Application Of Seismic Waveform Indicator Inversion In Horizontal Well Design

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Abstract. The imperfect zone of injection and production is formed at the side of fault due to lateral occlusion, and the remaining oil is relatively abundant. The horizontal well can enlarge the area of oil discharge, improve the utilization degree of the oil layer, and the horizontal section can pass through the interlayer, so as to effectively excavate the remaining oil at the edge of the fault. To achieve a better level wellblock reservoir prediction effect, based on waveform inversion instructions, the method of waveform indicates inversion of 1# fault zone of remaining oil prediction method to explore and PII reservoir in the studied area of channel sand body distribution pattern is forecasted, guiding the horizontal well trajectory design. Through the post-test well test of uniform distribution in the whole area, the recognition rate of the channel sand body above 2m is more than 80%, showing a good application prospect of waveform indicator inversion.

1. Introduction
Three major faults were developed in the study area. With large fault extension distance and bigger slip, to avoid fault purpose layer of edge off loss, few development wells were drilled in large faults within the scope of 50 ~ 100 m distance of edge. At the edge of the fault, the distribution wells are mainly oil wells, relatively few injection wells. Therefore, the residual oil accumulation area is formed in the side of the fault because the density of the well net is relatively low and the injection-production relationship is not perfect. It is difficult to excavate the remaining oil effectively by means of horizontal wells. For this purpose, the design of horizontal Wells is carried out to dig the residual oil at the edge of the fault to the maximum extent. The key to the design of horizontal wells is to optimize the trajectory design and find the correct sand layer. Only relying on a well point information to predict reservoir is quite uncertain. With the advantages of rich horizontal information, three dimension development seismic data can provide effective information between wells. Seismic inversion technique is one of the important application of seismic reservoir prediction method. In this paper, the seismic waveform indicator inversion method is used to predict the reservoir, which provides a reliable geological basis for horizontal well trajectory design.

2. Principle of seismic waveform indicator inversion method
The characteristic indicator inversion of seismic waveform is a kind of inversion method to represent the spatial structure variability by replacing the variable difference function with the horizontal variation information of seismic waveform. According to the integrated the similarity and the space distance, the statistical samples were determined. Under the bayesian framework, Markov Chain-Monte Carlo simulation has been done between the logging curve cycle structure characteristics and
the seismic impedance as the conditional distribution probability. This method realizes the high resolution reservoir characterization technology of well seismic combination, and changes the spatial geostatistical method based on variation function of traditional statistics. Using the structured inversion algorithm driven by seismic waveform, the idea of phased inversion is realized, and the certainty of high frequency components is improved. Because the seismic waveform contains the sedimentary cycle information of the strata, the lateral variation is related to the sedimentary environment. That is, under similar sedimentary environment, it has similar characteristics of curve cycle. Similar composite structures produce similar seismic waveforms. The horizontal variation of seismic waveform can indicate the classification of reservoir structure (Figure 1).

Seismic waveform indicator inversion is a structural inversion, and the main difference from geostatistical inversion is the simulation of high-frequency components. It simulates the high frequency components of the initial model under the bayesian framework. The simulation results accord with the characteristics of seismic medium frequency impedance and well curve structure. The waveform indicates that the low frequencies come from wells, the medium frequencies come from earthquakes, and the high frequencies are divided into two parts. One part is completely random in high frequency above 600hz, and this part conducts random simulation through well statistics. The other part is less than 600hz and above the seismic band. This part can be evaluated using the method of waveform indicates a phased relative deterministic inversion. This paragraph is not completely random, is not entirely sure. We call this a step by step from completely random to determine a spectrum.

3. Inversion method optimization
Geostatistical inversion requires a high number of wells and well distribution, so the reservoir prediction is carried out by the optimal waveform indication inversion instead of geostatistical inversion aiming at the uncontrollable remaining oil in the pattern of wells in the fault zone of 1#. There are two specific reasons. One reason is, according to the requirement of the difference in geostatistics reverse evolution function, the spatial variation of uniform distribution of sample points can calculate the variation degrees of sample space. Thus, in the study area, under the condition of uneven well distribution, a suitable variations can't be calculated. The other reason is that the horizontal well design aims at a single sand layer and requires high transverse resolution. The minimum spacing of wells in the study area is 50 meters and the sampling point of earthquakes is 10 meters. The geological statistical inversion completely depends on well information and the horizontal resolution of the simulation results based on well information is low. Therefore, the seismic waveform horizontal variation information is selected to characterize the reservoir spatial variation structure and
improve the lateral resolution of the reservoir, which is suitable for the design requirements of the horizontal well.

4. Precise structural study
The design of horizontal wells has high requirements on the structure, and the structure cannot be layered. To ensure a high quality of structural surface in the inversion, there are two key points. Firstly, there should be high quality well shock calibration. Secondly, during synthetic record production process, the method of the overall passenger coefficient was adopted. It avoided the local tensile caused incorrect speed(Figure 2). A total of 112 Wells were built in the project area and the synthetic records of 103 Wells were made. The correlation coefficients of the synthetic records were all over 76. Secondly, the level accuracy is improved by constructing the trend correction layer(Figure 3). Particular way is as follows. First, the horizon of time information is read in the high quality synthetic records and is imported into petrol modeling software. Second, trend surface correction is done through the structural surface inoue and imported into the I - GeoSeis software to carry on the horizon of interpolation. Next, import the horizon into SMI inversion software and construct the model. Finally, the inversion is carried on.

5. Waveform indication inversion

5.1. Multiwell consistency processing
Due to the long time span of logging curves and the variety of instruments used, there will be some systematic error and random error between multiple wells. In order to make all the logging data of the study zone have a unified scale and the same logging response characteristics, the standard layers and wells need to be selected from the study zones and the logging data need to do quality and standardization control. The stable mudstone layer is usually selected as the standard layer. The standard wells have a complete series of well logging curves, complete horizon development, no hole diameter collapse, no fault loss and the same time as seismic data collection. The method is to compare the histograms of the acoustic time in the standard wells with that of other wells in the work area and correct them until they coincide.

5.2. Analysis of reservoir sensitive logging parameters
By analyzing the different logging characteristics of the sand mudstone in the study area, the wave impedance, density, natural potential and deep lateral resistivity are optimized for sensitive parameter analysis. The so-called reservoir sensitive parameters of the past inversion software's analysis is to
make feasible analysis if longitudinal wave impedance can predict the reservoir. Though the density and natural potential can distinguish the lithology well, post-stack wave impedance inversion can not get. The software used in this inversion is the characteristic indicator inversion software of SMI seismic waveform, which can not only invert the wave impedance, but also simulate the reservoir sensitivity curves such as density and natural potential.

5.3. Inversion parameter setting
"Effective sample number" is one of the most important parameters in seismic waveform indicator inversion. The setting of this parameter is mainly based on the statistical results of known wells. In the "quality control" menu of "sample" and "relevance" earthquake statistics analysis, correlation increases gradually with the increase of the number of samples. To a certain degree, the correlation is not increases with the increase of the number of samples, showing more samples can't improve prediction accuracy. The sample number of maximum correlation shows that the reservoir changes little and heterogeneity is weak. In the fast lateral change and strong heterogeneity areas, the sample number can be appropriately reduced.

Seismic waveform indicator inversion is a statistical inversion method and its inversion results have the characteristics of "low frequency real, high frequency random". The low frequency is mainly affected by seismic frequency band and seismic facies while the high frequency is mainly controlled by samples of the same sedimentary structure. Therefore, it is of great importance to set the optimal cut-off frequency for the inversion results. This parameter is related to the parameter of "effective sample number" and the parameter of "optimal cut-off frequency" should be determined after the effective sample number is determined. If it is more inclined to the certainty of inversion, this parameter should not be set too high. On the contrary, if it is more inclined to the resolution of inversion, it can accept random results and set a higher cut-off frequency.

5.4. Output of inversion results and accuracy Analysis
In fine geologic framework model, input 3d seismic volume, extract average wavelet and logging curves of standardized processing. According to waveform similarity, statistical relationship can be established to describe the data relationship of the spatial data. Furtherly, get the sand body prediction results indicated by seismic waveform inversion (Figure 4). The results have higher vertical resolution ability. The horizontal distribution of the sand body is natural and basically consistent with the seismic waveform characteristics. The prediction results are in good agreement with the posterior well interpretation results.

6. Inversion results guide horizontal well trajectory design
In the accurate interpretation and seismic inversion sand body prediction research, on the basis of optimization design, well trajectory parameters inversion results show that the PII6 develops good
sandstone. Therefore, PI16 layer was set as the goal layer of horizontal wells, extending from southeast to northwest. Its horizontal design length is 389m.

7. Conclusion

(1) It is necessary to control the quality of logging curve standardization, well seismic calibration and inversion parameters. Optimize inversion parameters and improve reservoir prediction accuracy.

(2) The deployment of horizontal wells at the edge of the fault requires the effective processing and fine interpretation of the seismic data of the target layer, accurately describing the formation structure and providing accurate geological structure information for the drilling trajectory design of the horizontal wells.

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