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# A Study on Seismic Inversion Method for Identification of Sand

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***Abstract:*** - With the continuous improvement of exploration technology and the increasing degree of energy resource exploration, it becomes more and more demanding of looking for new oil and gas. Seismic inversion is an important method for seismic exploration and oil-gas identification. It is a process of eliminating interfering wavelet from the synthetic seismogram. By retaining the reflection coefficient sequence, thus the wave impedance can be computed. First we should make the inspection, splicing and standardized processing on all logging curves, then use statistical method to predict the relationship between the known properties and the forecasting curves, and at last determine the four parameters of geostatistical inversion: the S/N ratio of seismic data, seismic sampling rate, variogram and the ratio of total thickness of sandstone and the thickness of strata. Take Yong 56-96 block of the eighth oil recovery factory of Daqing oil field as the study area, and adopt the joint inversion method of pseudo-acoustic and geostatistics for identification of sand. As a result, its profile form is more natural, its vertical resolution and transversal extensibility are better, and its coincidence rate of the well is much higher as well.

***Keywords:*** *- seismic inversion, wave impedance, pseudo-acoustic, identification of sand*

## I. INTRODUCTION

Seismic inversion is a process of mapping on the spatial structure and physical properties of the underground reservoir combined with the data of logging, drilling and geological characteristics on the basis of the observed seismic data of land surface [1]. Judging the characteristics of wave impedance and the distribution of velocity of underground reservoir by the seismic inversion method, and estimating the reservoir parameters, we can predict the lithology of the reservoir and describe the reservoir characteristics, and then provide accurate basic data for oil and gas exploration.

## II. THE INVERSION PRINCIPLE OF SEISMIC IMPEDANCE

Seismic record is the convolution of wavelet and reflection coefficient sequence, as is shown in formula (1).

$$S(\mathrm{t}) = W(\mathrm{t}) * R(\mathrm{t}) + N(\mathrm{n}) \tag{1}$$

In which, $S$(t) is the synthetic seismic record, $W$(t) is the seismic wavelet, $R$(t) is the reflection coefficient sequence, $N$(n) is the noise series.

Assuming that the seismic incident ray is perpendicular to the rock interface, then the expression of reflection coefficient sequence of the normal incidence is:

$$R_{\mathrm{i}} = \frac{\rho_{\mathrm{i}} \mathrm{V}_{\mathrm{i}} - \rho_{\mathrm{i-1}} \mathrm{V}_{\mathrm{i-1}}}{\rho_{\mathrm{i}} \mathrm{V}_{\mathrm{i}} + \rho_{\mathrm{i-1}} \mathrm{V}_{\mathrm{i-1}}} \tag{2}$$

In the formula, $R_{\mathrm{i}}$ is the ith reflection coefficient sequence of the reflection interface, $\mathrm{V}_{\mathrm{i}}$ is the speed of the ith layer, $\rho_{\mathrm{i}}$ is the density of the ith layer.

The inversion is to estimate the inverse wavelet, so make inversion of the seismic wavelet $w$(t), and then the relationship of the inverse wavelet in time domain can be obtained as follows:

$$w(t) * a(t) = \delta(t) \tag{3}$$

In the formula, *a*(t) is the inverse wavelet, $\delta$(t) is the unit impulse function.

Making the inverse wavelet *a*(t) be in convolution with the seismic trace *s*(t), thus we can get the reflection coefficient sequence *R*(t) as the following:

$$R(t) = s(t) * a(t) \tag{4}$$

Finally, recursively calculate the reflection coefficient sequence *R*(t), after that the wave impedance values of each layer can be obtained:

$$Z_{i+1} = \rho_{i+1} v_{i+1} = \rho_i v_i \frac{1+R_i}{1-R_i} = Z_i \frac{1+R_i}{1-R_i} \tag{5}$$

Thus we can realize the conversion of the reflection profile of interface type and the stratigraphic section [2].

## III. KEY STEPS OF THE SEISMIC INVERSION

3.1 The pretreatment of the logging curve

3.1.1 The choice of the standard layer

If the target bed of the work area changes little in buried depth, then we first choose the standard well, and afterwards choose the standard layer, by taking the logging reaction of the standard layer segment of the standard well as the standard of the whole zone, and eventually we can implement the standardization of the well logging curve.

3.1.2 Method of the standardization of logging curves

①The mean correction technology

In order to determine the normalization, we compare the average logging curve of the standard layer of each well with that of all wells on the basis of the environmental correction of mud invasion.

②The histogram correction technology

After a series of environmental correction, we adopt the method of statistical analysis to make statistics on a certain curve of the standard layer, and obtain the frequency distribution histogram, then take it as the analytical calibration standard of the normalization of the logging curves, and then make statistics on the corresponding curve of the standard layer of each well, after that compare the frequency distribution with the standard well, and at last determine the normalized correction.

③Normalization of the curve of DT, DEN and GR

The curve of DT and DEN can be normalized in view of the target bed by using the histogram correction method. After the correction, we discovered that the acoustic wave changed little before and after correction, which indicates that the formation in this area is stable, and the quality of the acoustic wave is better.

④Standardization of SP curve

SP is highly influenced by depth within short distances, and the SP curve is inclined. Because the value of SP curve is relative to the limit value, first of all, we have to delimit the baseline of SP curve, and then make use of the baseline to make correction of the SP curve (Fig 1), the SP curve is dispersed before the drift of the baseline, and there is no unified standard, the wells can't contrast with each other either. After the drift of the baseline, all wells establish a unified baseline. On this basis, we choose the histogram method to complete the standardization of the SP curve in the study area.

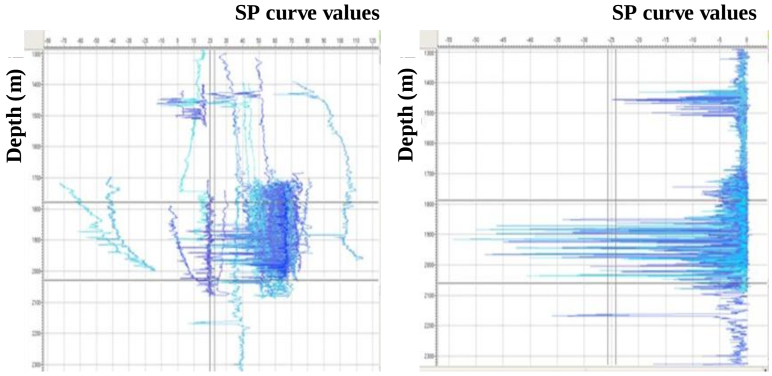


Fig 1 the before (left) and after (right) effect drawing of the drift of the baseline

⑤Standardization of resistivity curve

The resistivity curve is merely the characterization of the oiliness of reservoir, it does not represent the real value of formation, so using formula to complete standardization of the curve.

$$R_{\mathrm{std}} = \frac{\log\left(R_0\right)}{\log\left(R_0^{'}\right)} \times R$$

In which, $R_{\mathrm{std}}$ is the resistivity after standardization; $R$ is the original resistivity; $R'_0$ is the baseline value; $R_0$ is the standard baseline value.

3.2 Prediction of density curve

3.2.1 The loading of logging curves

When loading curves participating in prediction, we should as much as possible choose the curves with all wells, and make use of the curves to calculate various kinds of attributes as the characteristic curve.

3.2.2 The relationship between statistical attribution and objective curve

In most cases, the objective curve and other curves are usually not necessarily linear relationships, however, the relationships between the objective curves and the deformation of attributes(such as square, reciprocal, logarithm) are more apparent, so we must give full consideration to the deformation of various attributes in the multiple attribute prediction. Comparing the correlation of the deformation of various attributes of the measured objective curve, and sorting them according to the correlation coefficient, thus we can obtain the multiple attribute lists.

3.2.3 Determine the length of the convolution factors

Because the logging curve has a certain trend of background, if merely utilizing the weight sum method to calculate density, it may not be able to correctly reflect the background. By judging the length of the convolution factors, we can remove the possibility of producing incorrect background.

3.3 Key parameters of seismic inversion

There are four critical parameters in seismic inversion, the S/N ratio of seismic data, seismic sampling rate, variation function and the ratio of total thickness of sandstone and the thickness of strata. The appropriate parameter values can improve the inversion accuracy, reduce the multiplicity of the inversion, and lay a foundation for the application of inversion technique.

3.3.1 Well-seismic calibration and extraction of seismic wavelet

In the process of the research, we had made the wavelet estimation on the whole superposition data. After standardization of the wells in the work area, we used the conventional well-seismic calibration method to extract wavelet.

3.3.2 The S/N ratio of seismic data

The higher the S/N ratio is in the process of inversion, the greater the proportion of the seismic is in the inversion result, and the smaller the proportion of the wells is. On the contrary, the lower the S/N ratio is, the smaller the proportion of the seismic is in the inversion result, and the greater the proportion of the wells is.

3.3.3 Seismic data resampling

The purpose of seismic data resampling is the improvement of the matching degree of borehole-side seismic trace and logging data in the longitudinal direction, retain more high frequency logging information, thus further enhance the vertical resolution of the seismic [3].

3.3.4 The variation function

Variation function is a kind of statistical function. It is used to describe the relationship between data in space data field [4]. But the variation function figure is obtained by taking the lag distance h of the experimental variation function as abscissa and $\gamma(x, h)$ as ordinate(Fig 2).

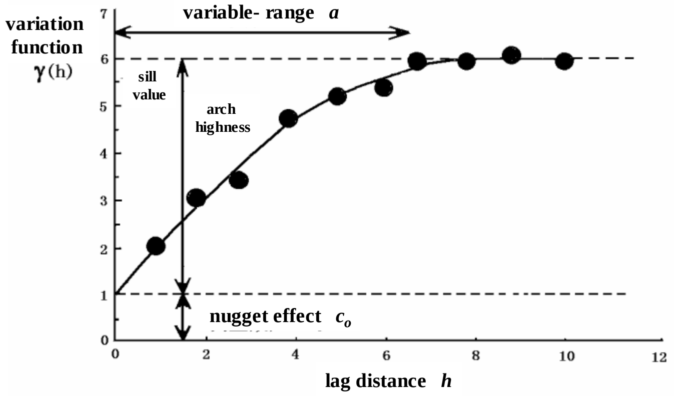


Fig 2 the schematic diagram of theoretical model of the variation function

3.3.5 The ratio of total thickness of sandstone and the thickness of strata

The value of the ratio of total thickness of sandstone and the thickness of strata has a great influence on the prediction accuracy of the inversion. The greater the value is, the more sand prediction there are, whereas the less.

## IV. SAND PREDICTION AND EFFECT ANALYSIS

Taking Yong 56-96 block of the eighth oil recovery factory of Daqing oil field as the study area, after completing the optimization of inversion parameter of this area, we conducted the inversion of the whole work area, and began to carry out the sand prediction work. Before prediction, we had first made statistical analysis on the sandstone and wave impedance data, and established diagram of the relationship between wave impedance and sandstone (Fig 3), but looking from the figure 3, in addition to the P112 layer, wave impedance cannot distinguish the sand-shale in other layers, therefore, directly using the original curve to conduct geostatistical inversion can't solve the problem of reservoir prediction in this area.

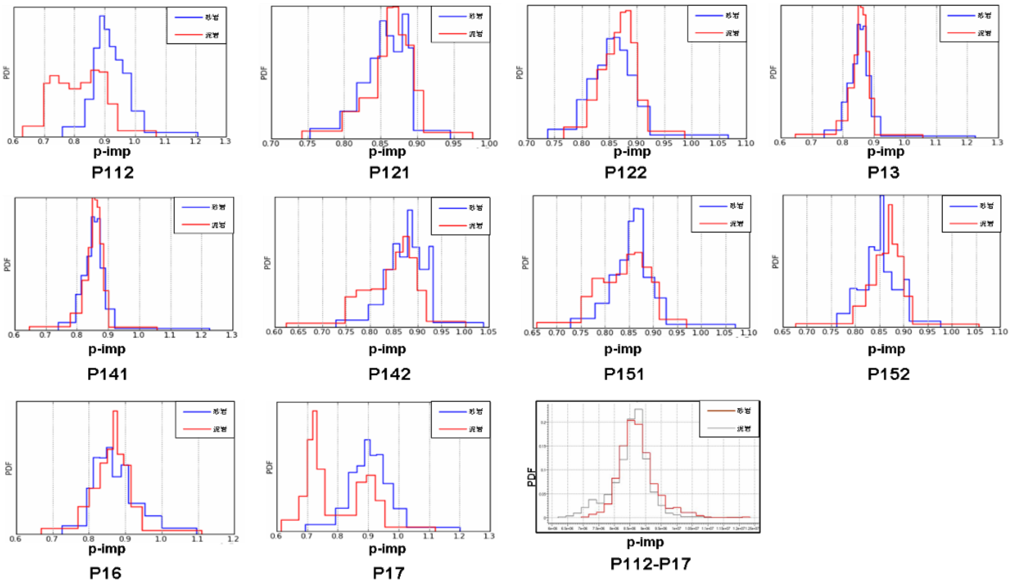


Fig 3 the histogram of the relationship between sand-shale and wave impedance in Putaohua oil layer

So we have to find the relationship between other curves and sand-shale. Looking from the figure 4 (Fig 4), the relationship of GR curve and sand-shale is the closest, for this reason, so we apply GR curve for the fitting of wave impedance, and make use of the fitting wave impedance inversion to distinguish sand-shale.

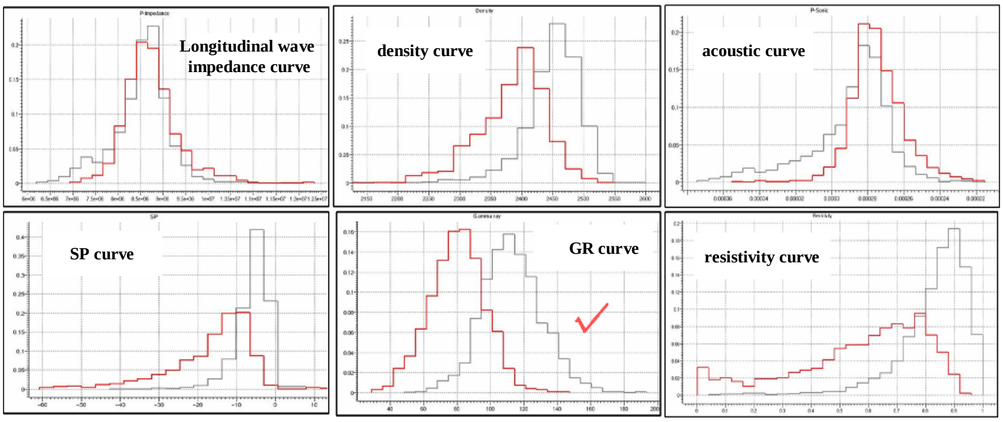


Fig 4 the histogram of sand-shale and logging curve

We have applied the yong48-S87-fang204-90 connected wells' profile to carry out contrast experiment on the joint inversion method of pseudo-acoustic and geostatistics (Fig 5), the results show that the resolution of constrained sparse spike inversion is too low, the well coincidence rate of the original wave impedance geostatistics inversion is low as well, and its profile form is unnatural.

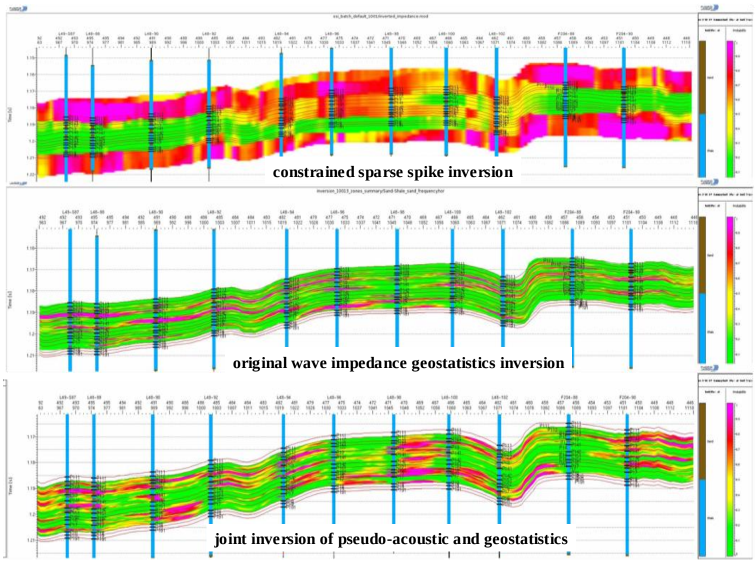


Fig 5 the contrast diagram of the joint inversion method of the fitting wave impedance and geostatistics

## V. CONCLUSION

In this seismic inversion, we have used the fitting wave impedance inversion combined with statistical inversion method to carry out sand prediction, this method combines the advantage of pseudo-acoustic and geostatistics inversion, which not only ensured the vertical resolution, but also accurately identified sand. At the same time, by adopting the joint inversion method of pseudo-acoustic and geostatistics for identification of sand in this study, its profile form is more natural, its vertical resolution and transversal extensibility are better, and its well coincidence rate is much higher too.

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