

Thin reservoir prediction technology with sensitive parameters of tight gas in southwest Ordos Basin

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Abstract. In the southwest of Ordos Basin, the loess layer is very thick, the surface elevation changes rapidly, and the near-surface low-velocity zone velocity changes greatly in vertical and horizontal directions, resulting in prominent static correction problems. Affected by the strong absorption of the loess layer, the effective frequency band of the original data is narrow, the apparent main frequency is low, and the "double high" processing is difficult. The reservoirs of He-8 and Shan-1 are deep-buried, thin and dense, and their lateral changes are fast. In this paper, the sensitive data of "two widths and one height" 3D seismic is optimized to obtain high-quality sensitive data. The sensitive orientation is optimized by combining drilling data, and the sensitive parameter based on pre-stack inversion technology is adopted to improve the prediction accuracy of thin reservoirs. The new Chengtan-3-Long19 He-8 sand belt was discovered, the well location deployment plan was optimized, the efficient drilling of horizontal Wells was supported and the fracturing plan was optimized. 26 well locations were deployed using 3D seismic, 11 were completed drilling, and 9 were class I + II, an increase of 30% compared with 2D seismic.

Keywords: Southwest Ordos Basin; "Two widths and one height" three-dimension seismic; Sensitive data optimization processing; Pre-stack inversion technique with sensitive parameters

1. Introduction

The southwestern Ordos Basin, with an exploration area of $2.7 \times 10^4 \text{ km}^2$, is a typical loess mountain landform with large relative elevation difference and rapid changes in the thickness and velocity of low-deceleration beds. Since 2010, through comprehensive seismic and geological research, the oil field has increased the deployment of exploration well locations, and Qingtan and Chengtan Wells have successively obtained industrial gas flow in Shan-1 and He-8 members, and significant progress has been made in exploration. In 2018, Qingyang gas field was discovered and proved reserves of more than 30 billion square meters were submitted, which kicked off the large-scale exploration and development of natural gas in Longdong area.

Changqing Oil field is planned to produce more than 50 billion cubic meters of natural gas in 2025, and the southwest of the basin is the key block of Changqing oil field to increase storage and production, and the natural gas production in Longdong area will reach 1.5 billion cubic meters/year in 2025. At present, Qingyang Gas field has three main sets of reservoirs: Development He-8, Shan-1 and bauxite. The proved reserves submitted in 2018 have a high degree of utilization. Therefore, it is urgent to carry out comprehensive research combined with three-dimension seismic, screen gas-rich areas, and cooperate with oil field companies to submit proved reserves, so as to provide reliable basis for the next well location deployment and production capacity construction, and help the oil field company to achieve a smooth realization of 52.65 billion cubic meters of natural gas production in 2025.

At present, the problems of exploration and development in the southwest basin are as follows: (1) The near-surface conditions are complicated, the elevation changes greatly (1000-1600m). The thickness of the low deceleration rate changes sharply (0-300m) in vertical and horizontal directions, the original data noise interference is serious, the initial identification is difficult, the signal-to-noise ratio is low, and the static correction problems are prominent; (2) Due to the strong absorption of

loess layer, the effective frequency band of the original data is narrow, the apparent main frequency is low, and the "double high" processing is difficult; (3) The reservoirs of He-8 and Shan-1 are deeply buried, thin and dense, and their lateral changes are fast; (4) The local structure changes greatly, so the implementation of horizontal Wells is difficult.

With the implementation of the "two widths and one height" three-dimensional seismic in the southwest of the basin in 2019, multi-dimension seismic information from multiple directions and angles is used to play the role of multi-dimension data in reservoir prediction, and it is urgent to improve the accuracy of reservoir prediction. In order to improve the identification ability of the Upper Paleozoic He-8 and Shan-1 thin reservoirs in the southwest of the basin, and based on the targeted processing of "two widths and one height" 3D seismic data, this paper first introduces the optimization of sensitive orientation and sensitive incidence Angle, and uses the sensitive data for pre-stack inversion, and finally predicts the distribution of thin reservoir sand bodies by attribute fusion technology.

2. Sensitive data optimization

"Two widths and one height" [1-4] technology refers to the use of wide-band source excitation, wide-azimuth observation arrangement and high-density spatial sampling in field acquisition, and the adoption of appropriate methods and technologies in data processing and interpretation to obtain more reliable information to serve the characterization and description of complex structures and reservoirs.

2.1 Static correction technology of high-precision tomography modeling in complex loess mountain

In the southwest of Ordos Basin, the loess layer is very thick, the surface elevation changes rapidly, and the near-surface low-slowing layer velocity changes greatly in vertical and horizontal directions. How to invert the near-surface velocity model with high accuracy is the key to solve the basic static correction in this area, and also the key to improve the depth modeling accuracy of the complex loess tableland.

(1) Aiming at the problems of insufficient ray density and low velocity model accuracy caused by the uneven distribution of shot detection points caused by the very thick yellow soil layer and its thickness change, and at the same time, the shallow layer velocity of depth migration cannot be accurately obtained, while the cannon's initial arrival can accurately reflect the current situation of shallow layer velocity. The static correction technology of variable grid double-constrained full first approach tomography inversion is innovatively adopted to establish a high-precision velocity model, that is, the short-pass first approach is first used for large-grid inversion, and the weight constraint is applied to microlog data during the inversion process to improve the accuracy of the ultra-shallow velocity model on the basis of ensuring the shallow ray density, and then the small-grid inversion is performed using the full first approach. In the inversion process, the weight constraints of the shallow model are applied to ensure the accuracy of the inversion of the overall velocity model, and a set of high-precision inversion velocity model that takes into account both the time domain and the depth domain is finally formed (Fig. 1).

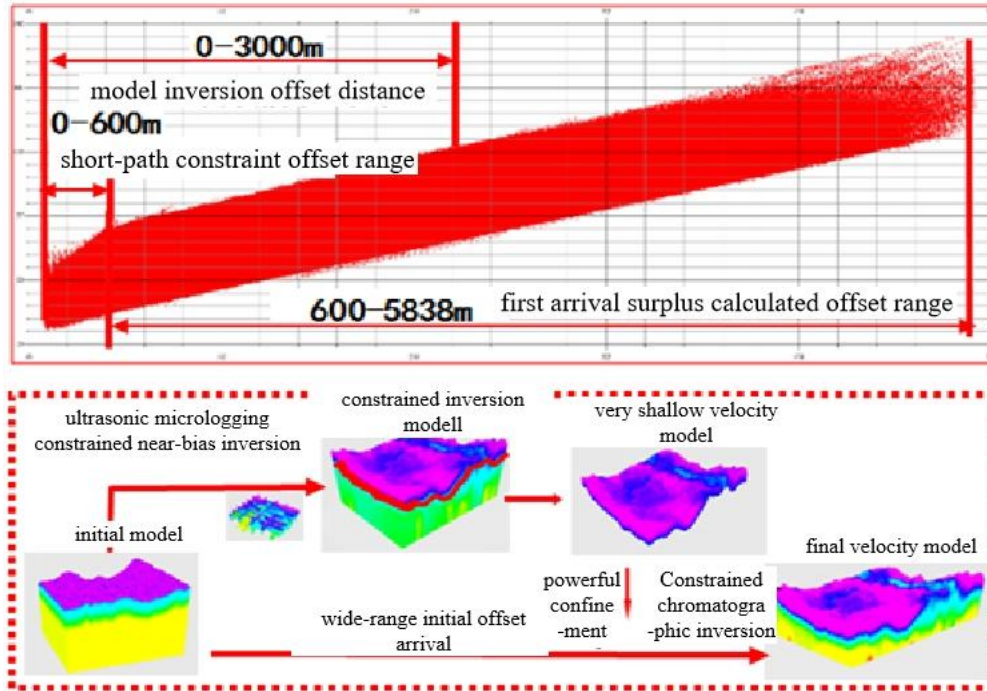


Fig.1 Flow chart of stepwise inverse chromatographic statics with double constraints

(2) To solve the problem of high frequency imaging, the research focuses on the residual static correction technology of previous initial arrival waves. For areas with low signal-to-noise ratio and poor imaging, the high-frequency disturbance method is used to normalize the high-frequency component, eliminate the outliers of the high-frequency component, and finally form a set of statics that can take into account high, medium and low frequencies to solve the basic static correction problem in the complex loess plateau. A set of statics which can take into account high, middle and low frequency is formed to solve the problem of foundation statics in the complex loess tableless area.

2.2 Fidelity compression and noise processing technology in the huge thick loess Tableland

The southwest of Ordos Basin is a typical area of low signal-to-noise ratio on the huge thick loess plateau. The seismic data are affected by surface conditions, and various kinds of regular and irregular disturbances are extremely developed, among which surface wave disturbances, scattering disturbances, near-offset strong energy disturbances, and industrial disturbances are the main ones. Meanwhile, several sets of high-wave impedance strata of coal measures are developed in the Upper Paleozoic. This results in the development of multiple waves between layers and throughout the seismic data. A lot of interference makes the quality of seismic data poor, the signal-to-noise ratio low, and the amplitude preservation processing difficult.

In view of the characteristics of the noise in the study, the "six division method" (that is, zoning, classification, step by step, domain division, frequency division, time-sharing window) is adopted to gradually fine de-noising, and the quality monitoring is strengthened in the de-noising process. Under the premise of not losing effective weak signals, the fidelity and amplitude are highlighted to improve the signal-to-noise ratio of data.

2.2.1 Adaptive surface wave attenuation

Due to the influence of surface conditions, the distribution of shot points in the study area is extremely irregular, and the denoising effect of three-dimensional cross arrangement FK domain is not ideal. Adaptive surface wave attenuation uses the time-frequency analysis method, and according to the differences between surface wave and reflected wave in frequency domain distribution characteristics, spatial distribution range, apparent velocity, energy intensity and other aspects. The apparent wave distribution range in time and space is first estimated according to the

apparent velocity of the surface wave, and then the face wave is detected and analyzed according to the inherent low-frequency characteristics of the surface wave to determine the accurate location of the surface wave distribution. Finally, the opposite wave is weighted according to the difference in frequency and energy between the reflected wave and the surface wave, and the opposite wave suppression effect of this method is very obvious (Fig. 2).

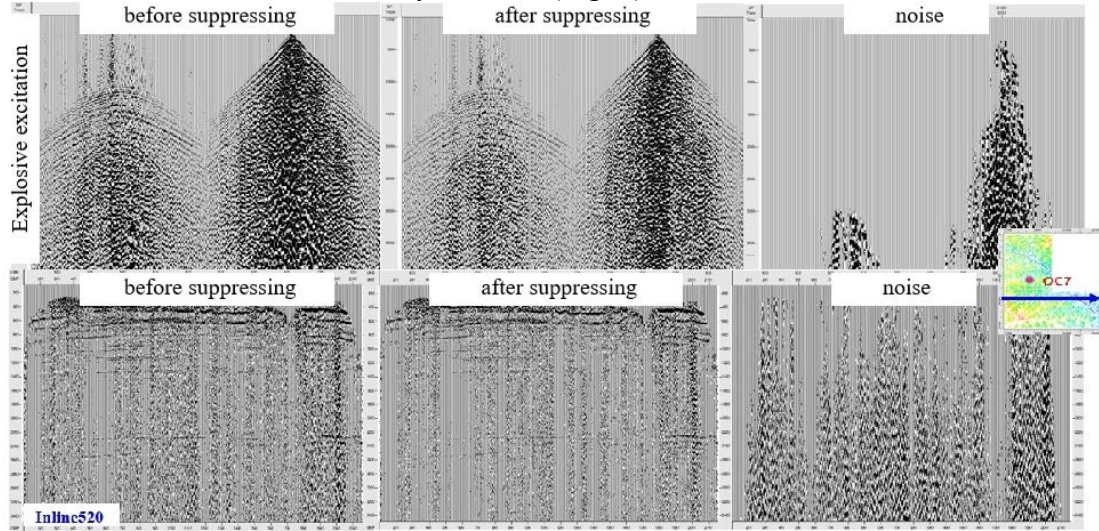


Fig.2 Single shot and section before and after adaptive surface wave pressing

2.2.2 Multi-domain frequency division abnormal amplitude suppression of strong energy interference

The technique of frequency division abnormal noise suppression is to set the corresponding threshold value in different frequency bands and different time periods, and compare the average absolute amplitude of a sample point with the calculated median amplitude and threshold value in a certain space. If the value exceeds the product of the threshold value and the median amplitude, it is considered as an outlier. The ratio of the median amplitude of each channel in the space to the abnormal amplitude is used as a multiplication operator to homogenize the abnormal amplitude to achieve the purpose of suppressing the abnormal amplitude. This technique is not only suitable for identifying abnormal channels and suppressing abnormal energy in common shot set, but also for suppressing relatively strong energy noise in CMP channel set, common receiving point set and common offset set.

The frequency division abnormal noise suppression technique is applied in the shot field to effectively suppress the abnormal amplitude and external interference (Fig. 3). However, for the near shot point strong energy, it is difficult to suppress effectively in the shot area, so the seismic trace is randomly ordered in the common offset domain, and then the frequency division abnormal noise suppression technology is applied to suppress the near shot point strong energy effectively. Regardless of the domain in which noise suppression is performed, the basic principle must be to reduce the damage to the effective signal.

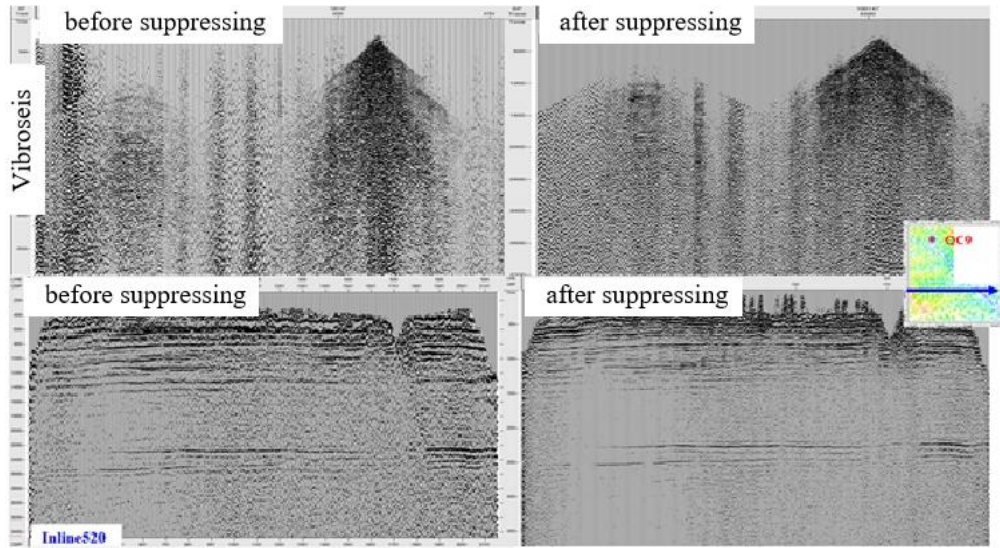


Fig.3 Single shot and profile before and after abnormal amplitude compression

2.3 OVT wide azimuth processing technology

Offset vector slice (OVT for short), also known as offset vector slice, is an extension of the cross track set and a data subset in the cross track set. In a cross arrangement, many small rectangles are divided according to the equal distance between the shot line distance and the detection line distance, then each rectangle is an OVT slice. An OVT track set is formed by extracting all the OVT slices of the corresponding position in the cross arrangement track set. Each OVT slice has a limited range of offset and azimuth, so the OVT domain can be understood as the offset domain containing the orientation. The basic steps of OVT domain processing and regular processing are the same, the main difference is that the domain is different. Conventional processing is carried out in the common offset range domain for regularization and offset processing, while OVT domain processing is carried out in the subdivided cross array domain. In addition, because OVT domain processing retains rich azimuth information, azimuth anisotropy processing can also be carried out. The processing includes four main steps: OVT partition and track set data preparation, OVT domain data regularization, OVT domain pre-stack time migration and offset track set processing. In this process, the OVT domain Kirchhoff integral method is used for pre-stack time migration, and the VSP data in the working area and the construction model is used to establish the equivalent Q field in the middle and deep layers. The Q pre-stack time migration technology is used to improve the consistency and resolution of the data. After Q migration, the resolution is improved, the inside reflection of the target layer is clearer, the inside reflection of the target layer on the isochronous slice is clearer, and the accuracy of geological phenomenon characterization is higher (Fig. 4).

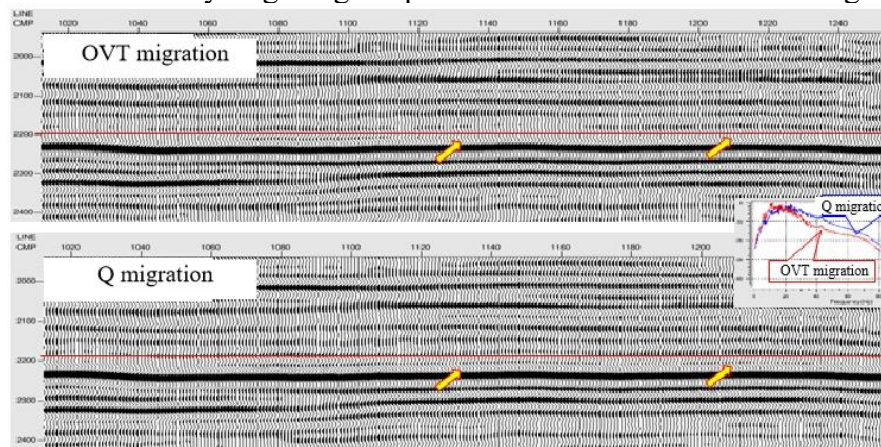


Fig.4 Comparison of the effect and spectrum of Q pre-stack time migration and OVT domain migration

3. Thin reservoir prediction technology based on sensitive parameters

Yin et al. proposed a five-dimensional seismic interpretation technique based on OVT data domain, and confirmed that azimuthal anisotropy can improve lithology interpretation and fluid identification, and then obtain reservoir fluid characteristics by constructing anisotropic fluid factors.

3.1 Sensitive orientation optimization

The lithology change is more obvious in the wide azimuth seismic data, and the special lithology body is different in the different azimuth seismic data. After targeted processing, the seismic data volumes of different azimuths are obtained. Through the matching of well vibration at different azimuths and the correlation analysis between the amplitude class attributes of the azimuthal data volumes and the sand thickness after drilling, the sensitive orientation of the sand body is selected. The vertical strike azimuth superimposed section reflects the boundary of the sand body more clearly, while the parallel strike azimuth superimposed section reflects the extension length of the sand body(Fig. 5).

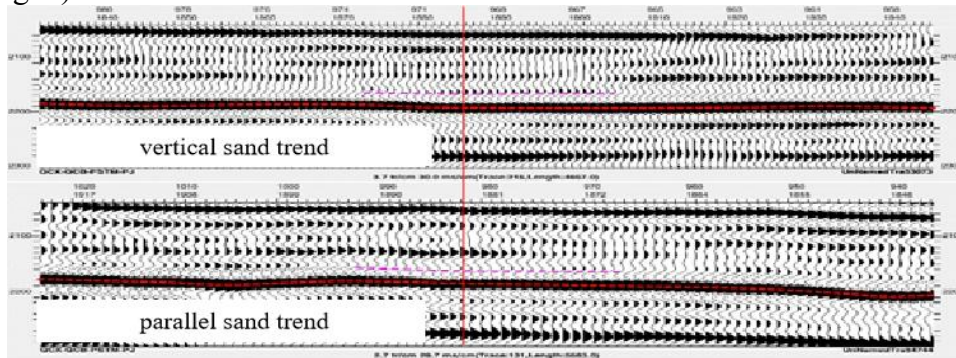


Fig.5 Seismic overlay sections in different directions

3.2 Based on sensitive data pre-stack inversion technology

In order to further improve the precision of pre-stack inversion and eliminate the influence of fractures on the precision of pre-stack inversion, seismic trace set data paralleling the direction of fractures is superimposed in three angles to highlight the use of 3D seismic azimuth information. By analyzing the sensitivity of seismic data of different orientations to sand bodies, the most sensitive azimuth data is selected for inversion to achieve fine identification of thin reservoirs. The results of pre-stack inversion of basic sensitive data are obviously better than those of pre-stack inversion with omnidirectional superposition data. The contrast profile between conventional pre-stack inversion and pre-stack inversion based on sensitive data for over-developed Wells in the three-dimension area of the southwest basin was showed in Fig. 6. The pre-stack inversion based on sensitive data can portray sand bodies more accurately and boundary changes more clearly. The new Chengtan-3-Long19 He-8 sand belt was discovered, the well location deployment plan was optimized, the efficient drilling of horizontal Wells was supported and the fracturing plan was optimized. 26 well locations were deployed using 3D seismic, 11 were completed drilling, and 9 were class I + II, an increase of 30% compared with 2D seismic.

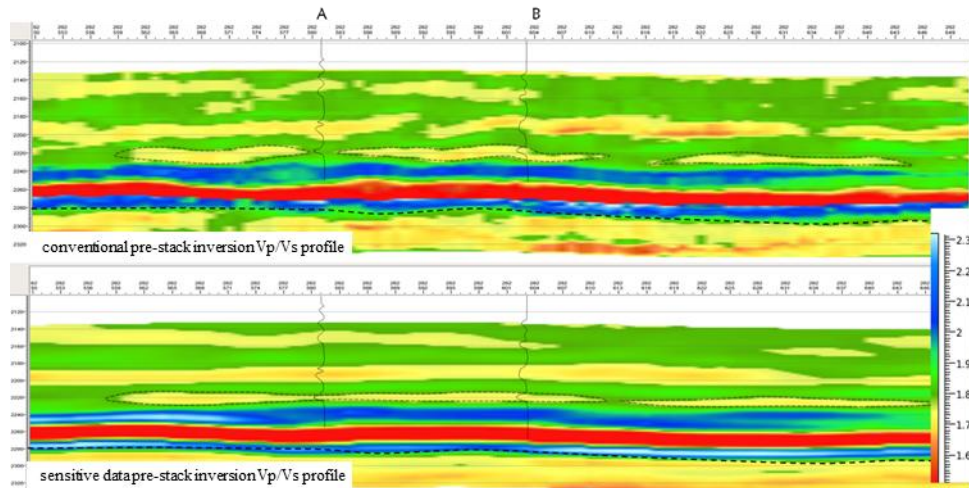


Fig.6 Comparison between prestack inversion and conventional prestack inversion based on sensitive data

4. Conclusion

The "two widths and one height" 3D seismic has the information of azimuth Angle and offset (incident Angle), and the data has better amplitude preservation. Through the division of azimuth Angle and the optimization of offset, it is more conducive to the study of reservoir prediction. The vertical sand body strike azimuth overlay section reflects the boundary of sand body more clearly, and the parallel sand body strike azimuth overlay section reflects the extension length of sand body.

Based on the pre-stack inversion with sensitive parameters, the ability of sand body identification in different orientations is fully considered. Compared with the conventional pre-stack inversion technique, the sand body boundary can be characterized more clearly and with higher precision.

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