logging data has a good correspondence with the sand body distribution range predicted by reservoir prediction based on seismic low frequency properties. In the absence of well data to participate in the calculation, the reservoir prediction method based on the low-frequency properties of the earthquake can directly reflect the distribution range of the sand body, and the reliability of the predicted sand body boundary range is higher.

1. Introduction

At present, the exploration focus of each major oil field is developing from direction of structural hydrocarbon reservoir to lithologic hydrocarbon reservoir and structure-lithologic hydrocarbon reservoir. The exploration target gradually changes from shallow to deep, from large to small, from simple to complex. In order to do well in the exploration and evaluation of structure-lithologic hydrocarbon reservoir, a new reservoir prediction method is needed.

Among them, "low frequency shadow" is one of the important attributes that directly indicate hydrocarbon reservoir [1]. In the low frequency range of seismic data, hydrocarbon reservoirs often show high anomalies [2]. In terms of mechanism, it is because that oil-bearing reservoirs increase the reflection coefficient in the low frequency range, expand the effective seismic bandwidth, and expand it to a lower frequency range, showing the potential of using the low frequency information of seismic waves to predict hydrocarbon reservoirs [3]. At the same time, it can be found from the actual data in the laboratory that the main frequency of the reflection in-phase axis of fluid saturated porous media decreases, time shifts and low frequency and high amplitude phenomenon, and the high absorption phenomenon in low frequency is closely related to the phase delay [4]. In the actual seismic data
processing, it is found that the low-frequency signal in the reflected seismic wave contains extremely important information related to the hydrocarbon reservoir, which can intuitively display the hydrocarbon reservoir, display a good imaging ability for reservoir prediction, and have a high coincidence with the drilling results\(^{[5-8]}\).

2. General Situation

\(J_{2x2+3}\) of Jurassic Xishanyao Formation in SN58 well area has not made a significant breakthrough since it was found in 2016\(^{[9-15]}\). The reason is that due to the shielding effect of upper and lower coal seams, there is little difference in seismic response between sand wells and non-sand wells, the distribution of sand bodies is unclear, and it is difficult for conventional reservoir prediction methods to predict pinch out line of sand bodies. It is necessary to try new reservoir prediction methods to overcome the cover of strong seismic reflection of coal measures and enhance the response of weak reflection reservoirs. More and more geophysicists realize that seismic low frequency information is closely related to hydrocarbon reservoir area. Seismic low frequency information can reduce the impact of strong reflection of coal measure strata, so it can be used to predict the distribution condition of sandstone shielded by two sets of coal measure strata.

3. Forward Modeling of Low frequency Information of Seismic Wave

Forward modeling is an important method in seismic exploration, which is to establish an ideal geological model in line with the actual situation, so as to obtain the propagation regularity of seismic wave in the model. Through forward modeling, we can study the propagation regularity of seismic wavelet in the formation medium, establish the seismic response mode according to the simulation results, and then guide to solve the actual geological problems\(^{[16-17]}\).

In the \(J_{2x2+3}\) stratum of Jurassic Xishanyao Formation in SN58 well area, there are two sets of coal seams sandwiched with one set of sand layer. The sand body is pinched out towards the high part of the structure, and the thickness of the sand body is 20-39m, with an average of 30.8m. According to the actual drilling situation, first establish a geological model in line with the well area, set the thickness of the upper and lower coal seams as 8m, and a set of pinched out sand layer is sandwiched in the middle of the coal seam (Fig.1 a). The wavelet with different main frequency is set to carry out forward modeling, and the range of main frequency is from 8 to 50Hz. The results show that under the condition of wavelet with high frequency (40Hz), under the influence of strong energy reflection formed by coal seam, sandstone and mudstone form the same seismic response characteristics, so the cusp of sandstone cannot be determined (Fig.1 b). In the case of low-frequency (15Hz) wavelet, effective reflection is formed at the developed sand body of \(J_{2x2+3}\), and the cusp of sandstone can be well identified (Fig.1 c).
4. Application of Low Frequency Information of Seismic Wave

The narrow-band seismic information of 15 Hz main frequency is extracted by frequency division method. The results show that there is obviously a set of reflection in-phase axis at the low frequency end of sand wells, and there is no such set of reflection in-phase axis on non-sand wells (Fig. 2, Fig. 3). The in-phase axis and single well sand body has a good correspondence. 20 wells have been drilled, and the coincidence rate is 100%. The frequency division method can effectively distinguish sand and non-sand. Therefore, by extracting the planar information of the in-phase axis, the planar distribution range of J2x2+3 sand body can be predicted and the pinch out line of sand body can be depicted (Fig. 4).

Figure 1. Forward modeling section of the J2x2+3 of Jurassic Xishanyao Formation in the SN58 well area

Figure 2. Frequency division cross-section of S141-SN22-SN58-SN59-SN23 well
5. **Data Verification**

In the field of hydrocarbon exploration, data interpretation depends on inversion results to a certain extent. Inversion is a mathematical method that infers the structural form and fluid composition of the formation according to various data of earth exploration, and calculates various related geophysical parameters quantitatively. The general working procedure is to estimate a result first, then correct the previous result according to the new observation data, and finally, reasonable inversion results are obtained to predict hydrocarbon reservoirs [18-19].

On the one hand, quantitatively depicting the pinch out line of $J_{2x2+3}$ target sand body by wave impedance inversion, the results show that (Fig. 5), the sand body distribution inversed and the sand body distribution displayed by extracting the low-frequency seismic information with the main frequency of 15Hz are consistent, and it can be considered that the sand body distribution range depicted by two different principles and methods is relatively high.

On the other hand, it can be seen from the sand body verification results of two verification wells H17 and S103 and section (Fig. 6), there is no sand body in layer $J_{3x2+3}$ of new well H17, which is
consistent with the prediction results and inversion results of seismic low-frequency information. S103 is a well that does not participate in inversion, and there is sand body on the well, which is consistent with the result of low-frequency seismic information prediction and inversion.

The seismic low-frequency signal has a larger wavelength. When it passes through the coal seam, it shields the influence of the coal seam on the sand body, filters the coal seam, and retains the effective signal of the sand body, so it can predict the sand body well. The pinch out line of J2x2+3 target sand body and the pinch out line of seismic low-frequency attribute prediction are depicted quantitatively by wave impedance inversion, which shows an amazing consistency; Through the comparison of single well logging interpretation results, it can be found that the sand body boundary predicted by using seismic low-frequency information and the sand body interpretation results of single well have good correspondence without single well data participating in the calculation.

Figure 5. Planar graph of J2x2+3 wave impedance inversion in SN58 well area
6. Conclusion

(1) In view of the shielding effect of coal seam on sand body, through the method of forward modeling, the matching geological theoretical model is established, and the suitable low-frequency signal range is selected to eliminate the shielding effect of coal seam;

(2) Forward analysis can obtain suitable low-frequency signals, guide the actual reservoir prediction, extract the corresponding low-frequency amplitude attributes through wavelet transform, and predict the distribution range of sand body;

(3) The reconstructed characteristic curve improves the conventional inversion results. The results show that the reservoir prediction results based on seismic low frequency attribute are very consistent with the inversion results, and the reservoir prediction method based on seismic low frequency attribute is feasible.

References

[1] Sheriff R E. Encyclopedic dictionary of applied geophysics (fourth edition). Houston: The Society of Exploration Geophysicists, USA, 2002.

[2] Chapman M, Liu E, Li X. The influence of abnormally high reservoir attenuation on the AVO signature[J]. The Leading Edge, 2005, 24(11): 1120-1125.

[3] Goloshubin G. M, Korneev V. A. Seismic low-frequency effects from fluid-saturated reservoir[C]. SEG Expanded Abstracts, 2000, 19 : 1671-1674.

[4] Korneev V. A, Silin D, Goloshubin G. M, et al. Seismic imaging of oil production rate[C]. SEG Expanded Abstracts, 2005, 24 : 1-4.

[5] Goloshubin G. M, Connie V. A, Korneev V. A, et al. Reservoir imaging using low frequencies of seismic reflections. The Leading Edge, 2006, 25(5): 527-531.

[6] CHEN Xuehua, HE Zhenhua, WEN Xiaotao, et al. Numerical Simulation and Detection of Low Frequency Shadows[J]. Oil Geophysical Prospecting, 2009, 44(3): 298-303.

[7] CHEN Xuehua, HE Zhenhua, HUANG Deji, et al. Low frequency shadow detection of oil and gas reservoirs in time-frequency domain[J]. Journal of Ball Physics, 2009, 52(1): 215-221.

[8] BIAN Lien. Full-band seismic information mining and oil and gas identification [D]. Chengdu : School of Information Engineering, Chengdu University of Technology, 2009.

[9] YANG Fan, HOU Lianghua, WEI Yanzhao, et al. New perspective on Shinan 21 and Shinan 31 reservoirs in the central Junggar basin [J]. Journal of China University of Mining &
[10] XU Changsheng, WANG Bin, YANG Mengyun, et al. Classification of Cretaceous bottom boundary in hinterland of Junggar basin[J]. Xinjiang Petroleum Geology, 2005, 26(3) : 278-279.

[11] TANG Yong, ZHOU Wenquan, ZHAO Kebin, et al. Geological era adscription and petroliferous formation classification of Shinan-31 wellblock in Junggar basin[J]. Xinjiang Petroleum Geology, 2007, 28(1) : 119-121.

[12] WANG Wei, CHEN Weiquan, PANG Shuwei, et al. Study on oil, gas and water zones distribution rules of Qingshuihe formation of Shinan31 wellblock in Junggar basin[J]. Xinjiang Geology, 2011, 29(2) : 194-197.

[13] XU Changsheng, YANG Mengyun, JIANG Zuqiang, et al. The exploration of Toutunhe lithologic reservoir in Shinan field, Junggar basin[J]. Xinjiang Petroleum Geology, 2004, 25(6) : 639-640.

[14] GONG Jianqiang. The application of the forward modeling in exploration[J]. Petroleum Geophysics, 2009, 7(2) : 13-17.

[15] XIAO Mingguo, AN Zhiyuan, CAO Shaofang, et al. Sequence stratigraphy division and characteristic of Qingshuihe formation in Shinan31 wellblock[J]. Inner Mongolia Petrochemical Industry, 2007, 17(8) : 349-351.

[16] GUI Hongbing. Study on the deep Seismic forward modeling in the Dongpu Sag [D]. Yangtze University, 2014.

[17] YANG Tianchun, Wang Yanlong, Feng Jianxin, et al. Two-dimensional joint forward modeling and analysis of concealed structures[J]. Xinjiang Petroleum Geology, 2013, 34(06) : 697-701.

[18] SA liming, YANG Wuyang, YAO Fengchang, et al. Review and prospect of seismic inversion technology [J]. Oil Geophysical Prospecting, 2015, 50 (01) : 184-202+20.

[19] ZHAI Jianhua, WU Tao, FEI Liying , et al. Hydrocarbon accumulation conditions of Qingshuihe Formation in Shinan area of Junggar Basin[J]. Xinjiang Petroleum Geology, 2017, 38(06) : 658-664.