Application of frequency extension processing technology in logging constrained inversion

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Abstract. The resolution of seismic data affects the accuracy of sand body identification. Generally, the higher the resolution of seismic data, the higher the accuracy of sand body identification. Aiming at the problem of low seismic resolution in block X, this paper attempts to increase the effective signal bandwidth of the original seismic data by using the frequency extension method, maximize the resolution on the premise of ensuring that the seismic data are not distorted, and then use the waveform indication inversion technology to predict the reservoir after the frequency extension. Compared with the drilled wells, it is found that the combination of frequency extension and waveform indication inversion can not only improve the vertical resolution of seismic data, but also maintain the lateral continuity of seismic data, which conforms to the distribution characteristics of sand body and has higher prediction accuracy. The method of frequency extension + waveform indication inversion has a good application prospect, which provides a new idea for the next step of sand body characterization and well location deployment.

1. Introduction

In recent years, with the deepening of oil and gas exploration, a lot of simple structural reservoirs have been identified, more lithologic reservoirs need to be found, and the insufficient resolution of seismic data has brought great difficulties to the prediction of thin sandstone. Frequency extension technology has been applied in many oilfields in China. Wangjiang (2020) applied HFE frequency extension technology in Wuerxun fault depression, and identified 9 sets of favorable sand bodies, of which 6 sets obtained industrial oil flow; Zhou Jiannan et al. (2020) applied anti-Q filter frequency extension technology to well Haihai a, and drilled 1 m gas layer and 6.6 m oil layer at 1192m of the well; Yang Zipeng et al. (2019) applied the frequency extension technology based on compressed sensing theory to igneous fault interpretation, and the low order faults were clearly displayed after frequency extension; Cheng Liang et al. (2017) applied the frequency extension technology based on the step iteration method to Shengli Oilfield, and obtained a clearer well seismic combination relationship. It can be seen that the principle and method of frequency extension technology appear constantly, which has higher accuracy for identifying thin sand body.
Inversion, as the most widely used method for sand reservoir prediction, has the characteristics of high vertical accuracy and good lateral extension. At present, the commonly used inversion methods include sparse pulse inversion, waveform indication inversion, AVF frequency division multi-attribute inversion, BP neural network inversion and so on. Each inversion method has its own characteristics. Fully considering the characteristics of seismic waveform, it has advantages in continental petroleum exploration. This paper attempts to combine the frequency extension processing technology with waveform indication inversion technology. On the basis of improving the seismic resolution, we use waveform indication inversion technology to depict the thin sand body, and finally complete the sand body prediction, so as to provide guidance for the next reservoir desserts.

2. Frequency extension processing
Resolution is always the key to obtain high quality data in seismic data processing. The low frequency usually reacts the thick sand body, and the high frequency usually reflects the thin sand body. To describe the thin sand body in detail, it is necessary to improve the high frequency component of the earthquake. The extension processing is to project the signal of the low frequency section of the earthquake to a higher and wider frequency band. In other words, the channel data formed by the low-frequency wavelet is converted into the channel data formed by the high-frequency wavelet, and the seismic frequency increases after the conversion. The easier it is to describe thin sand bodies. Through spectrum analysis of seismic data in the study block, it is found that the primary frequency of the original earthquake is about 25Hz, and the acoustic wave propagation speed of the target section is about 3500m/s, and the theoretical resolution of reservoir inversion is $1/4 \lambda$, The thickness of the identified sand body is about 33m, but the majority of the sand body thickness in the study area is less than 30m, so it is impossible to describe the sand body simply by relying on the original earthquake. The frequency range of the target layer can be widened from 10-45Hz to 10-130Hz in the seismic data, which improves the resolution of the seismic data of the target layer obviously and achieves the expected effect. At the same time, the signal-to-noise ratio of the original data is basically maintained. After the frequency extension, not only the geological structure of the section remains unchanged, the wave group characteristics are still well maintained, but also the details between layers are more abundant, the breakpoints of each interface and fault become clear, which improves the accuracy of structural interpretation. By comparing the seismic profile before and after the frequency raising of well a (Fig. 1), it can be seen that: N1hl1-B and N1hl1_ C, there are four sets of sand bodies in the well between two small layers C. only one set can be described for the original earthquake, and 4 sets can be described after the frequency extension. The resolution after the extension is greatly improved.
According to the profile of well A-B (Fig. 2), it can be seen that N1hl1-B, N1hl1_ C, there are 4 sets of sandbodies developed in well a and 2 sets of sandbodies developed in well B between the two sublayers C, which indicates that there are sandbodies annihilation between the two wells. The original seismic body is a strong amplitude and can not describe the sandbodies. After frequency extension, it can be seen that there are 3 sets of strong amplitude peaks and 1 set of weak amplitude troughs in well a, and there are 2 sets of strong amplitude peaks in well B, which are consistent with the well. At the same time, the sand body annihilation can be seen in the frequency increasing section.
3. Waveform indication inversion

3.1. Basic principle
On the basis of fine interpretation of seismic structure, waveform indication inversion uses 3D seismic data and logging data to make fine reservoir prediction, organically integrates high-frequency logging data with low-frequency seismic data, and takes drilled wells as samples to identify fine sand bodies in undrilled blocks, so as to finally complete the sand body prediction of the whole area. This method is a kind of phase controlled prediction, which is a combination optimization process of reflection coefficient based on seismic waveform. Different from the variogram such as sparse pulse inversion, waveform indication inversion can keep the seismic medium frequency to determine the component, and use the high frequency component of logging, which has higher inversion accuracy.

3.2. Inversion idea
The basis of waveform indication inversion is fine structure interpretation and logging curve processing. Only accurate horizon and fault interpretation and accurate logging curve processing can ensure the correctness of inversion. The specific process is as follows: (1) logging curve processing, mainly including AC, den and target sensitive curve (such as SP, RT) normalization and standardization processing.(2) The calibration of high-precision synthetic record is completed, and the wave group relationship of the target section is adjusted to make the wave group corresponding accurately.(3) Waveform indication inversion method and Parameter Optimization: by selecting any line profile, 2D profile inversion is carried out for its common methods (such as waveform indication simulation, waveform indication inversion, target probability inversion and spectrum simulation), as well as sample number and high and low frequency settings, and the most appropriate method and inversion parameters are optimized by comparing with the drilled sand body.(4) The optimized parameters are applied to the whole work area to complete inversion. Figure 3 shows the calibration diagram of synthetic records before and after frequency extension. Through comparison, it can be found that the corresponding relationship of seismic wave group after frequency extension is clearer.

Figure 3. Synthesis record mark before and after frequency extension
3.3. Inversion effect

By analyzing the inversion profile before and after frequency extension, we can see that the inversion effect after frequency extension is significantly higher than that of the original seismic inversion, the lithology information is more abundant, the vertical resolution of the stratum is improved, and the horizontal lithology distribution is more clear. The original seismic body inversion can only get one set of sand body, but after increasing the frequency, three sets of sand bodies can be obtained, 22m, 13m and 27m, which are consistent with the three sets of sand bodies on the well.

![Inversion profile](image)

**Figure 4.** Inversion profile. (left, before extension frequency; right, after frequency extension)

4. Conclusion

Frequency extension processing is to transform seismic trace data formed by low frequency wavelet into seismic trace data formed by high frequency wavelet. The higher the seismic frequency is, the easier it is to depict thin sand body. Waveform indication inversion is a kind of phase controlled inversion technology, which fully considers the characteristics of seismic waveform and replaces the variation function of traditional inversion, so it has higher inversion accuracy. The combination of frequency extension technology and waveform indication inversion technology can achieve fine description of thin sand body, which has a good application prospect and provides a new idea for the next oil and gas exploration.

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