Application of quantitative prediction technology based on reservoir inversion in sedimentary facies research

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Abstract: The traditional sedimentary facies research method based on rock ratio or comparison method has the disadvantages of strong uncertainty and low precision, which is difficult to meet the accurate description of lithologic reservoir boundary. Seismic reservoir inversion prediction technology makes full use of the sand body reflection information contained in seismic facies, which provides a guarantee for the final realization of quantitative study of sedimentary facies between wells and non-well areas. Taking Wang 955 well block on the north slope of Caoqiao as an example, the paper comprehensively uses curve reconstruction technology and seismic inversion technology to quantitatively predict the sandstone between wells and non-well area, and finally realize accurate description of sedimentary facies boundary.

Key words: North Slope of Caoqiao, sedimentary facies, curve reconstruction, reservoir inversion

1. Introduction

The traditional single factor sedimentary facies analysis method based on drilling sandstone statistics has good applicability for areas with high degree of exploration [1]. Le'an oilfield in the south slope of Dongying sag is an old oilfield with nearly 50 years of exploration and development [2]. In the northern slope of reserve concentration area of Shicun fault, there are few oil and gas discoveries and low degree of exploration. And beach bar sand reservoir were discovered in upper Es4 for the first time in wells Wang 955 and Wang 956 completed recently, as there are few the exploration wells of this type, the traditional sedimentary facies research method is difficult to accurately depict the sand body distribution. How to precisely depict the sand body distribution range of beach bar has become a key problem restricting the exploration in the area. In the paper, we use seismic inversion technology to realize sandstone prediction between wells and non-well area, and finally realize accurate description of sedimentary facies boundary.

2. Regional sedimentary characteristic

In the early stage of the upper part of Es4 on the north slope of Caoqiao, the fan delta deposits from Guangrao uplift were mainly developed, and the "blue fan" deposits corresponding to the early “red fan” deposits in the lower part of the fourth member of Shahejie formation were called. The lithologic association was mainly composed of blue gray and light gray gravelly sandstone and siltstone. The
single layer thickness of the sand body was relatively large, generally about 3-10m, and it was characterized by weak positive cycle sequence vertically. Recently, wells Wang 955 and Wang 956 completed drilling in the east slope of Caoqiao encountered multiple sets of oil layers in the third member of chunxia of the upper part of Es4. The lithologic combination is mainly composed of gray, light gray siltstone, dolomitic sandstone, mudstone and thin marlite deposition. Vertically, there are fine coarse reverse cycles or fine coarse fine compound cycles. According to the core data in the adjacent well Wang 73, there are many sedimentary structures on the core, such as wavy sand grain cross bedding, vein bedding, and vertical biological burrows (Fig.1a, Fig.1b). At the same time, thin skinned limestone oolite and calcareous intraclast are found in the clastic rocks under the microscope (Fig.1c). These sedimentary characteristics have the characteristics of shoal environment of shore shallow lake sand body transformed by coastal current[3-6]. Combined with the cumulative grain size curve characteristics of core slice, the wang73-xi1 curve shows the characteristics of 2-segment jumping components, reflecting the hydrodynamic characteristics of shore scouring and backflow. Therefore, it is considered that wang955-wang73 area is the type of beach bar sand sedimentary facies on the flank of fan delta.

Since the beach bar sand reservoir is found in well Wang 955, the reservoirs in wells Cao 36 and Cao 38, which are rising southward, are not developed. The key problem to be solved is how to distribute the beach bar sand and the relationship between the beach bar sand and the fan delta sand body of the "blue fan". Therefore, it is necessary to conduct inversion with logging constrained seismic data to find out the distribution of the sand body.

3. Quantitative prediction technology based on reservoir inversion

Through the analysis of seismic data in the study area, it is found that the main frequency and effective frequency band are 19HZ and 5-60HZ. If the main frequency is changed to the maximum frequency, the main frequency is about 12.5, and the reservoir in the target interval is relatively thin, and the reservoir thickness is generally less than 10m, or even less than 5m. Therefore, it is impossible to accurately describe the distribution of the reservoir only by seismic data. Wave impedance inversion is the processing technology of seismic wave impedance inversion using seismic data. It takes drilling and logging data as constraints to identify and image the underground space structure and physical interface. It is mainly applied to the prediction of reservoir distribution and provides technical basis for oilfield exploration and development [7-9].

3.1. Curve reconstruction technology

Conventional wave impedance inversion is using logging curve (mainly acoustic curve) for drilling constraints, so as to use seismic data for wave impedance inversion. However, the practical application shows that acoustic data cannot reflect the variation law of lithology, so it is necessary to carry out curve reconstruction research refer to other well logging information.

Firstly, through the analysis of the logging data in the study area, it is found that the logging curve needs to eliminate the abnormal points, depth correction and baseline migration. In addition, due to the
different testing instruments and surrounding rock environment, the logging response values will be greatly different, and the wave impedance values of adjacent wells in the same reservoir will be greatly different. Therefore, it is necessary to further standardize the logging curves. The standardization is based on the principle that the response values of mudstone layers in each well should be consistent. The standardized acoustic curves and other applied curves are treated as consistent intervals.

Secondly, through the analysis of logging data on the fourth member of Shahejie formation on the north slope of Caoqiao, it is considered that the acoustic curve of the target section is not very sensitive to lithology, while the natural gamma curve (GR) can well reflect lithology changes, and can distinguish reservoir and non-reservoir better (Fig.2). Therefore, the study will use the pseudo acoustic impedance inversion that is, fitting of acoustic wave and gamma for reservoir refinement. Its principle mainly considers the combination of low-frequency information of acoustic curve (formation background velocity) and high-frequency information of natural gamma curve (sensitive to formation lithology change) to reconstruct pseudo acoustic curve. This construction technology is more reasonable and more accurate to predict reservoir.

3.2. Quantitative prediction technology based on reservoir inversion

Firstly, on the basis of well seismic calibration in the whole area, strict and precise horizon interpretation is carried out according to the results of horizon calibration. Then, through the comparison of reservoir prediction with different frequencies, it is found that with the increase of frequency, the inversion results have improved, but the overall resolution is still low, and the reservoir characterization effect is not ideal. The solution is to improve the seismic initial model Line modeling, conventional linear modeling is obtained by using borehole wave impedance in horizontal uniform interpolation, modeling phenomenon is serious, and fractal modeling value in horizontal use of seismic amplitude variation to adjust, the result is more reasonable. In addition, it is found that 2ms sampling rate can basically meet the inversion requirements, and can identify the horizontal continuity and vertical distribution of sand body better. The vertical and horizontal resolution of the 1ms sampling rate inversion results is relatively higher. According to the actual needs, the inversion results of 2ms and 1ms sampling rate can be combined. According to the inversion profile of well Wang 955, the reservoirs of Wang 955-wang 732 in the target layer of Chunxia 3 sand formation are well developed, and the reservoirs to well Cao 38 and well Wang 92 are poorly developed, which shows that the overall reservoir inversion prediction is more accurate.
4. Inversion result

4.1. Correction of sedimentary facies based on inversion results
The quantitative prediction of reservoir inversion adopts the combination of forward modeling and inversion, the combination of unconstrained attributes and well constrained inversion, the combination of conventional impedance inversion and characteristic impedance inversion, so as to reduce the multi solution of reservoir identification and improve the reservoir resolution. At the same time, through the adjustment of the color code, the root mean square amplitude, variation function and other seismic attributes in the top to bottom time window of Chunxia 3 are extracted, and the superposition correction is carried out with the sand body thickness of well point statistics (Fig.4), so as to achieve the purpose of quantitative prediction of reservoir in non-well area.

The overall "blue fan" on the north slope of Caoqiao is developed in the area of cao328-tong20-guan115 (Fig.4), which is NW trending on the plane, there is beach bar sand distributed nearly east-west in the well Wang 955, which is separated from the main body of the "blue fan" in the West. Therefore, the sedimentary facies distribution map on the north slope of Caoqiao is modified.

4.2. Application effect
From the application effect, based on the above understanding, we deployed Wang 956, Wang 955-xie1 and Wang 955-xie2 in the high part of beach bar sandstone reservoir in well Wang 955 block, and drilled several beach bar sand reservoirs respectively, which showed the accuracy of sedimentary facies boundary depiction, and the reservoir thickness was basically consistent with the inversion prediction results The application of reservoir inversion prediction technology in fine description of sedimentary facies in this area has good exploration effect.

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