# PS A New Method of Making the Thickness Map of the Shallow Sand Body Constrained by Seismic Attribute*

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## Abstract

Sand body thickness map is one of the most important results of geophysical exploration, especially for offshore oil fields, it directly or indirectly determines the scale of the platform and the oilfield development plan. The conventional flow is always based on 90°phase shifted data or inversion data, and the general steps are as follows: 1) tracking the top and bottom of the sand body; 2) obtaining the gross thickness by subtracting top depth from bottom depth; 3) obtaining the corrected gross thickness by using the well point thickness; 4) obtaining the net thickness by net-to-gross ratio. The flow has two problems when thickness laterally varies quickly: 1) under certain conditions, top and bottom surfaces tracked by interactive interpretation are not the real interfaces; 2) in the process of correction, some unreasonable values will be introduced because of the mathematical interpolation algorithm. To solve the above problems, a new method for making the shallow sand body thickness map is proposed. The shallow sand body always has better seismic response; therefore, there is a good correlation between the thickness and seismic attributes. Forward modeling results show that the cumulative thickness of sand body is positively correlated with reflection amplitude and negatively correlated with instantaneous frequency when the thickness of the sand or the interbed sand is less than 1/4 seismic wavelength. The relationship between the thickness and seismic attributes can be established by means of linear fitting or artificial neural network. In the step of correction, we adopt Kriging interpolation method: the thickness is consistent with well point thickness in the well control area, and consistent with seismic attributes outside the well control area. The well control area can be obtained by means of variogram function. In this paper, we also give the steps of calculating the effective thickness: 1) calculating the net thickness using seismic attributes and the well point thickness; 2) getting the gross thickness through the net-to-gross ratio; 3) removing the gross thickness under the oil-water interface; 4) calculating the effective thickness using the remaining gross thickness multiplied by the net-to-gross ratio. This method has achieved good results in practical application. This method considers sedimentary facies by seismic attributes, so the obtained thickness map agrees more with our cognition.

# A new method of making the thickness map of the shallow sand body constrained by seismic attribute

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**Abstract**: Sand body thickness map is one of the most important results of geophysical exploration, especially for offshore oil fields, it effects the scale of platform and the oilfield development plan. The conventional process is always based on 90°phase shifted data or inversion data and generally with the following steps: (1) Tracing the top and bottom surfaces; (2) Obtaining the gross thickness by subtracting top depth from bottom depth; (3) Obtaining the corrected gross thickness by well point thickness correction; (4) Obtaining the net thickness by net to gross ration correction. This process becomes powerless when the thickness laterally varies quickly, and mainly has two problems: (1) Under certain circumstances, top and bottom surfaces traced by interpretation are not the real top and bottom surfaces. (2) In correction process, unreasonable values will be introduced because of the mathematical algorithm, we called this phenomenon "seesaw effect".

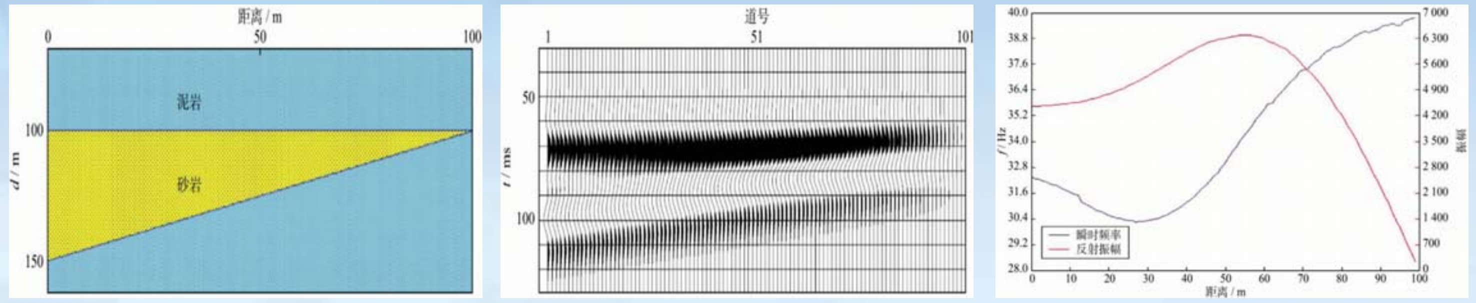
In order to solve above problems, this paper proposes a new method to map thickness for shallow sand bodies. The shallow sand bodies always have better seismic responses, then the thickness will correlate closely with the seismic attributes. Forward modeling shows the thickness has positive correlation with seismic amplitude attribute and negative correlation with instantaneous frequency attribute, when the thickness of the sand or the interbed sand is less than 1/4 wavelength. Then we can construct the relationship between thickness and seismic attributes by linear fitting or artificial neural networks, and calculate the thickness with seismic attributes. In the correcting process we adopt Kriging interpolation method to ensure that the thickness in the well region is consistent with well point thickness, and the thickness out of the well region the thickness is consistent with the seismic attributes. The range of the well region can be calculated by variogram function. This paper also builds the process for effective thickness : (1) Calculating the net thickness using the seismic attributes and the well point thickness; (2) Calculating the gross thickness using the net thickness divided by net to gross ratio; (3) Subtracting the gross thickness under the oil-water interface; (4) Calculating the effective thickness using the remaining gross thickness multiplied by the net to gross ratio. Practice has proved this process is effective.

This method constrained by seismic attributes considers the sand bodies in different deposition positions have different development characteristics, so the obtained thickness map is more agreed with our geological understanding.

## 1. Methods and principles

### 1.1 Forward modeling analysis of single sand body model

As can be seen from Fig.1, when the thickness is less than 1/4 wavelength, the thickness is positively correlated with the amplitude, which is negatively correlated with the instantaneous frequency.




(a) (b) (c)

Fig.1 Analysis of amplitude and instantaneous frequency of a single wedge sand body (a) geologic model; (b) synthetic seismogram; (c) the curve of reflection amplitude and instantanous frequency;

### 1.2 Forward modeling of thin interbed sand body model

It can be seen there is a positive correlation between the cumulative thickness and the amplitude, which is negatively correlated with the frequency.

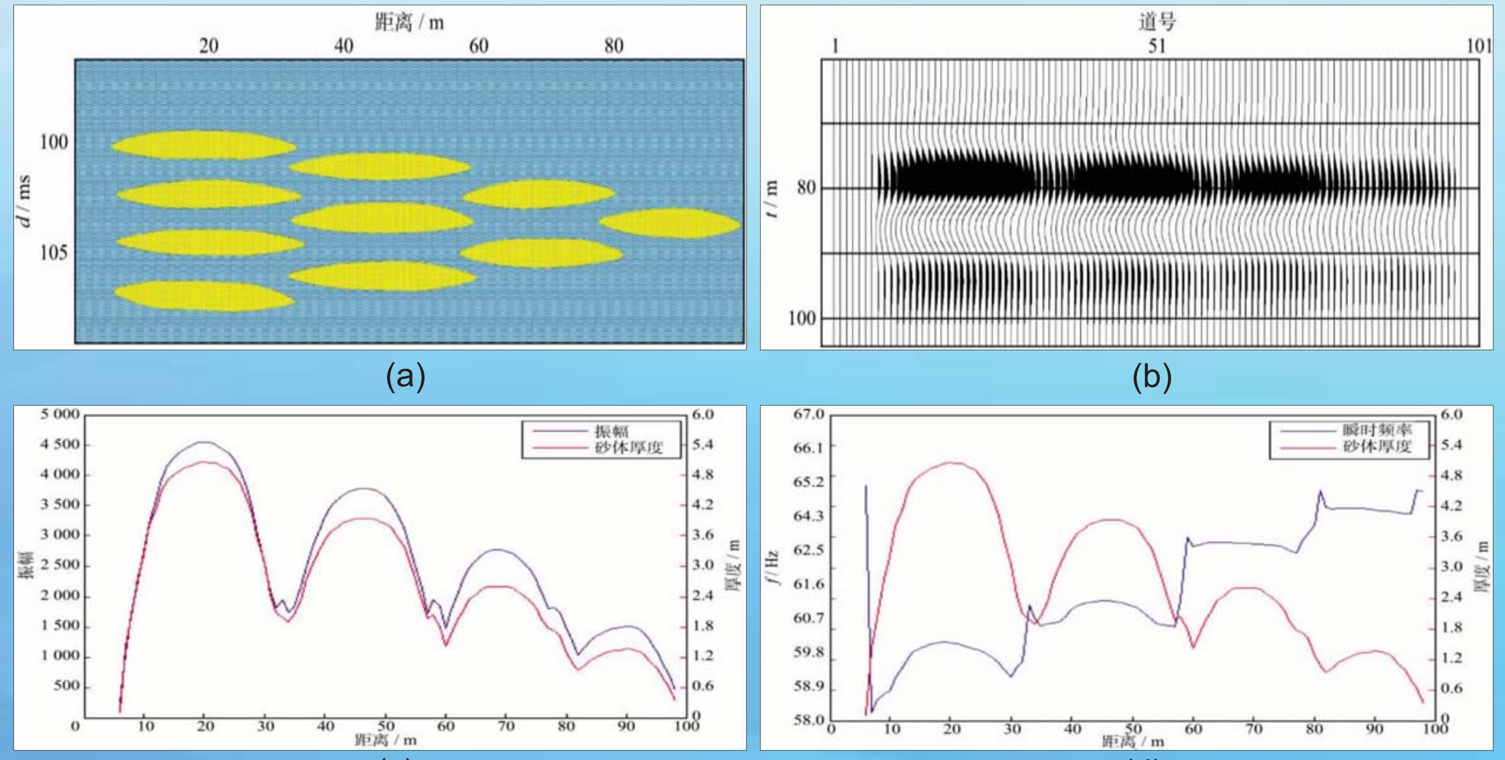



Fig.2 Forward modeling of thin interbed sand body (a) geologic model; (b) synthetic seismogram; (c) the relationship between the reflection amplitude and the thickness; (d) the relationship between the instantaneous frequency and sand body thickness;

### 1.3 Forward modeling of fluvial facies sand body model

In order to make the research more close to the actual situation, the relatively complex fluvial facies interbed sand is established, as shown in Figure 3(a). The frequent shifting of the river makes the sand bodies overlap with each other, and the combination of sandtone and mudstone varies laterally. The velocity of the sand body is 3500m/s, the mudstone velocity is 2500m/s, the single sand body thickness is about 10m, the maximum cumulative thickness of thin interbed of sand body is less than 1/4 seismic wavelength(22.5m). The forward modeling results are shown in Figure 3(b) (the source is Ricker wavelet and the dominant frequency is 39Hz). In the same way, the values of reflection amplitude and instantaneous frequency are extracted from forward data, which are compared with the cumulative thickness of sand body. The results are shown in Figure 3 (c)and (d). The minimum cumulative thickness of sand body is about 1m, and the maximum cumulative thickness is about 14m. It can be seen that there is a positive correlation between the cumulative thickness and the amplitude value, which is negatively correlated with the instantaneous frequency.

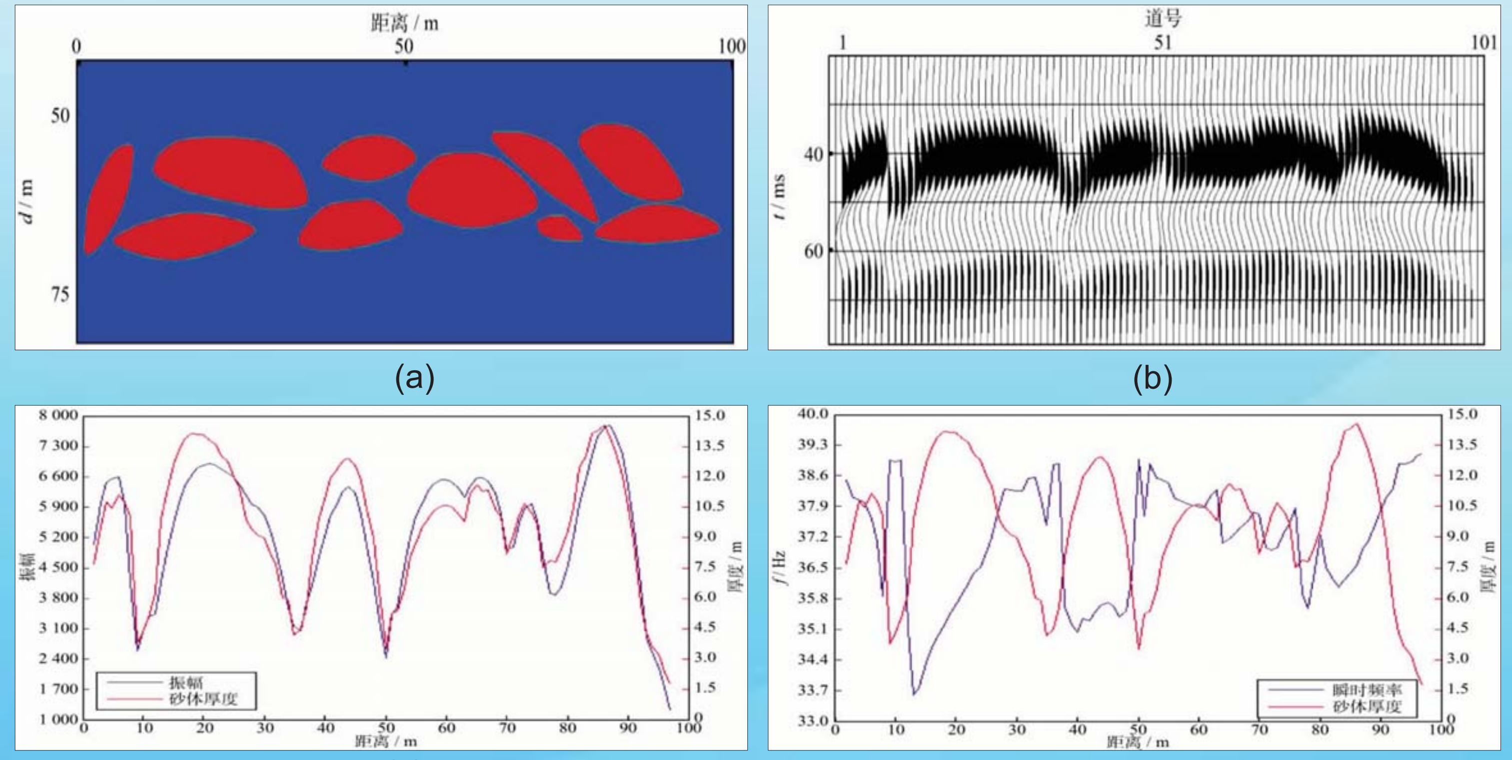



Fig.3 Forward modeling of fluvial facies sand body (a) geologic model; (b) synthetic seismogram; (c) the relationship between the reflection amplitude and the thickness; (d) the relationship between the instantaneous frequency and sand body thickness;

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On the whole, the correlation between the cumulative thickness of sand body and reflection amplitude is better than that of the instantaneous frequency.

### 1.4 Brief summary

Through the above forward analysis, we can draw the conclusions: for the single sand body or thin intered sand, when the cumulative thickness of sand is less than 1/4 seismic wavelength , reflection amplitude and sand body thickness is positively correlated, and the larger the sand body thickness , the stronger the reflection amplitude. The instantaneous frequency has a negative correlation with the cumulative thickness of sand body, and the smaller the cumulative thickness of sand body, the higher the instantaneous frequency.

According to above conclusions, in the case of single sand body or thin interbed sandstone, as long as the total thickness of sandstone and mudstone is less than 1/4 seismic wavelength, the thickness of sand body can be predicted by using reflection amplitude and instantaneous frequency. The thickness of sand body is less than 15m in the continental sedimentary system of meandering river and delta sedimentary system of distributed channel. So in the current seismic resolution, most of the reservoir is in the 1/4 seismic wavelength range.

## 2 The basic flow of making thickness map of sand body constrained by seismic attribute

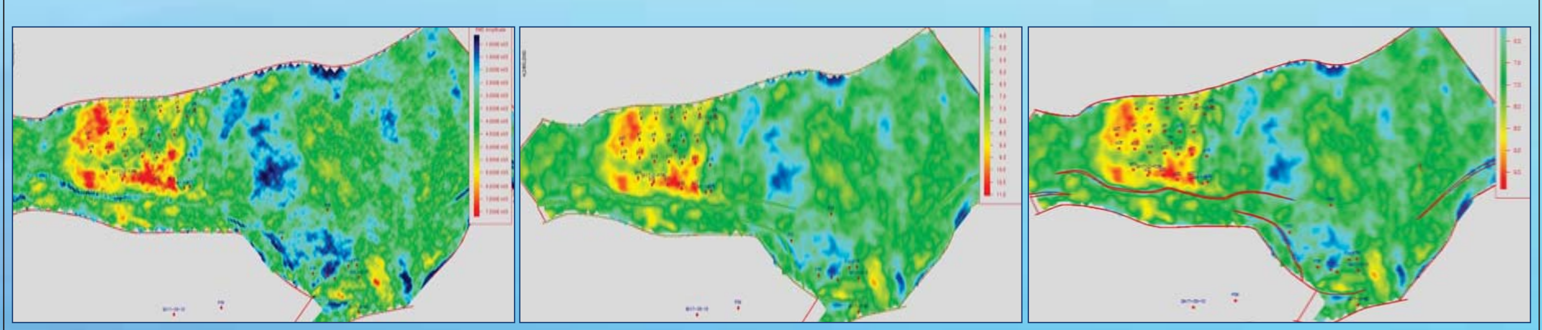
### 2.1 The production process of net thickness map

It is not necessary to consider the oil-water contact, so the process is relatively simple. (1) The seismic attributes are extracted by using the top and bottom interfaces of the sand body; (2) Based on the LPM(GeoFrame software) module, the correlation between the seismic attributes and the net thickness of the sand body at each well point is analyzed, and the formula is obtained; (3) In the LPM module, using the fitting formula to predict the thickness of sand body; (4) In the CPS3 module, correct the well point again.

Two issues should be pay attention to : (1) When using the fitting formula to predict the sand body thicness, it is necessary to correctly handle the "seesaw" effect when the well point correction is performed(the third step ); (2) What can we do if the correlation between seismic attribute and thickness of each well point is not high. Next, the two problems are analyzed.

The treatment of "seesaw" effect caused by well point correction. It can be seen from Figure 4 that the thickness map of sand body which is predicted by seismic attribute is in good agreement with the seismic attribute, but the correction thickness map is not consistent with the seismic attribute. The reason is that the seesaw effect caused by error mesh because of the interpolation algorithm in the correction process.

Ideally, the thickness map is consistent with the well in the well control area, and the thickness map is consistent with the change of the property in the area where the well is not controlled. In this paper, we use the Kriging interpolation algorithm, which can provide an optimal linear unbiased estimation for the research object. It can be seen from Figure 5 that the method can be used to quickly converge when it is corrected, and there is no need to correct the area far from the well. In this way, the error correction grid can be used to ensure that the sand body thickness is well matched with in the well control area, and the sand body thickness is consistent with the change of the attribute in the area without well control.



(a) (b) (c)
Fig.4 Comparison of thickness map and seismic attribute before and after LPM correction (a) seismic attribute; (b) thickness map of uncorrected; (c) the thickness after correction

The correction analysis between seismic attributes and petrophysical properties of well, it is inevitable that there will be some abnormal wells, which are inconsistent or even contradictory with other wells. This is also true correction analysis between seismic attribute and the thickness of the sand body. If all the

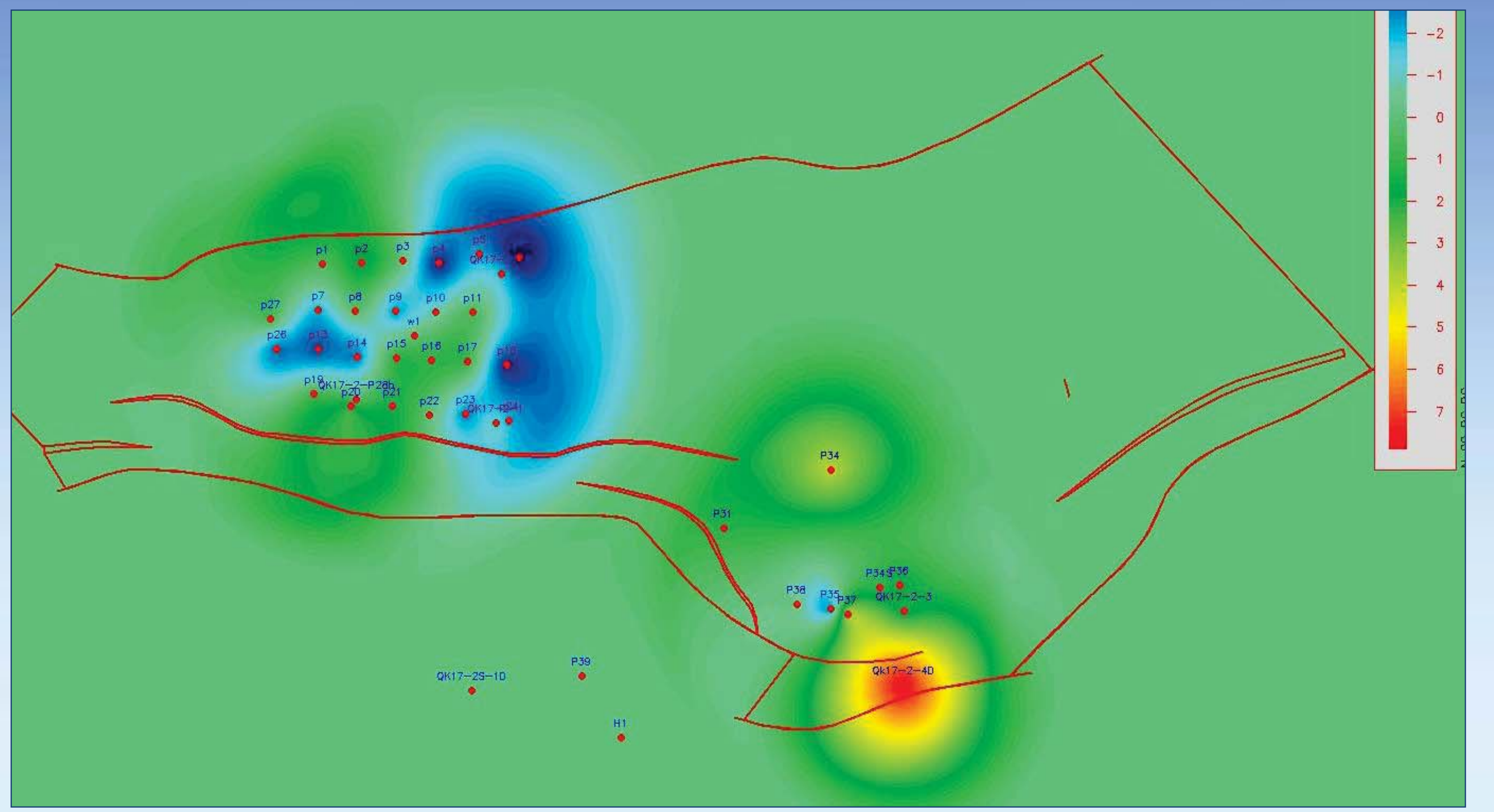


Fig.5 Error correction grid based on Simple 'Kriging' method

wells are involved in the correction analysis , it is bound to reduce the correction, thus affecting the accuracy of the fitting formula, then affecting reliability of predicting sand body thickness by seismic attribute. If only some wells are involved in the correction anslysis, the more accurate fitting formula can be obtained. However, the wells which are not involved in the correction analysis can not affect the error grid. Aiming at this problem, this paper puts forward the idea of "two steps".

The first step is to eliminate the abnormal wells and analyze the correlation between the remaining wells and the seismic attributes. When the degree of correction meets the requirements, an accurate fitting formula is obtained. The second step is that the correction analysis using the predicted sand body thickness and all the wells. And the Simple 'Kriging' interpolation method is used to form the error correction grid to ensure that the correction process will not affect area without well control.

Through the above steps, it can ensure the reliability of sand body thickness predicted by using seismic attribute, and make all wells participate in the correction. The results obtained by the "two steps" method are in good agreement with the seismic attribute .

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Figure 6 is the comparison of the sand body thickness map obtained by the conventional method and the new method presented in this paper. It can be seen that the sand body thickness map obtained by new method is basically the same as that obtained by the conventional method. However, the sand thickness map obtained by the new method is in good agreement with the

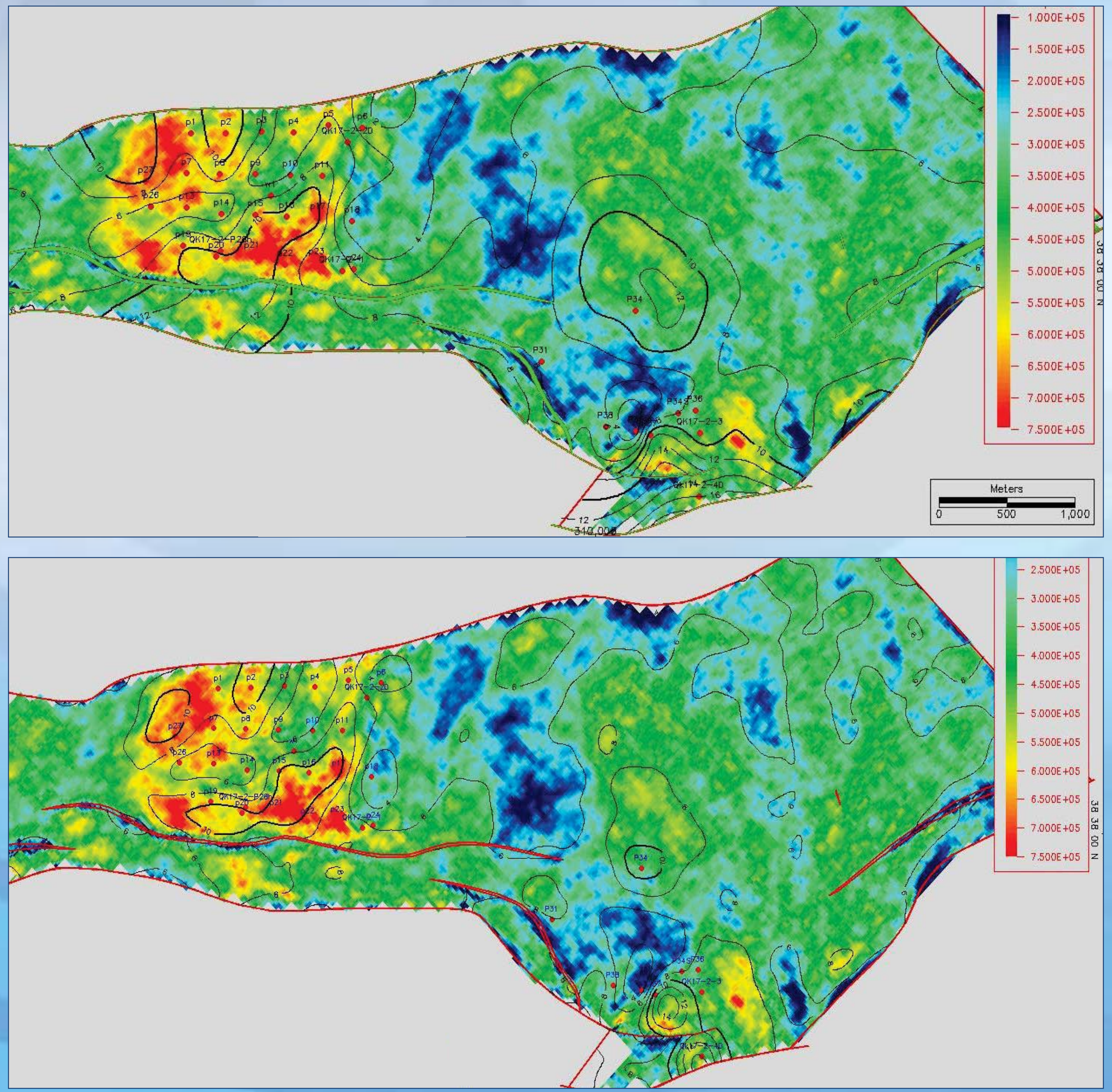

Fig.6 The comparison of sand body thickness maps obtained by conventional method and the new method presented in this paper. (a: sand body thickness map obtanined by the conventional method;b: sand body thickness map produced by seismic attribute constraint.)

seismic attribute in the area far away from the well or without well control. Because of the "seesaw" effect in the process of error grid correction, the sand thickness map obtained by the conventional process has no regularity, which deviates from the real geological condition.

## 2.2 The process of making effective thickness map

The process of making effective thickness map of sand body is shown in Figure 7. (1) Get the gross thickness map through the net thickness divided by net-to-gross(Figure7b); (2) remove the lower part of the oil water contact (Figure7c); (3) multiplied by the net-to-gross, get effective sand body thickness map(Figure7d).

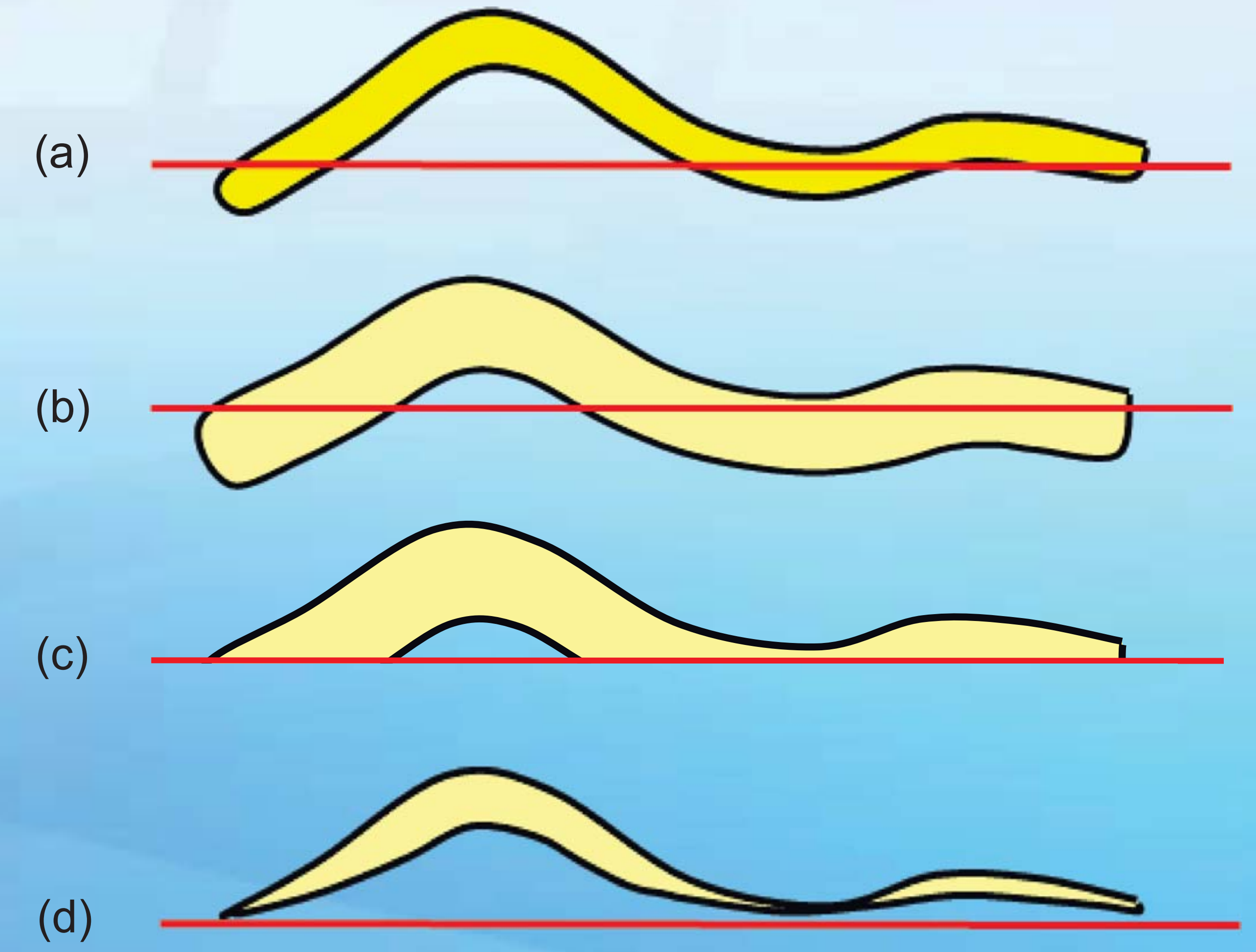


Fig7. The effective thickness map of sand body is obtained by using the net thickness map of sand body. (a: the sketch map of net thickness; b: the sketch map of gross thickness; c: the sketch map of gross thickness without the part below OWC; d: the sketch map of effective thickness map)

Figure 8 is the comparison of the thickness map obtained by the conventional method and the new method. It can be seen that the two are basically the same, especially the zero line.

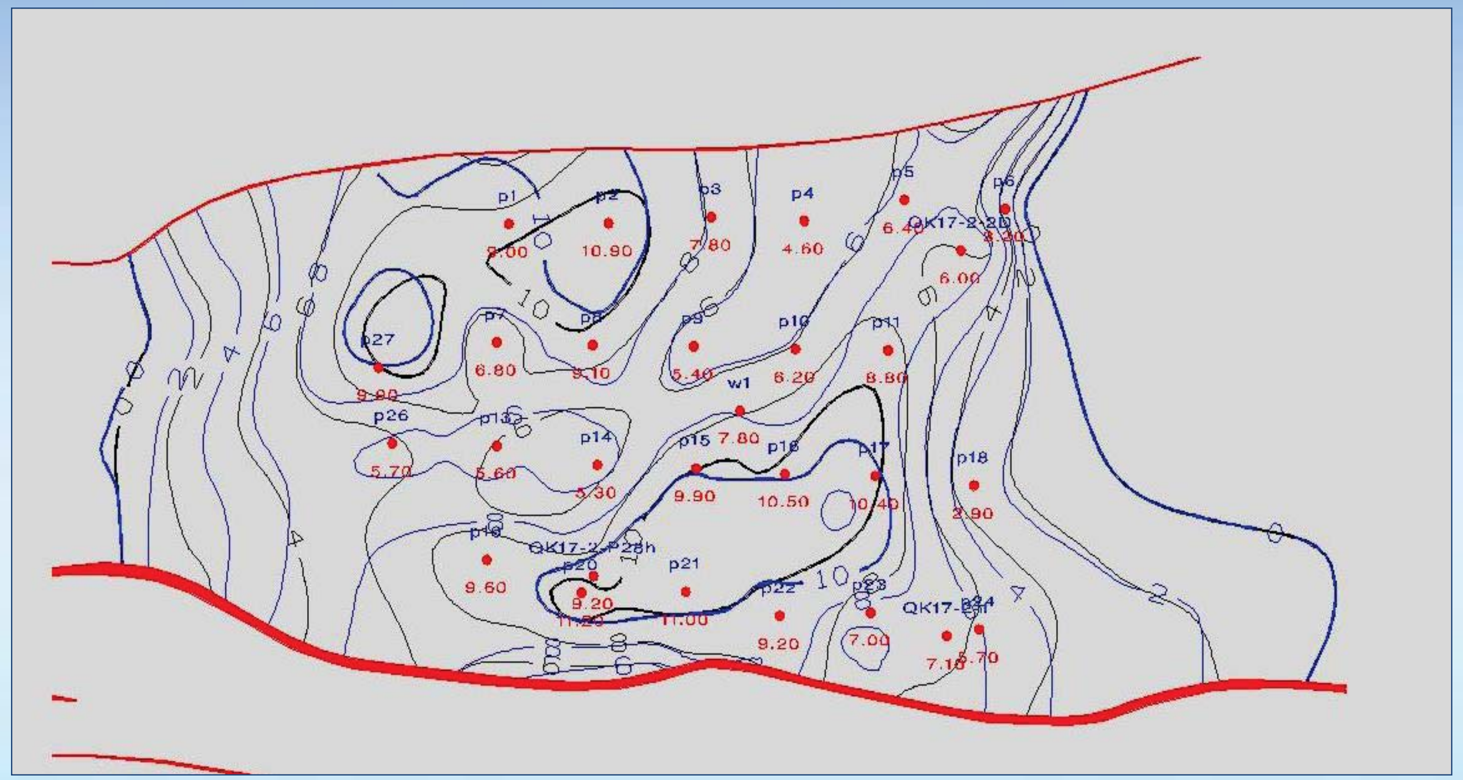

Fig8. The comparison of effective thickness of new and old. (the black line: the effective map obtained by the new method; the blue line: the effective thickness map by the traditional method)

# 3 Conclusion

In this paper, some existing problems in the process of making sand thickness map are analyzed in detail, and a new method of making sand body thickness map by seismic attribute constraint is proposed. This method is consistent with the geological law, the seismic attribute change reflects the change of sedimentary facies in a certain degree. Therefore, it is considered that the development of sand bodies with different sedimentary facies has different rules, which can effectively avoid the problems existing in the conventional process. Compared with the thickness map produced by the conventional process, the sand body thickness map produced by this method can accurately reflect the true thickness of the sand body and lay a solid foundation for the follow-up work.