PS The Study of the Influence of Stratigraphic Structure on Seismic Attribute Analysis*

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Abstract

Seismic attribute analysis is an important tool for reservoir prediction. In the process of attribute analysis, the choice of attribute extraction parameters is always determined by the characteristics of attribute itself, which ignores the analysis of the stratigraphic structure. There may be some artifacts in such results, which can lead to some wrong ideas. In this paper, a detailed analysis of the influence of different formation structures on the target layer is made, and the corresponding countermeasures and suggestions are put forward. 1) Energy shield of upper strong reflector. When there is a strong reflective interface over the target formation, such as igneous rock, conglomerate, coal seam and so on, most of the seismic energy will be reflected. Then the extracted attributes along the target formation cannot accurately reflect the change of reservoir, and we should compensate the attenuation of energy firstly. 2) The coverage of the strong reflection interface side-lobe. When the distance between the target formation and the strong reflection formation is less than one seismic wavelength, the strong reflection's side-lobe will interfere with the reflection of the target formation, and the effective signal of the target formation is completely submerged. For this case, we should remove the strong reflection before attribute analysis. 3) The interference of the adjacent interface. When there is a reflection interface whose reflection energy is equivalent to the target formation and the distance to the target formation is less than one wavelength, its reflection will interfere with that of the objective formation. Obviously, the attribute extracted along the target formation not only contains the information of the target formation, but also contains the information from the adjacent interface. In practical application, the distance should be analyzed. Which reflection (the top or the bottom) should be used when analyzing attributes of a single sand has also been studied. The results show that the selection of the time window should be based on the stratigraphic structure. If there is no change in the distance between the adjacent interface and the top of the sand, and the physical properties of the above surrounding rock almost have no change too, then we can use the top reflection information to extract attribute. But if the below stratigraphic structure matches the above conditions, the bottom reflection information should be used.

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Abstract: Seismic attributes analysis is the main technology for reservoir prediction. The conventional way always considers the parameters of the attributes themselves, such as time windows, and neglects the analysis of the target data. Then the attributes may exist some artifacts, and lead us some wrong ideas. This paper aimed at seismic data, analyses the different effects on target formation of different strata structures, and gives the countermeasures and advices respectively. (1) The effect of the energy shielding from up strong reflector. When strong reflectors, such as igneous rock, basal conglomerate, coal-bed, existing up the target formation, most seismic energy will be reflected, and the transmitted energy becomes less. Then the horizon attributes will not reflect the properties of the reservoir accurately, so we must compensate the reflected energy before attributes analysis. (2) The effect of energy submergence from the strong reflection's side-lobe. When distance from the strong reflective interface to target formation is less than the wavelength, the side-lobe will intervene with the objective formation's reflection, because the side-lobe's energy is much stronger, the useful signal is submerged completely. Now we should first remove the strong side-lobe, then take attributes analysis. (3) The interference of the adjacent interface. When existing interface whose reflection energy is comparable with the target formation's and the distance to the target formation is less than the wavelength, its reflection will intervene with that of the objective formation. The horizon attributes contain not only the information of the target formation, but also the adjacent interface. We should emphatically analyze the distance change from the adjacent interface to target formation to find out the effect of the interference.

1.Analysize the effect of strata structure on seismic attributes analysis

1.1 Energy shielding analysis

Based on the theory of the elastic wave propagation, the energy of the incidence p-wave is divided into four parts (Figure 1). When existing the high impendence formation, the reflection coefficient is large, and most parts of the seismic energy will be reflected, the transmitted energy will be less, and causing the energy shielding.

The shielding of a strong reflection surface with a positive reflection coefficient includes two aspects: energy shielding and path shielding (Figure 2). Energy shielding will occur when the incident angle is less than the critical angle. Path shielding will occur when the incident angle is larger than the critical angle, based on total reflection principle, all energy of the incident wave will be reflected.

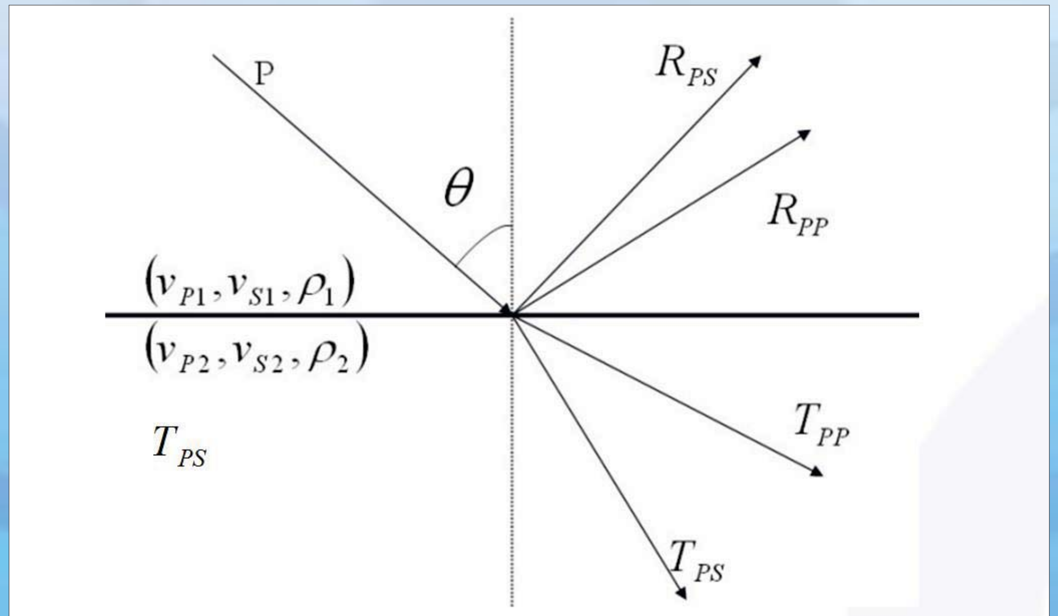


Fig. 1 Diagram of reflection and transmission of P-wave at horizontal interface

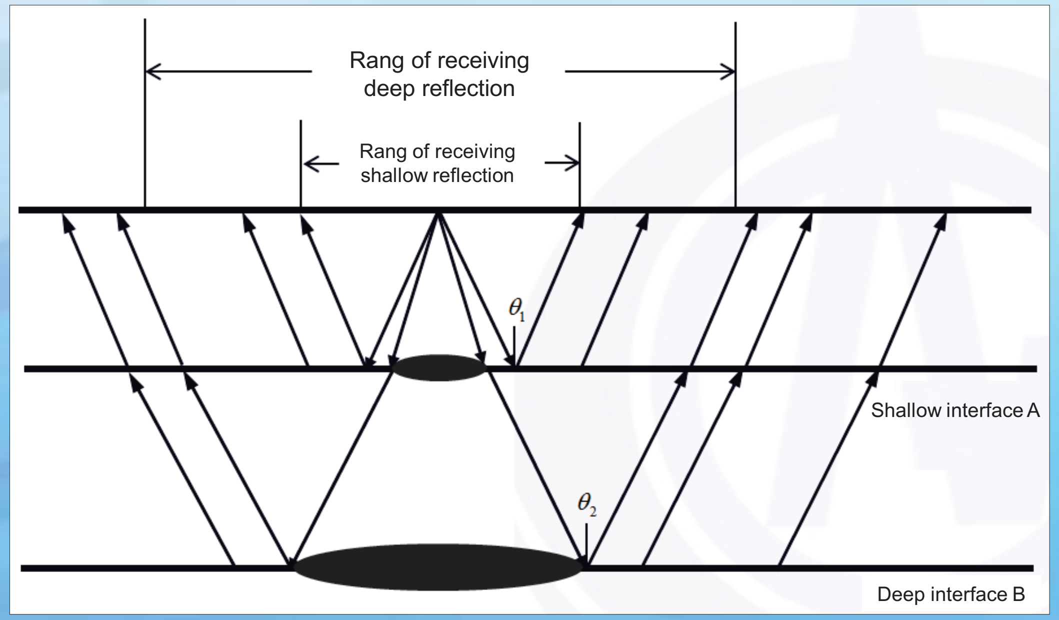
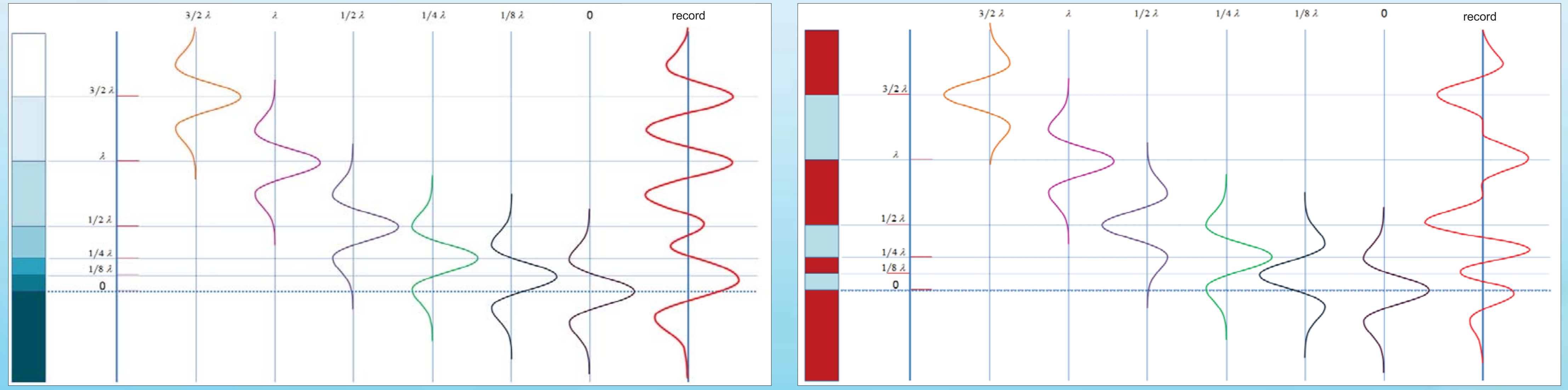


Fig. 2 Reflection and transmission of seismic wave in three layers medium

1.2 Energy interference analysis

when the distance between the adjacent interface and the target layer is less than 3/4 wavelength, the reflection of the adjacent interface will interfere with the reflection of the target layer, here we called this phenomenon "energy interference". In such condition, the attributes extracting from the time depth of the target layer contain both the effective information and the interference, and this will cause many uncertainties in the attributes analysis result.

Build the models shown in Figure 3. In first model the impedance monotonically increases gradually from shallow to deep, the reflection coefficients of all the interfaces are positive, in second model the change of impedance is not monotonically with the reflection coefficients positive and negative alternately. Convolute the reflection coefficients with a Ricker wavelet and obtain the records. The final records can be thought of linear superposition of each interface's reflection. We can see when the distance between interface and the target layer less than 3/4 wavelength, no matter in which model, the interface's reflection will interfere with that of the target. And as the distance decreases, the interference is more obvious.



(a) model 1 (b) model 2

Fig.3 Diagram of energy interference

1.3 Energy coverage analysis

Similarly to energy interference, energy coverage is caused by interference when the distance between the adjacent interface and the target layer is less than 3/4 wavelength. The difference is the reflection energy of the adjacent interface, in this way energy coverage can be thought of a special condition of energy interference. If the reflection energy is too larger, the linear superposition of each reflection at the depth of target layer will mainly display the characteristics of the adjacent strong reflection and the information of the target will be covered completely. In this case, attributes analysis is useless for our understanding of the reservoir. We should first remove the interference of the strong reflection and then take attribute analysis. And in the process of interference removing should be constrained by geological understanding.

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2 Application

2.1 Seismic attributes analysis for A oilfield

The main reservoir of A oil field of BoHai bay belongs to Braided-river delta deposit, and is classified to stratiform reservoir type dominated by structure. Total 59 developing wells were drilled. All evidences show that the lateral distribution of main reservoir is stable and the thickness is about 16-35m. However the energy intensity of the extracted RMS attribute for the reservoir changes rapidly, and the energy distribution is non-uniform. This is in contradiction with the geological knowledge in this oil field.

After detailed study, we excluded the effect of top gas, the physical attributes of the reservoir itself such as the permeability, porosity, etc, finally found it was generated by the overlying basal conglomerate, which is about 70m above and had much higher P-impendence than its surrounding rock. Extracted the RMS attribute for the basal conglomerate, we found the energy of it varies inversely with that of the main reservoir: the strong energy region of basal conglomerate above is corresponding to the weak energy region of the main reservoir below and vice versa (Figure 4 and Figure 5). We concluded the phenomenon of the reservoir is not only the response of the reservoir itself, but also caused by the overlying basal conglomerate.

Based on the theory of the elastic wave propagation, the energy shielding of basal conglomerate on the reservoir is mainly related to the reflection coefficient of the interfaces between the basal conglomerate and surrounding rock. According to the rock physical parameters from wells, energy compensation was adopted and the compensation result is shown as Figure6, the transverse energy variation is more uniform.

Take further analysis on the energy compensated attribute, we can see the strong energy is distributed in band in the trend of NE-SW direction. Only considering the attribute itself, we may think it represents the direction of the source or the distribution of the reservoir. Take a seismic profile along the direction shown in Figure 7, we find in the strong energy reflection area the reflection of the reservoir is just above the reflection of buried hill surface and in the weak energy reflection area there exists other reflections between the surfaces of reservoir and buried hill. This is consistent with the results of drilling, in structural high part the reservoir draping over the buried hill and in structural low part the sand-shale interactive deposits developing between the reservoir and buried hill. This concludes the strong energy is sum of energy of the reservoir reflection and the side lobe of buried hill surface reflection. Obtain the time thickness between the top surface of the reservoir and the surface of buried hill, which is shown in Figure 8, the area with the time thickness less than 25ms is basically corresponding to the strong reflection energy region.

In order to suppress the sidelobe interference of the buried hill reflection, subtraction method is adopted. The sidelobe energy can be calculated from the energy of the main peak, and in the process of subtraction the sidelobe energy should be multiplied by a correction factor changing with depth. With the increase of the distance between the top surface of the reservoir and the buried hill surface, the interference becomes weak nonlinearly. The energy of the attribute with the interference suppressed becomes more uniform in the plane as shown in Figure 9.

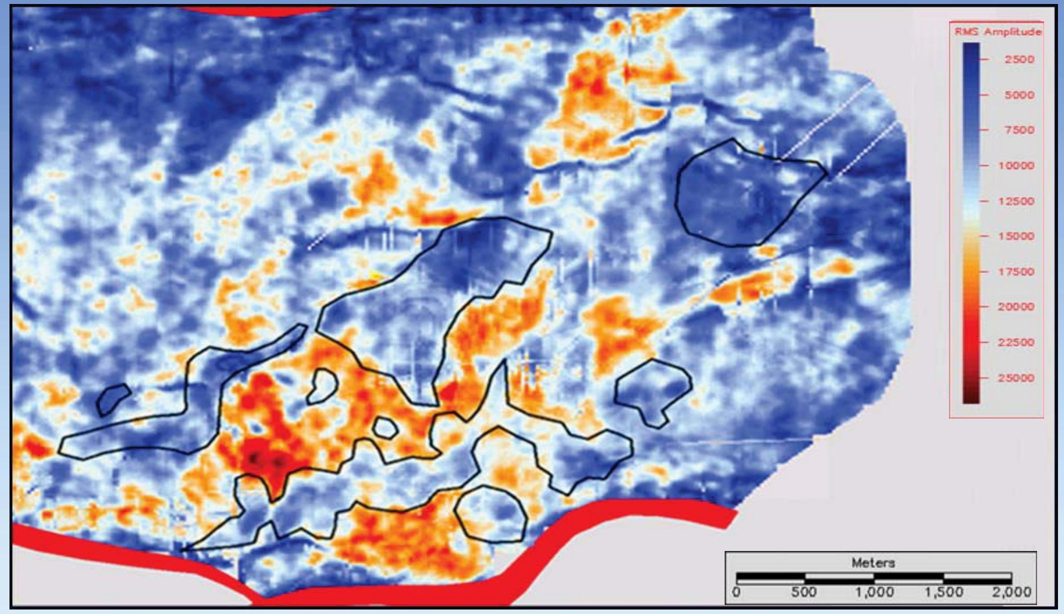
Fig.4 The RMS attribute of the reservoir

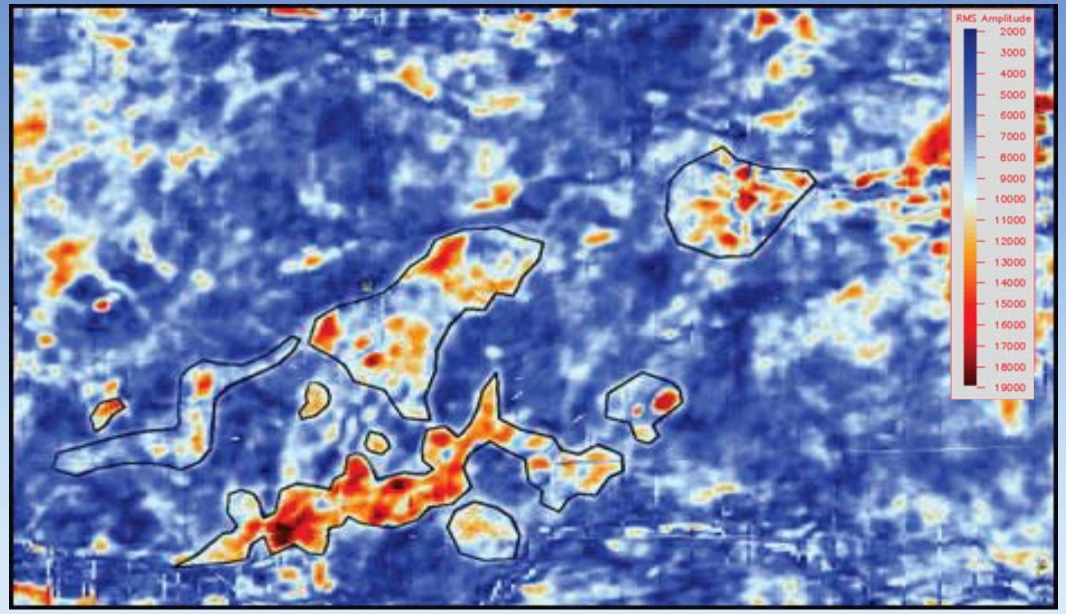
Fig.5 The RMS attribute of the overlying basal conglomerate

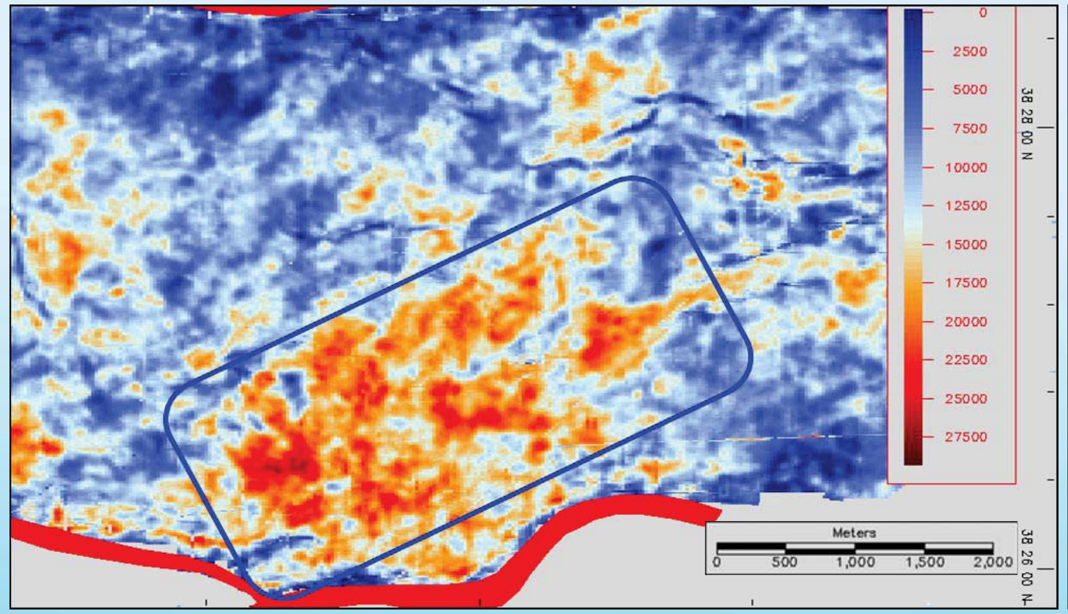
Fig.6 The RMS attribute compensated for energy shielding

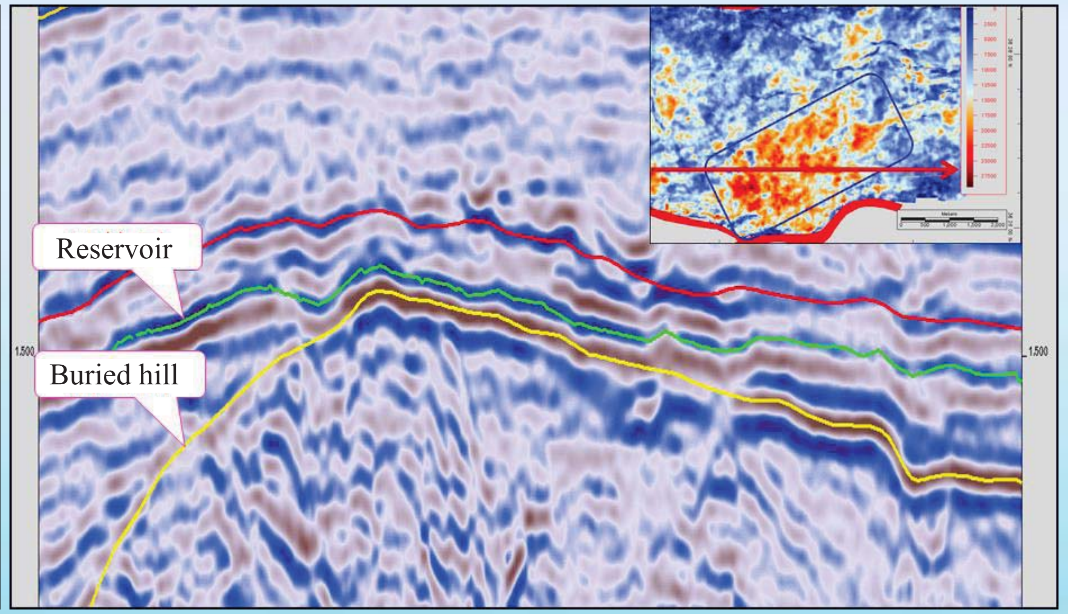

Fig.7 The seismic profile cross the strong energy area

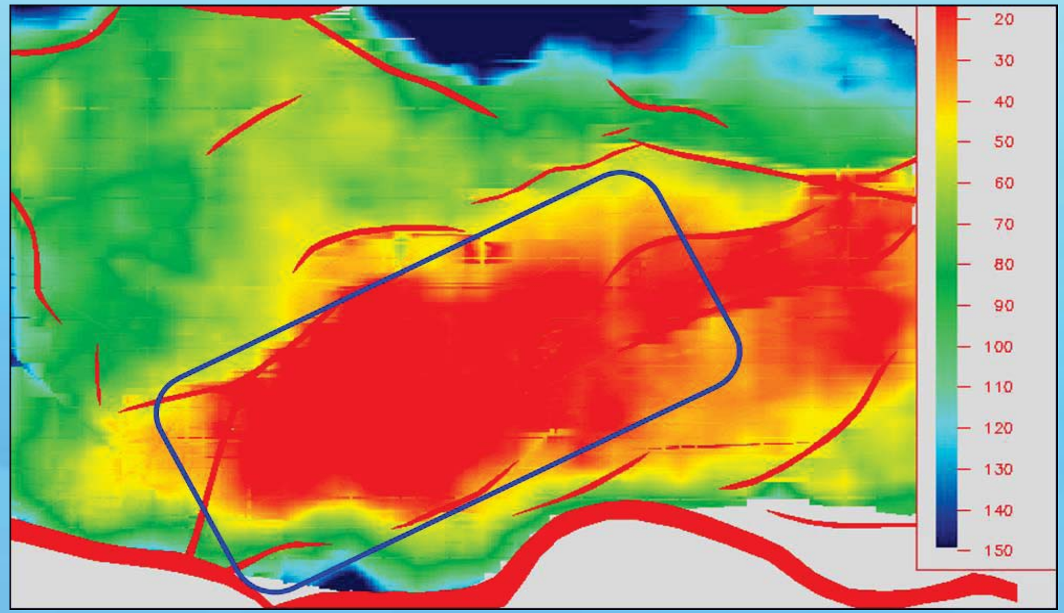
Fig.8 The time thickness between the reservoir and the buried hill

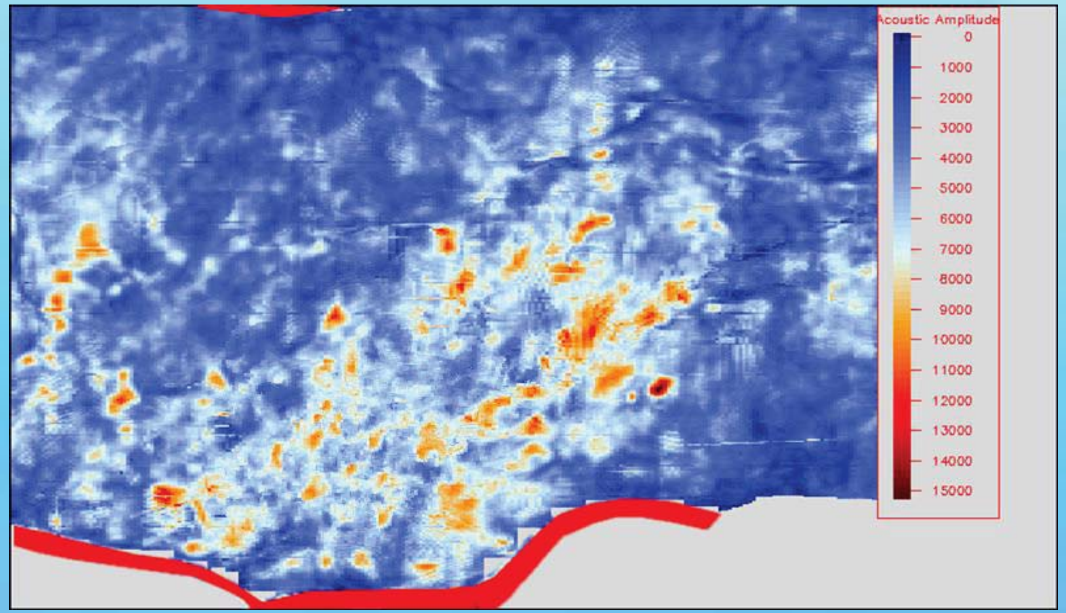
Fig.9 The attribute with the sidelobe interference suppressed

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2.2 Seismic attributes analysis for B oilfield

The reservoir of B oilfield belongs to shallow water delta depositional system developed in lowwer Minghuazhen formation of the Neogene system. Underwater distributary channel deposit sandstones are widely developed, but the thickness of them varies fast laterally. The reservoir of this oil field is generally characterized by strong reflection in seismic profile. Well 3 drilled gas layer with thickness of 7.3m and continuously drilled oil layers with thickness of 17.1m and 7.1m. The gas reservoir is characterized by strong reflection in seismic profile, which is according with our understanding, but the characteristics of the oil layers are weak, it's hardly to use them to describe sand bodies (Figure 10). The main frequency of seismic data in the target layer is about 45Hz. We think the reflection of the reservoir is weakened by the strong reflection of the overlying gas layer, because the distance between the bottom of the gas layer and the top of the oil layer is about 5m.

Built the geological model using logging data shown in Figure 11, and the seismic forward modeling result is shown in Figure12. The response characteristics between the modeling result and the seismic profile are basically identical. In the modeling result, the top of the gas layer characterized by a strong wave trough and the bottom characterized by a weak peak. The top and bottom of the oil layer characterized by a strong trough and a strong peak respectively within the area unaffected by gas, and in the gas affected area the top of the oil layer doesn't show the characteristic of strong trough, but a weak peak because of the interference of the bottom reflection of the gas layer. The results verified our above analysis.

Take reprocessing for the original seismic data, retain the low frequency components in the process and expand high frequency components at the same time. Compare the inversion results of the reprocessing data and the original data, the energy of the oil layer below the gas layer was compensated well. From the RMS attributes of the sand body, the energy becomes more uniform in the plane, which is in favor for sand body description, especially in the area affected by the gas layer(Figure13-16).

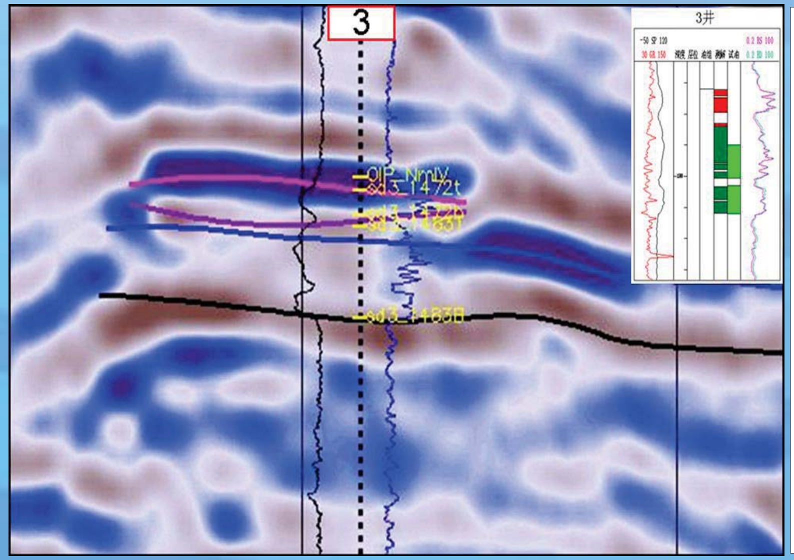

Fig.10 The seismic profile cross well 3

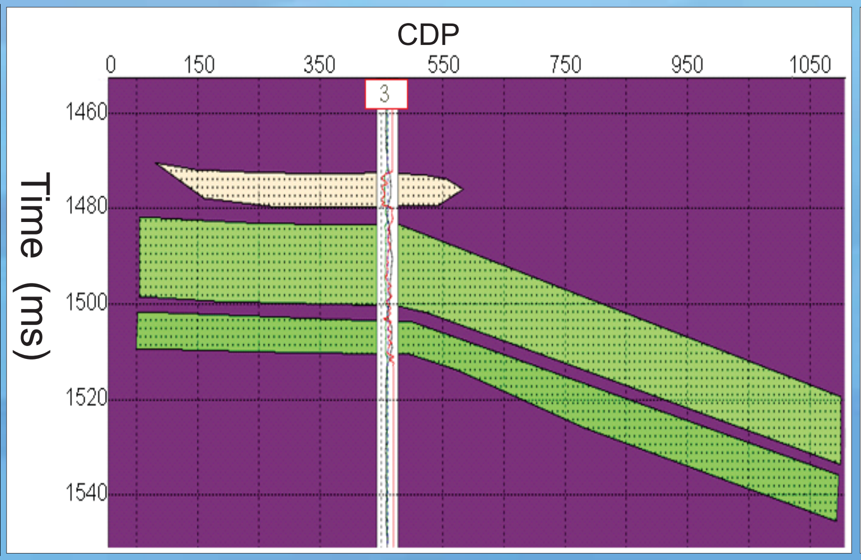

Fig.11 The geological model

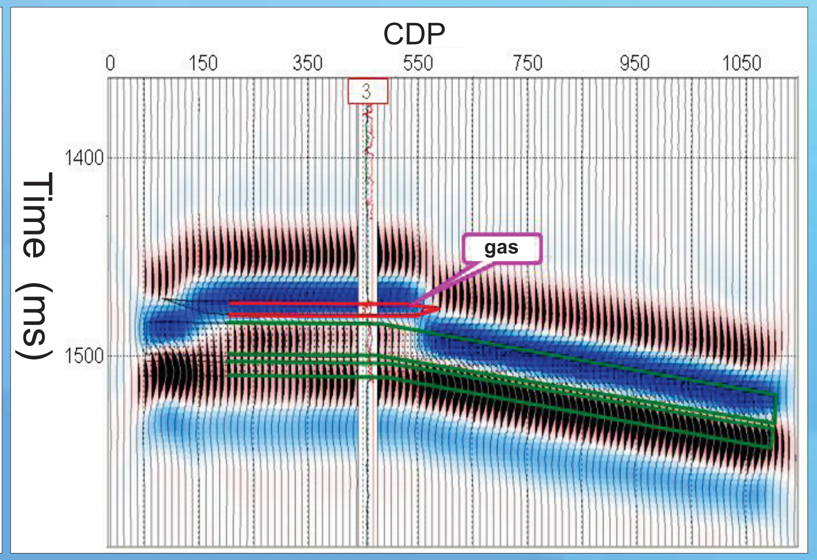

Fig.12 The modeling result

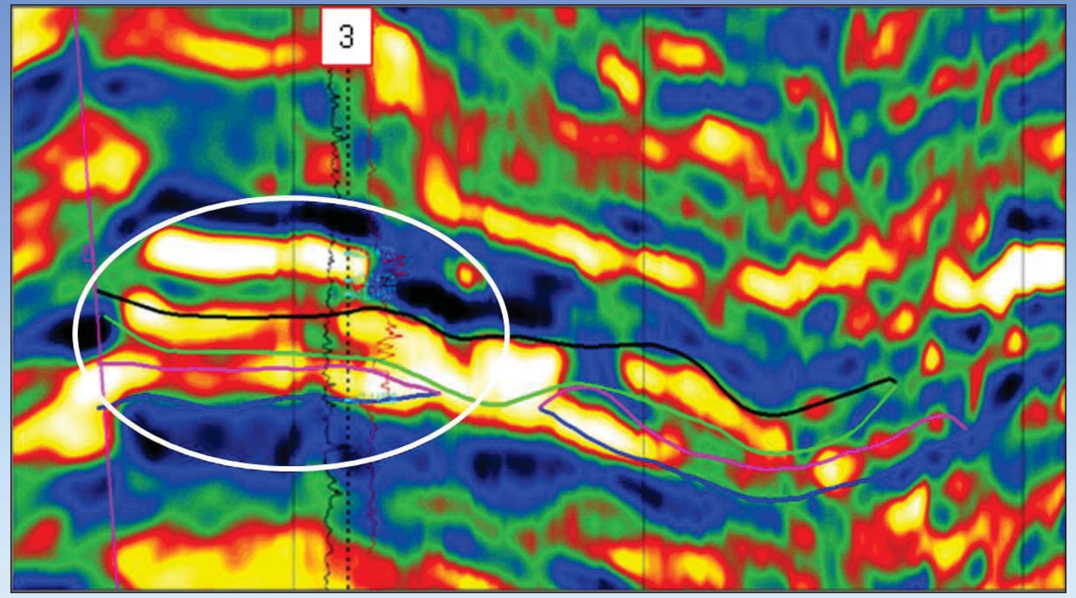

Fig.13 The inversion result of the reprocessing data

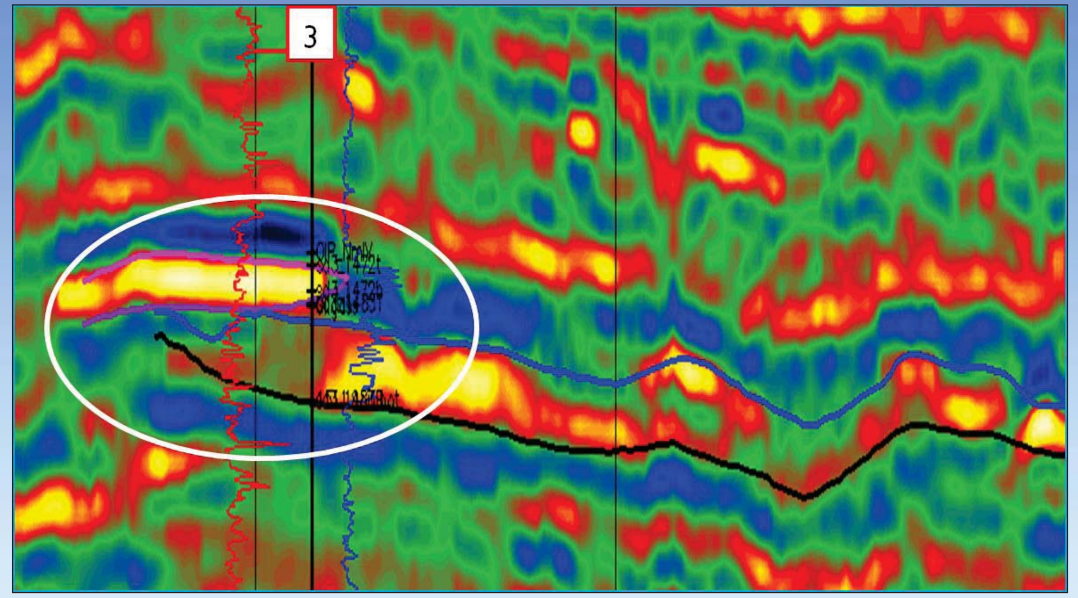

Fig.14 The inversion of the original seismic data

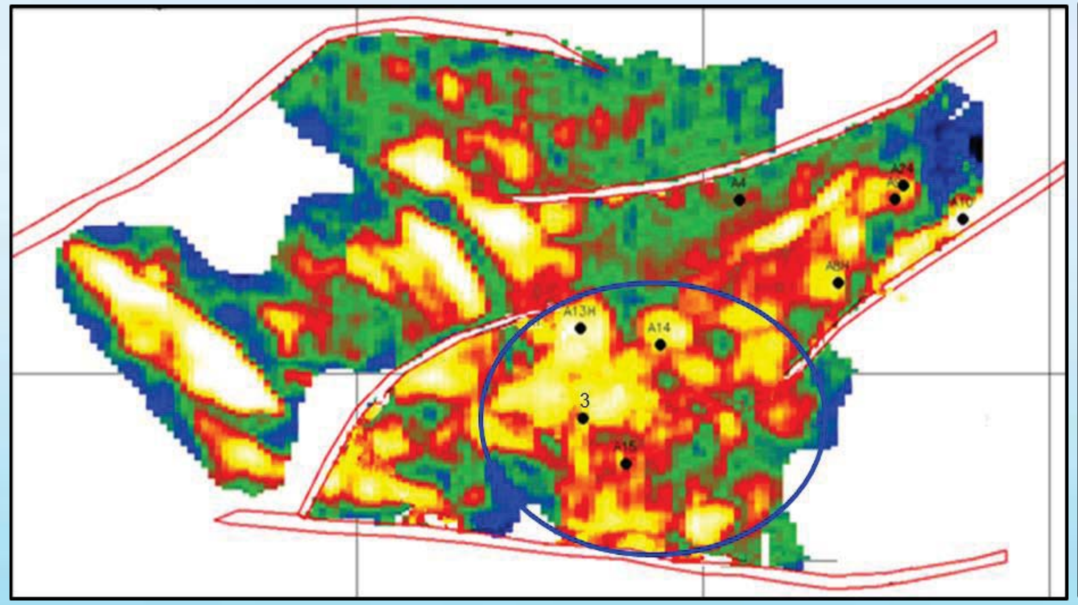

Fig.15 The RMS attribute of the reprocessing data

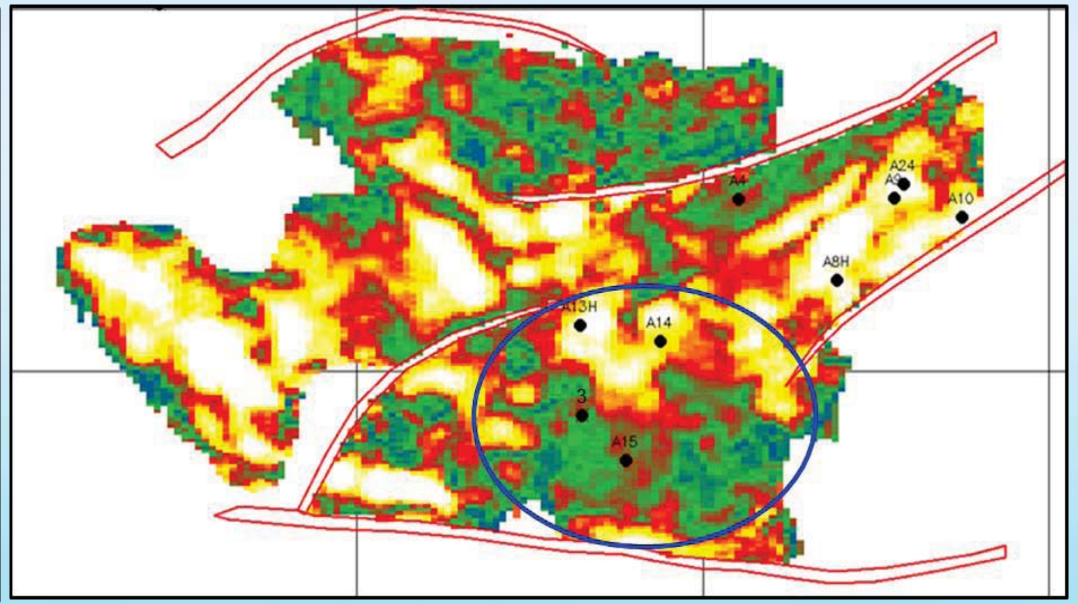

Fig.16 The RMS attribute of the original seismic data

3 Conclusion

① The affection of formation structure on seismic attributes analysis includes three aspects: energy shielding, energy interference and energy coverage. Energy shielding is caused by the strong reflection surface, which reflects most seismic energy and leads the transmitted energy less. Energy interference and energy coverage are both caused by the adjacent refection, the difference between them is the energy of the adjacent refection.

② In order to take reasonable attribute analysis, surrounding formation structure should be considered. We should not attribute all the changes to the response of target layer. In the process of attributes extraction, time window should be designed based on formation structure to obtain the optimal result.

③ In the process of attribute analysis, the affection from the formation structure should be suppressed by some reasonable methods, and take analysis for the results using geological understanding.