# Application of Seismic Waveform Difference Inversion and Characteristic Parameter Simulation in Shale Gas Dessert Identification

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**Abstract.** The marine shale gas work of the Lower Silurian Longmaxi Formation in the Sichuan Basin has entered the stage of large-scale benefit development from the initial resource survey and layer selection stage, and carried out small-scale shale formation division, fine contrast of shale reservoirs and shale. Fine prediction of reservoirs is an urgent need for shale gas exploration-development integration. In this paper, a new method of seismic waveform difference inversion and characteristic parameter simulation is used to realize the well-seismic cooperative high-frequency simulation, to solve the current thin reservoir prediction problem of shale gas exploration, and to accurately predict the 1 small layer of "Dessert of $S_1L_1^1 1+2$" Thickness (6–20 m) and characteristic parameters; this method makes full use of the lateral change information of seismic waveforms, better reflecting the influence of sedimentary environment on the reservoir. The practical application shows that the vertical and horizontal resolutions of the method are improved at the same time, and the inversion results are deterministic, which reflects the phase control idea, solves the problem of the current shale gas thin layer dessert identification, improves the drilling success rate and reduces the exploration and development cost; The method is applicable to three-dimensional work areas with few wells and non-uniform distribution, and most of the current shale gas three-dimensional work areas fall into this category.


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## 1 Preface

China's shale gas has gradually embarked on the road of industrialization and commercialization from the initial evaluation of the selected area to the large-scale benefit development. The shale gas of the Lower Silurian Longmaxi Formation in the Sichuan Basin is currently the development of shale gas in China. The main producing layers, exploration and development face the problems of complex mountain surface, complex underground structure, complex shale structure, large shale depth, thin reservoir and lateral heterogeneity. At present, the "dessert" area of shale gas exploration in China is mainly a small layer of the Long$_1^1$1 + 2 section of the Longmaxi Formation with a thickness of only 3–10 m. The $S_1L_1^1 1 + 2$ section is near the bottom of the Longmaxi Formation and is currently the shale of the Sichuan Basin. The main "dessert" layer of gas. The study area is a shale gas block in the early stage of development. The wells are very few (1–3 wells) and the lateral distribution is sparse. The model inversion of interwell interpolation is unreasonable. The traditional deterministic inversion resolution is low and random inversion. The sample is insufficient; the TOC of the shale gas characteristic parameter in the region has no good correlation with the geophysical parameters, and the TOC prediction in this region cannot be realized by the traditional method. Practice shows that relying on seismic tectonics can not meet the requirements of thin-layer prediction, and it is necessary to solve the thin layer problem of shale gas "dessert" through joint inversion of well-seismic; all high-resolution inversion methods are realized by "seismic + well". That is to say, high-frequency information can only be supplemented by wells; the problem is that the horizontal distribution of wells is sparse, and inter-well interpolation is obviously unreasonable. The key is how to reasonably predict the distribution of wells between wells. In this paper, a new method of seismic waveform difference inversion and characteristic parameter simulation is used to realize the well-seismic cooperative high-frequency simulation. While improving the reservoir vertical resolution, the lateral recognition capability is effectively improved, and the current shale gas exploration is solved. Thin layer problem, accurately predicting the "dessert" thickness and characteristic parameters toc.

## 2 Seismic Waveform Difference Inversion and Principle of Characteristic Parameter Simulation

The traditional inversion based on deconvolution theory such as sparse pulse is limited by seismic resolution and band-limited wavelet, and cannot be applied to thin-layer prediction. Neural network, genetic algorithm, ant colony algorithm and other inversion methods based on nonlinear inversion theory and feature analysis are inconsistent with the reality due to the lack of reliable well-seismic relationship and geological laws.

In recent years, the inversion of geostatistical stochastic simulation inquiries such as cokriging, sequential Gaussian and simulated annealing is based on the spatial distribution characteristics of reservoir parameters, and the logging data is interpolated under the constraints of seismic trend to obtain a group. An equal probability reservoir parameter model. Although this method can break through the seismic resolution limit and realize the stochastic simulation of thin reservoirs, its dependence on the prior model is more serious. The deterministic function is more determined by human factors, and the results of various equal probability distributions are poorly guided by production.

For the shale gas block in the early stage of development, there are often only 1–3 wells. If traditional deterministic inversion and statistical inversion are applied, it is obvious that the sample is insufficient, similar to the seismic waveform indication inversion, but different. Seismic waveform difference inversion and characteristic parameter simulation are suitable for reservoir prediction and parameter simulation in areas with less than 3 wells.

Seismic Modeling Inversion (SMI) is a new high-precision inversion method for reservoir well network conditions. The basic principle is to use the thin layer tuning characteristics of seismic waveforms as discrimination. Optimize the control conditions of the reflection coefficient structure, simulate the longitudinal distribution of the sand body, and truly combine the horizontal high resolution of the earthquake with the longitudinal high resolution of the well to realize the joint inversion of the well. The forward modeling practice based on convolution theory shows that the tuning characteristics of seismic waves are closely related to the structure and distribution of reflection coefficients. The vertical distribution of reflection coefficients, including the spacing, size and number of reflection coefficients, determine the tuning characteristics of seismic waveforms. Therefore, it can be considered that under substantially similar geological conditions, the reflected wave tuning waveform and the reflection coefficient structure can form a good matching relationship, so the vertical distribution of the reflection coefficient can be optimized according to the tuning characteristics of the waveform, which is the theory of SMI inversion basis.

The seismic waveform difference simulation is based on the assumption that the wavelet is invariant, and the seismic impedance difference is closely related to the change of the well impedance structure, that is, the seismic impedance changes with the well impedance. The four attributes of center of gravity, mean, variance and variance are used as the eigenvectors to describe the difference of seismic impedance. Then, the vertical variation function of the above variables and well impedance has been used to calculate the vertical impedance change of the well impedance to the seismic impedance difference. Contribution amount. Finally, the eigenvectors of the predicted seismic impedance are statistically predicted, and the above-mentioned differential function is used to simulate and predict the well impedance (Fig. 1).

Seismic waveform difference simulation inversion is mainly completed by data import, horizon calibration, wavelet extraction, model construction, inversion parameter selection (inversion parameter QC) and inversion in 6 steps.

In the Shaojing area, the traditional deterministic inversion resolution is low and the statistical inversion sample is insufficient. The eigenvector variogram model is established by using the relationship between the lateral variation of the waveform and the well impedance, and the well seismic high frequency is realized. Simulation; the "reservoir parameter simulation" function in the SMI software incorporates a waveform feature indication algorithm, which is more consistent with the deposition characteristics than the traditional simulation method, and can obtain the best simulation results.

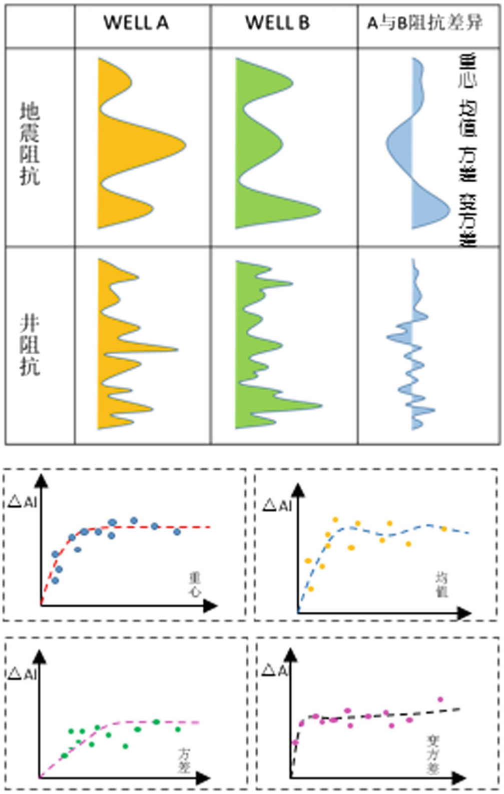


**Fig. 1.** Principle of seismic waveform difference simulation

# 3 Application

## 3.1 Regional Overview

The Sichuan Basin is located on the northwest side of the Yangtze quasi-station. It is a sub-tectonic unit of the Yangtze quasi-station. It has the rudimentary shape of the basin during the Indosinian period, and then forms the current tectonic features through the comprehensive fold of the Xishan movement. The geotectonic division includes the high-steep tectonic zone of the middle reaches of the southeastern Sichuan Basin, the low-lying tectonic zone of the Guzhong depression in the north of Sichuan, the gentle and tectonic zone of the Chuanzhong Gulong and the low-steep tectonic zone of the Zhongxin depression in western Sichuan. The three-dimensional area of S zone in

Sichuan Basin is the research area of this area. It is located in the high-steep tectonic area of the middle reaches of the southeastern Sichuan Basin, with complex structure and fault development. Only two shale gas wells were drilled in the study area.

## 3.2 Analysis of High-Quality Shale Logging Response Characteristics

Analysis of geophysical rock sensitivity parameters of high-quality shale in the study area. It can be seen from Fig. 2 that the Longmaxi Formation high-quality shale (I-type reservoir) and non-quality shale have higher density, gamma, longitudinal wave impedance and longitudinal wave velocity. Large overlapping areas make it difficult to identify high quality shale. Note: The high-quality shale defined in this paper is only the type I reservoir, $S_1L_1^1 1 + 2$, which is the main shale gas "dessert" area.

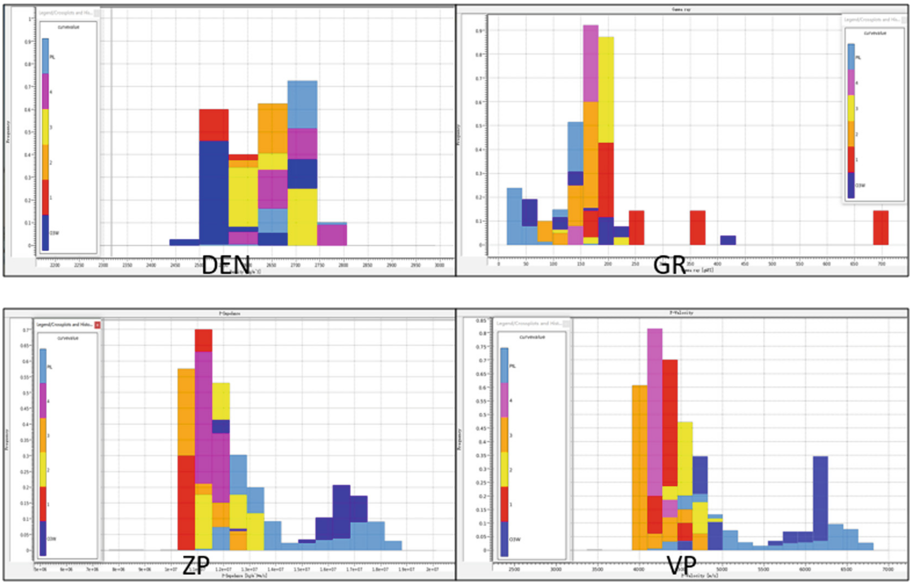


**Fig. 2.** Sensitive parameter histogram

It can be seen from Fig. 3 that the Longmaxi Formation high-quality shale and non-premium shale have large overlap areas in shear wave velocity, shear wave impedance and longitudinal-to-transverse wave velocity ratio, and it is difficult to identify high-quality shale.

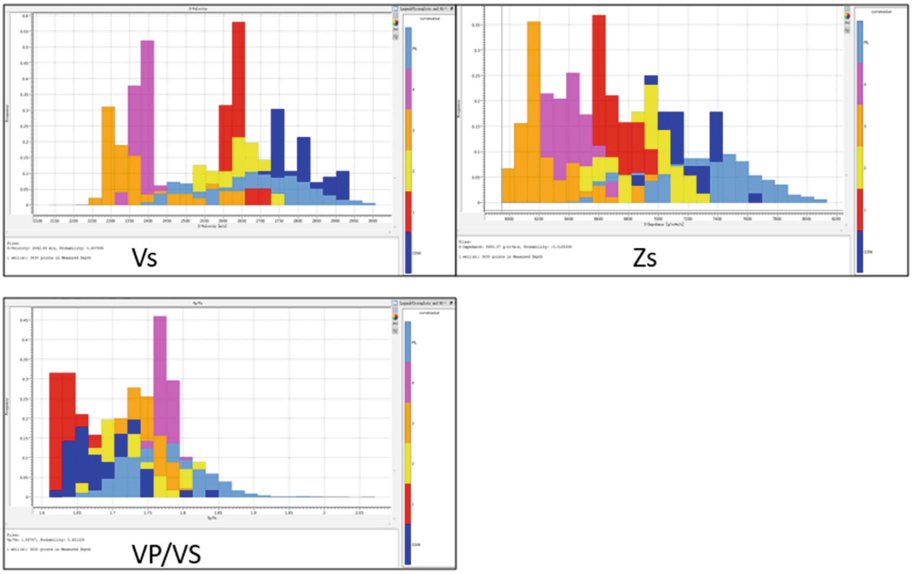


**Fig. 3.** Sensitive parameter histogram

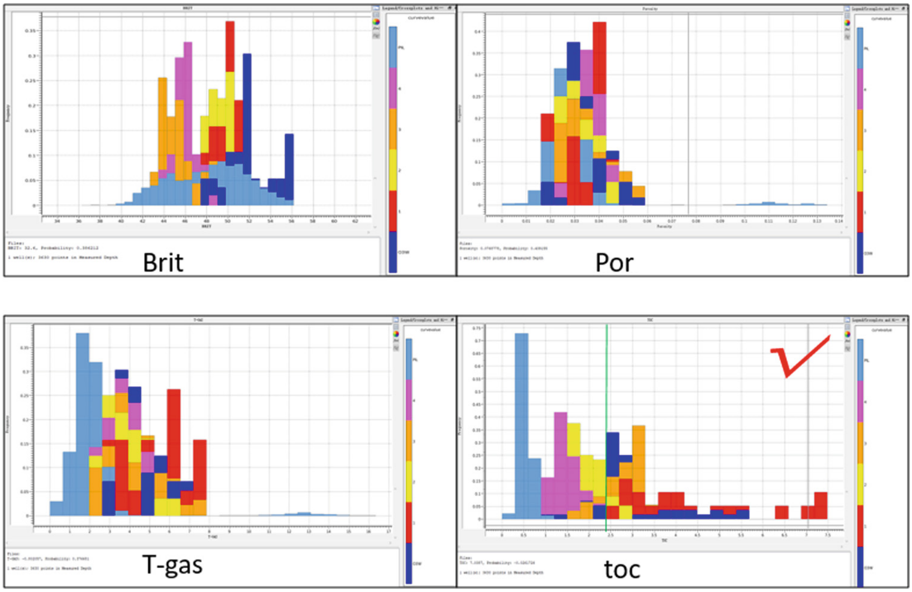


**Fig. 4.** Sensitive parameter histogram

It can be seen from Fig. 4 that the Longmaxi Formation high-quality shale and non-premium shale have large overlap areas in brittleness index, porosity and total gas content, but the total organic carbon can distinguish high-quality shale.

After analyzing the data in the area, the correlation between the total organic carbon and the elastic impedance parameters is relatively poor (Fig. 5), and the accuracy of the total organic carbon content by the traditional intersection method will be lower. In order to obtain a more accurate total organic carbon content, we have explored some new methods: using seismic waveform difference simulation and characteristic parameter simulation to calculate the total organic carbon content.

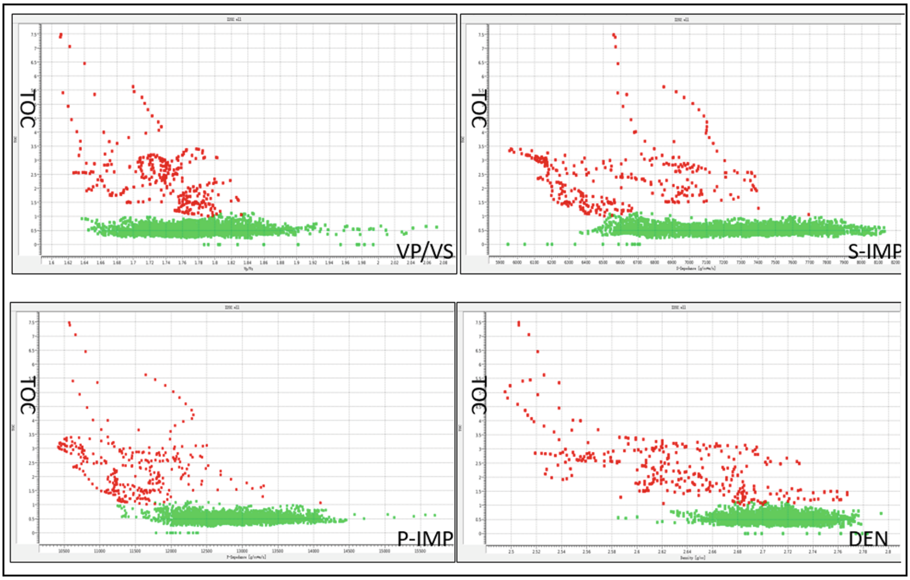


**Fig. 5.** Total organic carbon and elastic impedance parameter intersection diagram

## 3.3 Analysis of Seismic Waveform Difference Inversion and Characteristic Parameters Simulation

Figure 6 shows the total organic carbon content prediction profile of WELLA and WELLB. It can be seen that the inversion result of the well sideway on the predicted section has a high degree of coincidence with the well logging curve and the characteristics are basically the same. The total organic carbon content of the Longmaxi

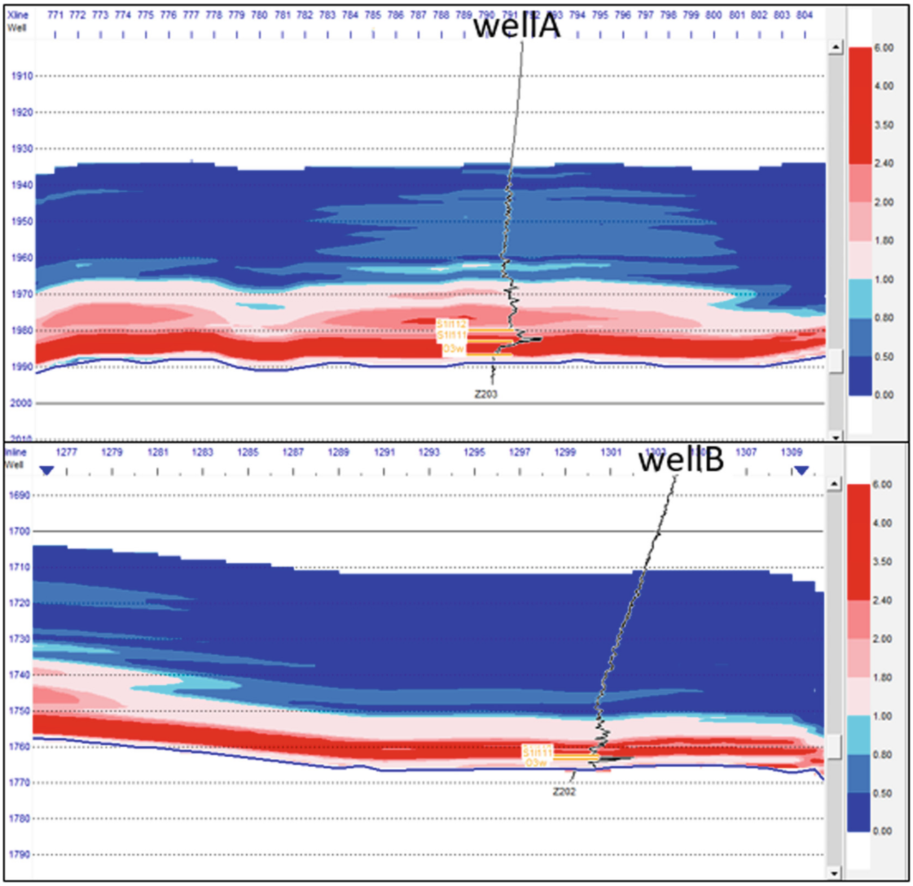


**Fig. 6.** WELLA and WELLB total organic carbon content prediction prfile

Formation high quality shale section is relatively high, and the lateral variation trend is reasonable. The method of seismic waveform difference inversion and characteristic parameter simulation is used to obtain the trend of total organic carbon which is consistent with the logging data and is consistent with the sedimentary environment.

According to the total organic carbon content prediction data volume, calculate the time cumulative thickness of the sampling point with the total organic carbon greater than or equal to 2.4 in the upper 30 MS, and multiply the corresponding point velocity to compile Longmaxi Formation Longyi 1-Upper Austrian high quality shale thickness plane distribution map (Fig. 7).

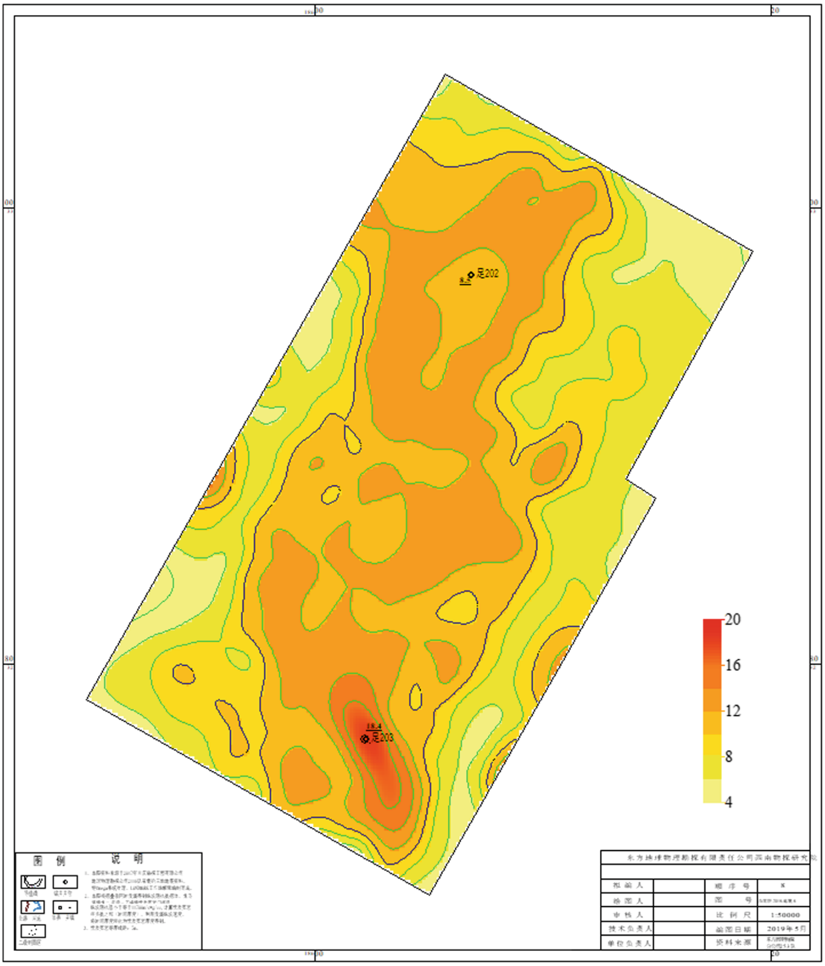


**Fig. 7.** High quality shale thickness map of Longmaxi Formation

## 4 Conclusion

(1) Using seismic waveform difference inversion and positive parameter inversion to overcome the influence of uneven well distribution and uneven distribution in the initial stage of shale gas block development, and effectively improve the resolution of inversion results.

(2) The inversion results show that the seismic waveform difference inversion and characteristic parameter inversion method can predict the total organic carbon content and accurately describe the total organic carbon and elastic parameters in this area. The thickness of the high quality shale section.

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