Fine processing and interpretation technology and application of seismic data in low SNR area*

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Abstract. For a low SNR and fracture region in the piedmont zone of north Tarim Basin, fine processing and interpretation and comprehensive evaluation of geological data were carried out, giving priority to favorable areas for oil-gas exploration. Through high-precision static correction processing, pre-stack time migration, reservoir prediction, gas bearing analysis and other technical means, it had further determined the tectonic characteristics, put the trap distributions into practice, predicted the favorable reservoirs, given favorable exploration areas, and put forward recommended well locations.

1. Research status and problems
The study area is located in front of the Altun Mountains of the northwestern Qaidam Basin, a piece of three-class structure in the northern margin of the Qaidam Basin. The whole area is characterized by large-scale basin marginal palaeohigh that has been developed since Paleogene, lifted from the south to the north and divided into several steps, with many structural traps. It may form many types of oil-gas reservoirs such as tectonic-lithologic, with gas-bearing petroleum geological conditions, which is a favorable area for finding tectonic-lithologic gas reservoirs.

However, the surface of the study area is dominated by sand-shale hard-alkali shells, and the overall terrain is relatively flat, at the ground elevation around 2900-3100m. The most parts surface of the work area, dominated by sand-sludge hard-alkali crust, has local existence of wind-erosion hills. The height difference varies from a few meters to a hundred meters, which limits the combination of normal excitation and acceptance, and affects the combined suppression effect, with relatively poor excitation influence. That the time span of material acquisition is large, the static correction problem is prominent, and the multiple refracted wave energy is strong with rapid changing speed, increases the difficulty of processing. The top stratum of the tectonic area is quite steep, with fault development, and the reflection continuity of the layers above the basement is comparatively poor with relatively low SNR. The subsurface structure is an overthrust nappe structure and severely fractured, which seriously affects the image quality. Therefore, it is necessary to accurately describe the subsurface structure through fine processing and interpretation, and to further evaluate the resource potential of...
the area.

Figure 1. Surface elevation map

2. Technical means
Aiming at the prominent problems such as large fluctuation of surface elevation and low SNR in the study area, the technical means of high-precision static correction, amplitude-preserved denoising, amplitude compensation, deconvolution, fine velocity analysis, residual static correction, pre-stack time migration, frequency attenuation attribute analysis and seismic data inversion, were used to carry out fine processing and interpretation.

2.1 High-precision static correction processing technology
For this area, the fluctuation of the elevation was violent, and the change of near-surface lithology was great. The static correction problem was so serious that a good static correction was the basis for ensuring accurate image. It was planned to use the elevation static correction, refraction static correction and tomographic static correction to process the backbone measuring line in this area. Based on the full analysis of the static correction processing results, the field static correction method suitable for this area was determined. In addition, for the purpose to ensure the closeness of the two-dimensional data, it was necessary to implement the pseudo three-dimensional processing after the static correction calculation, so that the closeness of cross measuring line would not be poor in the subsequent processing.

The static correction caused by the complex surface structure could not be corrected completely by one static correction. Due to the existence of the residual static correction, the effective reflection events could not be well focused during the velocity analysis, making it difficult to accurately extract the precise stacking velocity value of the effective reflected wave. For this purpose, we used the residual static correction and velocity analysis iteration to perform velocity analysis to improve the stacking velocity accuracy and improve the data quality of the pre-stack CMP gather. In the residual static correction process, the low-frequency part of the seismic data was utilized to cancel the large correction, gradually improving the speed analysis quality, and then the high-frequency part was used to eliminate the small correction, so that the partial intermediate frequency static correction problem could be eliminated. Due to the large amount of residual static correction in this area, multiple iterations were performed in the actual process, to obtain good results.

2.2 Improvement of SNR processing technology
There were various kinds of linear interference, multiple refraction, surface wave, outlier and other interferences in the study area, and many interference frequencies were close to the effective wave. Therefore, it was the key to eliminate the noise while maintaining the amplitude and improve the SNR of the seismic data. Different denoising methods should be adopted for different interference waves. The study area involved regional abnormal noise and linear noise, so in order to maintain the effective signal to the maximum extent, the noise attenuation process was managed following the principle of time division, frequency division, classification, domain division and step-by-step principle. For the regional abnormal noise attenuation technology, Boxcar filter and Median filter could be used to identify and eliminate the abnormal amplitude of the region. For linear noise, mainly utilizing the f-x
coherent noise attenuation technology, the coherent noise was simulated according to the inclination of the coherent noise, static competition, the lateral amplitude change, etc., and then the coherent noise was subtracted from the data, only the valid signal retained.

Figure 2. Denoising effect (from left to right: single shot before denoising, single shot after denoising, noise removed)

2.3 Amplitude processing technology
In order to eliminate the influence of wave front diffusion, medium absorption, and amplitude variation caused by changes in surface conditions during seismic wave propagation, spherical diffusion compensation, surface uniform amplitude compensation and residual amplitude compensation were combined to process the amplitude, enabling the amplitude of the seismic wave was able to reflect the change of the underground lithology more realistically. In order to achieve high-fidelity amplitude processing and ensure the consistency of amplitude in time and space, the distribution law of offset and amplitude in the whole work area was calculated on the basis of spherical diffusion compensation and surface consistency amplitude compensation. The surface consistency residual amplitude compensation technology could balance the insufficiency and excess of the geometric diffusion compensation and the surface consistency amplitude compensation in part of the gun and track records.

Figure 3. Amplitude compensation effect (before and after)

2.4 Deconvolution processing technology for the target strata
Since the surface excitation and reception conditions of this acquisition varied greatly, so surface consistency deconvolution and predictive deconvolution techniques were used to eliminate the influence of surface condition differences on the records and enhance the lateral stability of the wavelets. The surface consistency deconvolution had the advantages of strong anti-interference ability, good adjustment effect on wavelet amplitude and phase, and enhancing the lateral consistency of wavelet. The seismic wavelet was separated into shot point, receiver and common offset domain source wavelet. First, the statistical effect was applied to extract the wavelet in the shot field, and the wavelet deconvolution process was performed to eliminate the residual wavelet of the shot point. Then, the wavelet was converted to its receiver domain, and the common offset domain was subjected to further wavelet deconvolution processing. On the basis of surface consistency deconvolution, predictive deconvolution was also carried out, which further compressed the wavelet and improved the vertical resolution of the seismic data.

2.5 Post-stack and pre-stack time migration processing
The post-stack time migration was conducted with the F-X domain finite difference method. Establishing a reasonable migration velocity field was a crucial step in migration correct homing. On the foundation of the stacking speed, the interval velocity smoothing technology was applied to smooth the velocity according to the shape of the structure to determine the migration velocity field, and then the velocity field was adjusted depending on the migration effect until the optimal migration effect was achieved. Here the diffraction wave was correctly returned with clear breakpoints.

The pre-stack time migration processing was performed on the processed high-quality CMP gathers, with the requirement of a higher SNR and Spatially balanced amplitude energy. Time-speed pairs were interactively picked up on the speed spectrum, densifying control points, and root mean square velocity analysis was performed. By means of smoothing and interpolating the root mean square velocity function picked as the above mention, the initial root mean square velocity field was established. In accordance with the characteristics of the data, the migration aperture was determined by a large number of experiments, to carry out the pre-stack time migration. After pre-stack time migration, quality control was required to check whether the migrated section was abnormal and whether the CRP gather was flattened, to do further velocity analysis, carefully compare the difference between the previous speed and the new one, and analyze the specific reasons.

![Figure 4 Velocity spectrum for PSTM](image)

2.6 Fine interpretation and reservoir prediction
The section closure and coherent volume division technology were used to perform fine structural interpretation, to finely interpret regional structures and horizons, improving the reliability of structural styles and structural traps; Sedimentary construction, high-precision seismic interpretation and drilling geologic stratification were utilized to compare, calibrate and track the index horizon of the whole area, then to improve the reliability of fine structure interpretation results; The coherent volume analysis method was used to identify the unconformity surface, the geological anomaly and the division of the fracture development zone. According to the characteristics of seismic data and logging data, on the basis of the fine interpretation, the constrained sparse pulse inversion technology was utilized to carry out reservoir prediction research, combined with drilling, testing and analytical data to predict reservoir lithology. When the subsurface reservoir was full of fluid, the frequency of the seismic data would produce high frequency attenuation and partial low frequency compensation. According to this principle, the favorable reservoir distribution characteristics of the study area could be predicted through the frequency attenuation attribute of the seismic data. The gas-bearing property of the reservoir was predicted through the frequency attenuation attribute. Combined with the structural distribution characteristics, the favorable area was selected preferentially and well location was deployed and designed.

3. Comprehensive analysis
Studies have shown that there is a traps group in the study area, and many fault-nose and fault-block traps are formed by the fault barrier, with a good inheritance. The north fault of the anticline is divided into 4 to 5 fault-nose and fault-block traps. The favorable distribution is mainly concentrated in the structure high position, presenting a north-south trend, shown as Fig. 5.

According to the well logging interpretation and attribute intersection, it is discovered that the
reservoir in the study area has the characteristics of low natural gamma, low natural potential, low density and high acoustic time difference; the gas-bearing reservoir further reduces its wave resistance. The wave impedance of the reservoir is <10000 g/cm³·m/s, gamma <95API, density <2.5 g/cm³. It can be seen from the results of wave impedance inversion, that the study area is divided into three sets of sedimentary features in the longitudinal direction. The impedance of the strata above the upper section of the Lower Ganchai Formation is significantly lower than that of the strata below, less than 10000 g/cm³·m/s; Two sets of strong impedance deposits exist at the top of the Lulehe Formation. The Jurassic strata are characterized by moderate impedance deposition.

Figure 5: Distribution map of the Jurassic bottom traps in the study area

4. Conclusion
Based on geological understanding and drilling data, it was believed that the source rocks in this area were mainly large sets of mudstones of the Jurassic. Due to the large thickness variation of the overlying strata, the time of hydrocarbon generation was longer. The reservoirs were Jurassic, Lulehe Formation and Ganchaigou Formation. The mudstone of the Ganchaigou Formation was the regional caprock of the Eboliang area. According to the trap and frequency attenuation favorable area distribution, four favorable areas were given, and three recommended well locations were proposed, shown as Fig. 6.

The study believes that for the seismic data in low SNR areas, fine seismic data processing was the key. Through methods such as high-precision static correction and deconvolution to improve the resolution, and through a variety of means to jointly remove the noise and maintain the amplitude, fine speed analysis was implemented on this foundation, as well as post-stack and pre-stack time migration, finally the image was obtained. In addition, the comprehensive interpretation of seismic geology was also the top priority of the preferred favorable area. Through accurate structure interpretation, reliable reservoir prediction and accurate gas-bearing analysis, combined exploration favorable area, the success rate of exploration could be effectively improved, with a reduction of exploration risk.

Figure 6: Overlay map of study area frequency attenuation attributes and recommended well location
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