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Inversion prediction of reservoir in Putaohua reservoir of Aobaota structure and it`s both wings

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Abstract: Inversion prediction of reservoir is one of the effective method to realize the sand body all the time. Sand body space cognition in Putaohua reservoir of Aobaota structure and it`s both wings is not clear, which restricted the further exploration and development in the area seriously. The reservoir prediction by sparse pulse inversion is loyal to the original data and loyal to the well data, seismic data inversion, the inversion results and drilling results well point agree, participate in the well and a posteriori error is very small well. The error of partake wells and posterior well is small.

I. INTRODUCTION

Well seismic inversion is one of the core of reservoir prediction, and it has become an important means of reservoir description of reservoir[1-4]. The study area is located in the South of Songliao Basin in Daqing Changyuan two grade tectonic unit, go across Putaohua upper bend and Aobaota structure two three grade tectonic units, and it mainly composed of south of Putaohua upper bend and north of Aobaota structure, east to Sanzao sunken, west to Gulong sunken, the main construction extending direction is NNE, the study area north south high low, middle high and two sides low. Study area of about 320 km^2. The inversion layer is mainly of the upper CretaceousYaojia Putaohua reservoir.

At present, in the study area, 133 wells have been drilled evaluation, the Putaohua oil 90, oil test obtained industrial oil flow in 67 wells, oil-gas exploration potential in this area shows good. With the exploration and exploitation of the deepening of oilfield development area, the geological conditions are relatively good, oil gas water distribution relatively simple reservoir (the central anticlinal zone) chang to the poor geological conditions, oil and gas reservoir water distribution complex (East and west slope region)change. But in the East and West wings of Putaohua reservoir evaluation and favorable zone optimization work, the most difficulty is that reservoir thickness of vertical and lateral is variations, and thin interbeds of sandstone and mudstone is the main characteristics, spatial distribution of sand body clearly, oil scale and area are difficult to implement. Therefore, need to carry out prediction of reservoir sand body of grape flower based on existing geological theory and exploration results, to provide an important theoretical basis for the assessment of potential resources of the study area blank of Putaohua reservoir in block and select advantageous zones.

II. THE BASIC WORK IN RESERVOIR INVERSION

A The single well sandstone characteristic statistics

First of all, we must have a clear understanding of the sedimentary characteristics anddevelopment of sand body size, type of study area, on the basis of that, then we can choose proper inversion method.

We consulted study results of sedimentary facies, at the same time, according to a single well in sandstone interpretation data, the statistics of Aobaota areas of reservoirs (table 1), following conclusions are obtained:

(1) The study area is mainly delta front facies and shore shallow lake Hunan deposition, deposition of sand

body thickness, and the distribution area is small.

(2) Through statistics of different sandstone thickness of sand body, different sandstone thickness of sand body varies greatly, the single sand body thickness is 0<h<1,PI6-7, sandstone group relative to PI3, PI4-5, P8-11 three sandstone group of single sand body thickness.

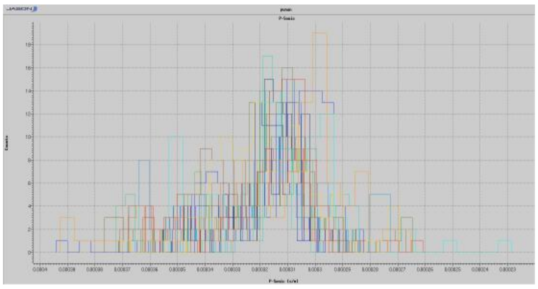
table 1 Different sandstone thickness distribution of single sand layer

Sand group	0m<h<1m	1m≤h<2m	2m≤h<3m	3m≤h<4m	H≥4m
PI3	56.0%	35.9%	6.25%	1.5%	**0.35%**
PI4-5	57.3%	35%	5.4%	1.9%	**0.9%**
PI6-7	38.5%	38.3%	15%	6%	**3.2%**
PI8-11	54.8%	34.4%	8%	2.1%	**0.5%**
all	**51.65%**	**35.9%**	**8.64%**	**2.88%**	**1.24%**

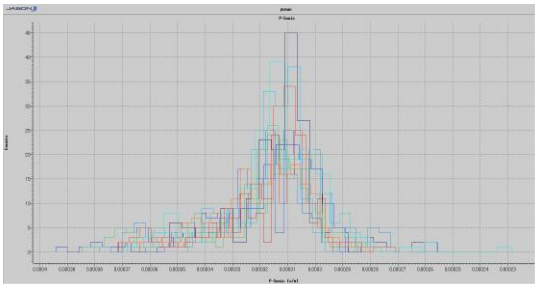
B Well logging data standardization

If you want to make reservoir prediction in the area, well logging data processing is particularly important. The curve of choice, not only to control the curve quality, but also Taking into account the all study area, in order to better realize the reservoir prediction, particularly for the well point control and constraint in the well populated place, in order to be able to control, inter well sand body distribution, and to achieve accuracy requirements. Differences in logging instrument type, standard calibrator and the different mode of operation is the main reason to cause the system errors of different well logging curves are similar, according to the similar logging curve of the same section in the same field or area has the characteristics of self similar distribution, standardization can be unified in the same log well to ascale, so as to eliminate the system error caused by the above reasons.

Through the research discovery, little change in resistivity curve, so do not standardized. This is mainly on the acoustic curve (AC) using the histogram processing method. Standardization of acoustic curve histogram peak distribution, while the distribution histogram peak concentration after standardization (Fig. 1).



a.Statistical histogram before sonic curve correction



b. Statistical histogram after sonic curve correction

Fig.1: Before and after the sonic logging curve standardization

C Fine calibration of synthetic seismogram andwavelet extraction

Through the spectrum analysis, the frequency distribution of seismic data in 18-89HZ, frequency is 60HZ, the quality of seismic data is better, can meet there quirements of inversion(Fig. 2).

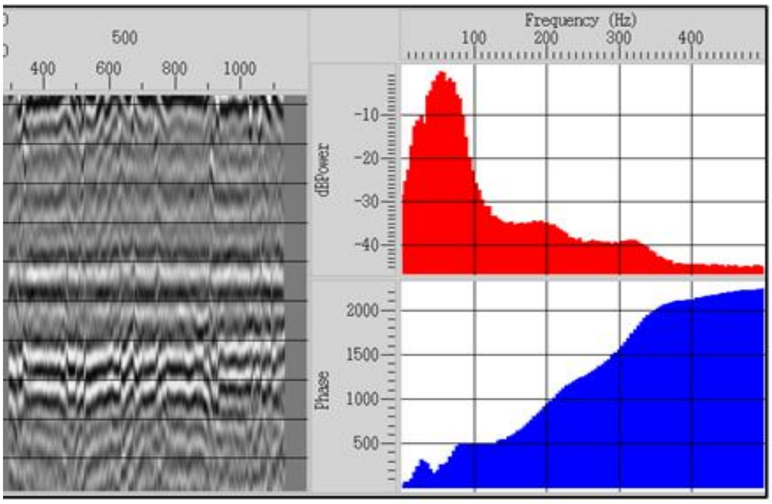
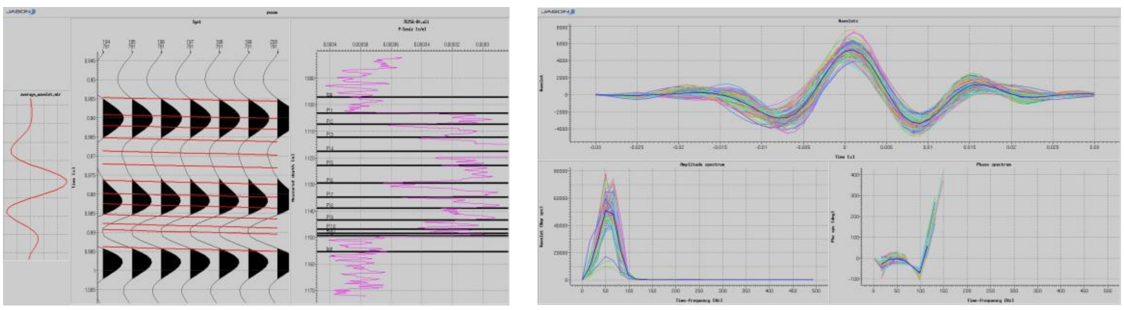


Fig.2: Analysis of spectrum

Synthetic seismic record accuracy directly affect the corresponding relationship of seismic and geological layers, is the precondition for fine reservoir prediction[5]. Making a synthetic seismogram wells to meet: Logging curve, curve without distortion value, integrated strata (try to avoid the fault of the wells). If no density log curves, the general can use sonic curve and Gardner equation fitting density curve, making synthetic seismogram using sonic curve and density curve.

A critical step of the seismic horizon calibration is wavelet extraction, noticing wavelet extraction from the actual seismic, laying stress on the quality control of wavelet, consistent with the frequency of the dominant frequency of wavelet and real seismic data.

The study area respectively on 350 wells in making synthetic seismic record, and extract their wavelet, and then calculate the average wavelet. From the figure shows average wavelet is positive phase wavelet, frequency is about 50HZ (Fig. 3), consistent with the earthquake; In the effective frequency band phase basically zero phase, and more stable, sidelobe is more stable, and can be used for inversion of the follow-up work.

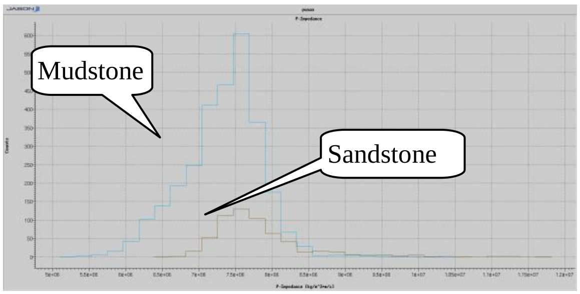


a. Well to seismic calibration b. Average wavelet, amplitude spectrum, phase spectrum

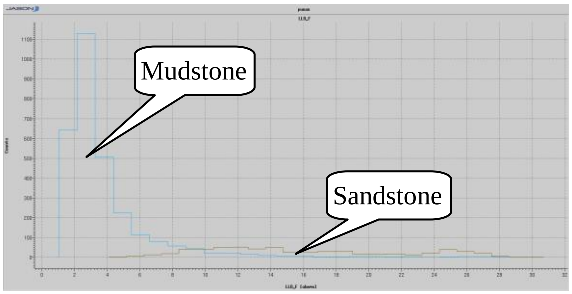
Fig.3: Fine synthetic seismogram calibration

III. SENSITIVITY ANALYSIS OF LOG CURVE AND LITHOLOGIC

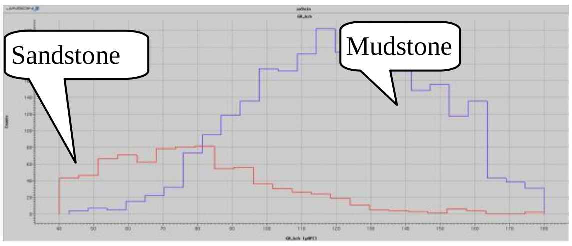
In order to distinguish sandstone, mudstone, good reservoir prediction, based on the preprocessing of logging curves, the sand, mudstone and various log curves (IMP,LLD, SP, GR) by overlay analysis. Through the study area histogram (Figure 4) can be seen, the wave impedance curve of sand, mudstone response is not obvious; The resistivity, natural gamma curve and the curve of natural potential value on the sand, mudstone response is more obvious, can well distinguish sand, mudstone in the work area. The inversion mainly uses the resistivity curve inversion[6,7].



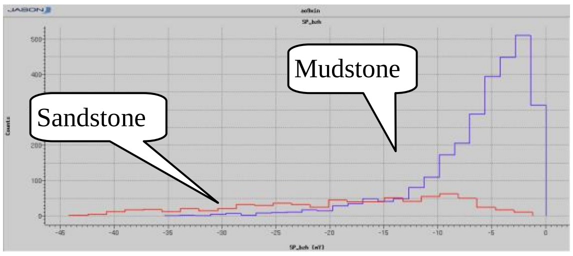
a. The wave impedance curve



b. Resistivity curve



c. gamma ray curve



d. the spontaneous potential curve

Fig. 4: sensitivity analysis of different logging response and lithology of Study area Putaohua reservoir

IV. CHOOSE BETTER INVERSION METHOD

The inversion method commonly used has the relative wave impedance inversion (integral), recursive inversion, seismic inversion basedon model, multi parameter lithologic seismic inversion, geostatistics inversion and Markov chain Monte Carlo inversion based on. Any kind of method in the prediction of seismic inversion and reservoir has its own scope of application (table 2), In practical work should be based on the different stages of exploration and development and the specific geological problems, the combination and inversion method to select, or choose geophysical attributes effectively, interpretation and application of the reasonable.

table 2: Different inversion methods advantages and disadvantages, applicable conditions

inversion methods	advantages	disadvantages	applicable conditions
relative wave impedance inversion (integral)	The calculation is fast and simple, recursive accumulated error is small, has a clear physical meaning	Low resolution, it is difficult to meet the need of thin layer interpretation acc uracy is relatively low	The initial exploration of lateral reservoir prediction
recursive inversion	Solution effectively restricting the inversion results, preserve more seismic data its amplitude, frequency and phase characteristics	The inversion results of low resolution	Each stage of exploration
Seismic inversion based on model	To overcome the deficiency of seismic data inversion results bandwidth, high resolution, tallies with actual drilling, reservoir resolution capability.	restricted by drilling number, in the case of a few well effect is not ideal	more drilling area
Geostatistical inversion	The inversion results of high resolution, can carry out the inversion results of uncertaintye valuation	Drilling in small area, because the statistical regularity is not strong artifact.	more drilling area

Markov chain Monte Carlo inversion	Objective to retain the geophysical information true, high vertical resolution, risk assessment to the inversion results, effectively overcome the multiple solutions;	The disadvantage is the data requirements are more demanding, time consuming, complex operation。	more drilling area

Considering the actual geological conditions of study area (area belongs to the low well district), main geological task is to identify the external area of sand body distribution law, but these areas drilling is relatively less and the distribution is not uniform, but both broadband constrained inversion model or multi parameter lithologic seismic inversion has higher requirements on well spacing density based on theinversion accuracy, have very high correlation with the well spacing density, so these methods are notapplicable in this area, inversion has multi solutions has not test, on the other hand also has risk exploration. Therefore, we choose the constrained sparse spike inversion in the area (seismic inversion method based on) combined with geostatistics inversion, constrained sparse spike inversion can more reflect the original features of the seismic data, has high reliability insparse or no well area, but because of the limited seismic data, the vertical resolution ability is limited, therefore, of geostatistical inversion on the basis of it, using CO kriging technique, I Chumi Ima Chumi from logging data, seismic wave impedance, effective integrated seismic and well log data, vertical wells with higher resolution, better reflects the characteristics of seismic data, reservoir prediction and inversion research. The inversion process as shown in Figure 5, through well seismic fine calibration, reservoir inversion, and combined with the geological study on equalled position, reservoir sand body distribution and plane distribution characteristics of sand body prediction.

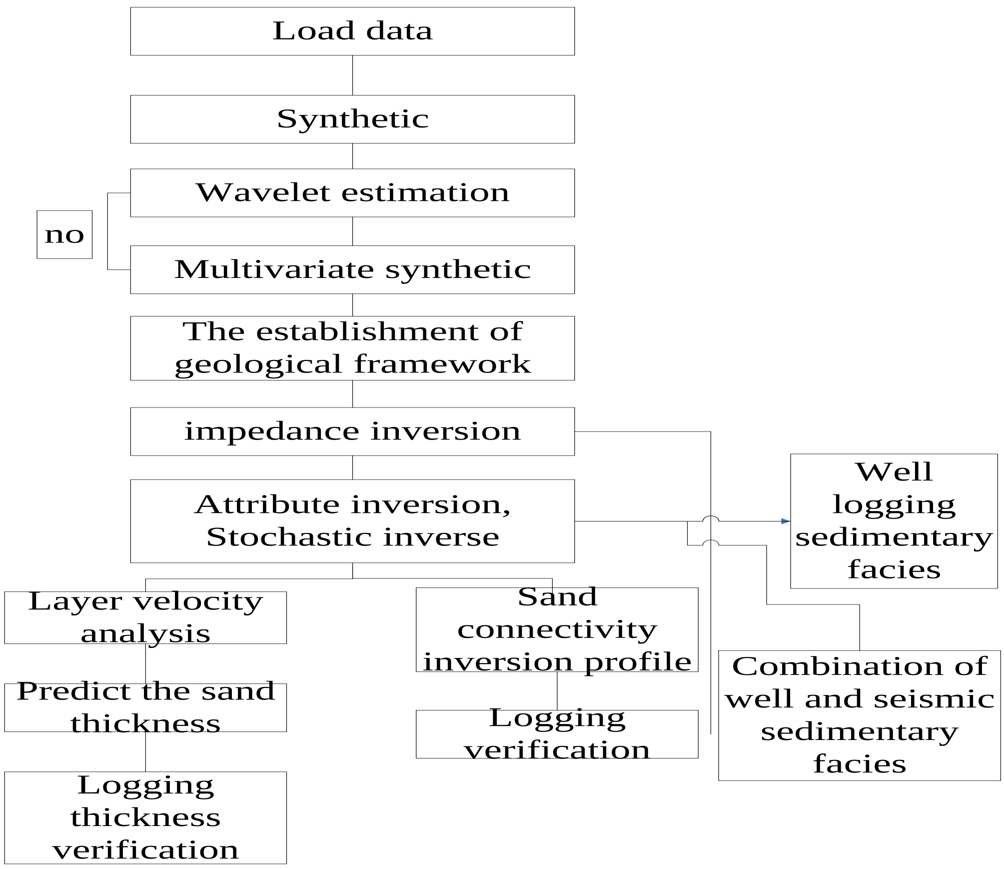


Figure .5: the study area Putaohua reservoir inversion technology route

V. CHOOSE INVERSION EFFECT EVALUATION

A sparse spike impedance inversion and stochastic inversion

(1) sparse pulse wave impedance inversion: low vertical resolution, sand and mud in the fuzzy boundary, Putaohua reservoir can be identified a set or two sets of sand body, but the inversion has high credibility, finally the original seismic information, sand lateral continuity, can reflect the overall trend of the development of sand body (Fig. 6).

(2) stochastic inversion: the sequential Gauss configuration co simulation of stochastic inversion, the inversion results of sandstone with clear boundary, the longitudinal resolution is high, can identify the reservoir thickness range is large,the inversion method of reservoir prediction of ideal (Fig.7). Suitable forreservoir facies belt type changes fast, multi region, to find the tectonic, lithologic oil and gas reservoirs is very ideal.

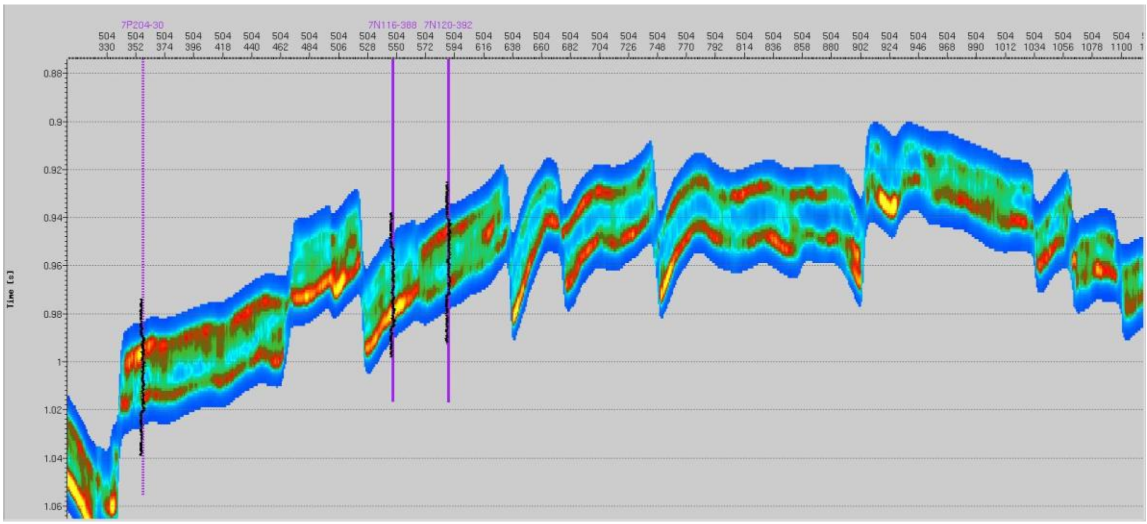


Fig. 6: The study area sparse pulse wave impedance inversion profile

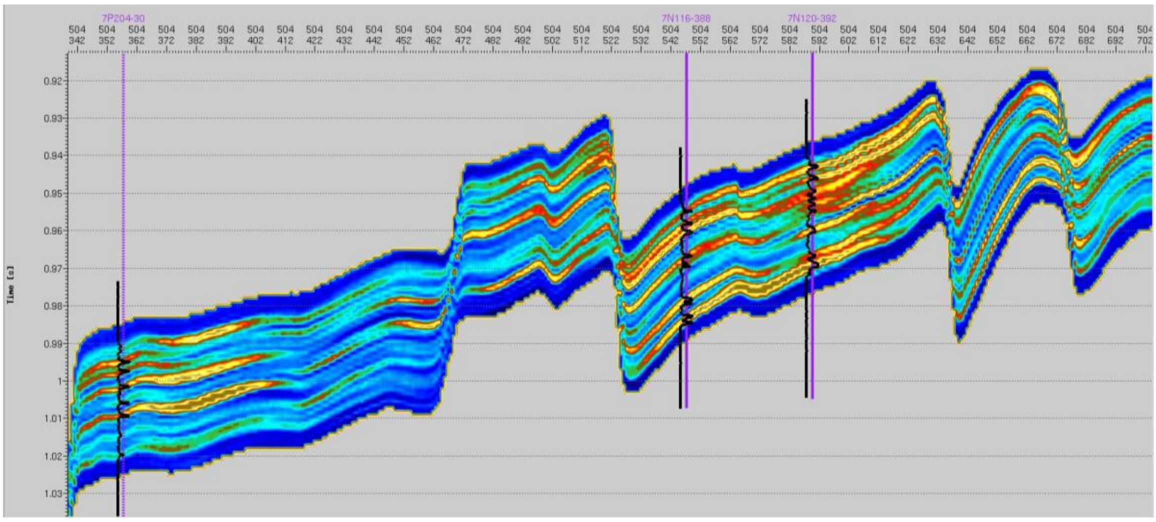


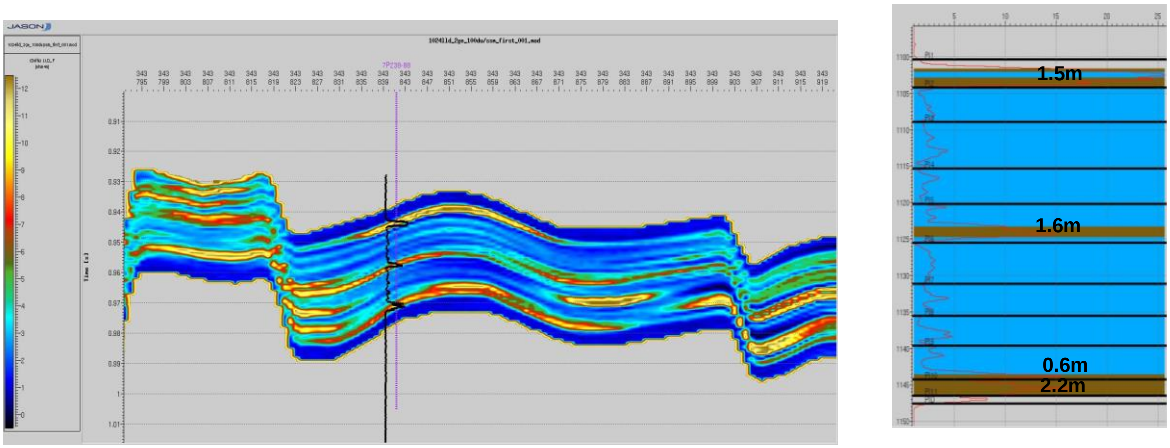
Fig. 7: The study area random resistivity inversion section

B The longitudinal resolution evaluation

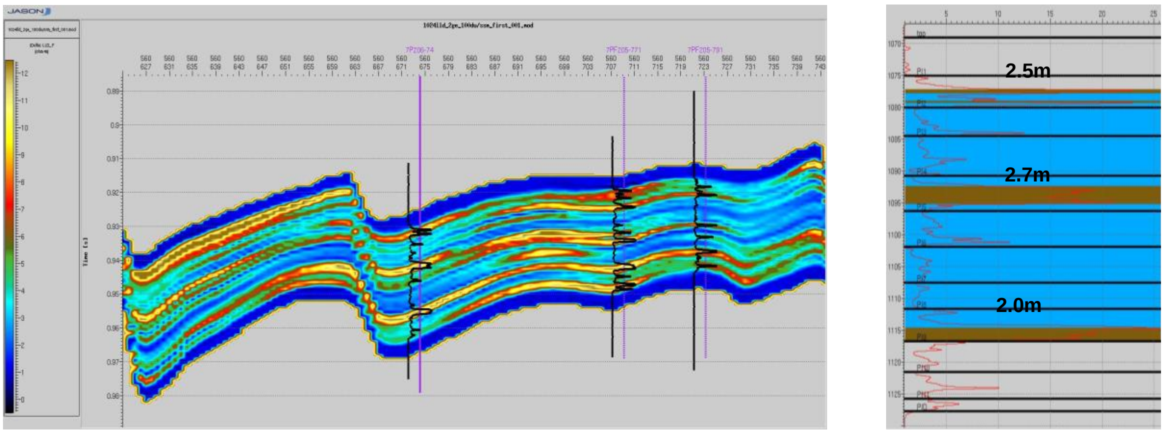
The vertical resolution is an important index to determine the inversion precision,it decides whether the fine description of the distribution of sand body in each layer. The inversion results of the resolution, which is one of the evaluation indexes and participate in wells and posterior well anastomosis. In the area of choosing a participation in the wells and aposteriori well test.

Selected to participate in the 1 test wells as well (Fig. 8a). In 1 wells are mainly developed 4 sets of sandstone, a set of about 1.5m development in PI1 layer within the sandstone, the PI5 layer growth of 1 sets of sandstone, as 1.6m, a set of about 0.6m development in PI10 layer within the sandstone, a set of about 2.2m development in PI11 layer of sandstone. From participation in the well inversion profile can be seen, if the single sand body of the longitudinal distance,the inversion of the longitudinal can accurately identify more than 1.5 sandstone,lithologic and anastomosis of inversion is better. But when the reservoir is toothin and two sets of sandstone are near, only when a set of sandstone combination inversion (PI10 and PI11 out of small layer sand body adjacent too close, can be considered as a set of sandstone inversion).

The posterior 1 wells (Fig.8b) as a posteriori well logging interpretation, the 3sets of sand body, set in the PI1 layer, is about 2.5m; set in the PI4 layer, is about 2.7m; set in the PI8 layer, is about 2.0m. From the 7P206-74 well inversion profile, interpretation of the 3 sets of sand body has show.



a. In the wells 1 inversion profile (inline) and sand mudstone interpretation (in wells)



b. posteriori wells 1 inversion profile (inline) and sand mudstoneinterpretation (posteriori well)

Fig. 8: Vertical resolution test (contrast inversion and lithology)

VI. THICKNESS OF SAND BODY PREDICTION AND ERROR ANALYSIS

A sandstone thickness prediction

Research on distinguishing total thickness through the above methods (PI11) and PI3, PI4-5, PI6-7, PI8-114 sandstones by inversion of the sand body prediction, get 5 sandstone thickness prediction, forecast map with a totalthickness of sand body (Fig. 9) as an example to analyze the prediction results.

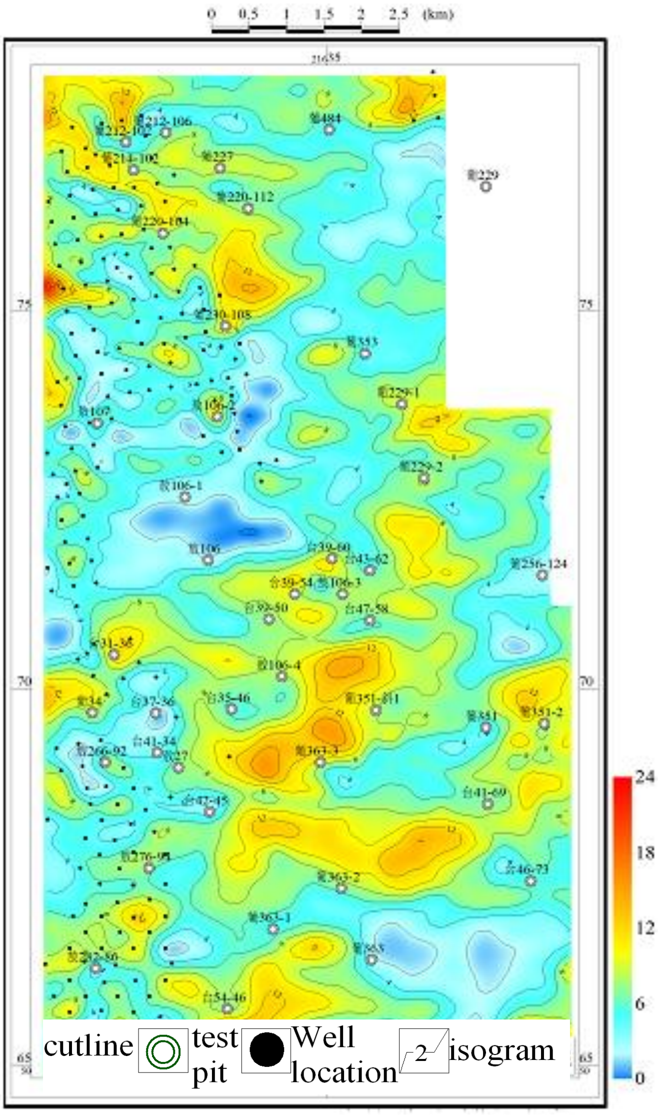


Fig. 9: Putaohua oil bearing sand thickness prediction map

Controlled by sediment provenance and sedimentary facies of the study area,distributary channel, mouth bar, sheet sand, intermittent and far sand damdeposition, which is characterized by sandstone thickness change is more complex, in the North West, north-south strip or sheet distribution, from the totalsandstone prediction map can be seen between the area, total thickness of sandstone between 0~23, meters, generally more than 10 meters, the area ofNorth and south there are high value areas of regional distribution.

B Error analysis

Error statistics to predict the thickness of sand (Fig. 10), between sandstone thickness ranged from 0-23m to the prediction of sandstone thickness, the absolute error absolute error of <0.5m accounted for 75%, >1m accounted for 3%(3-32), which explains the high precision inversion, the inversion results can reflect the planar and spatial distribution rule of sand body.

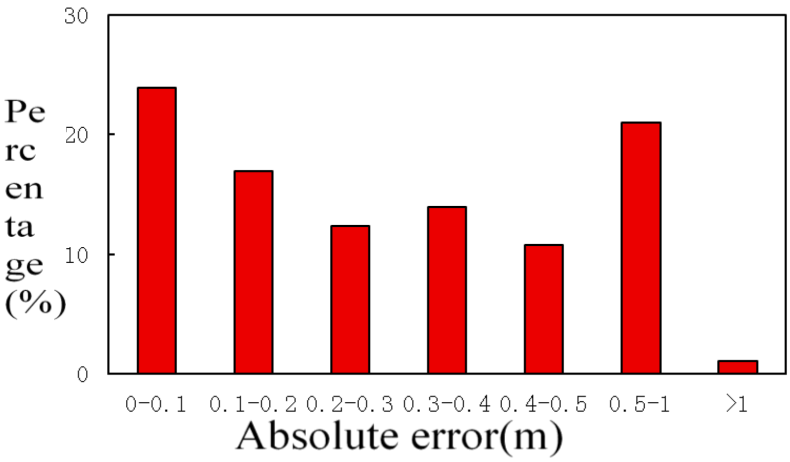


Fig. 10: Sand thickness prediction absolute error histogram

VII. CONCLUSION

A Logging data to standard can effectively improve the accuracy of inversion;

B Sparse pulse inversion and stochastic inversion combination has better application effect in thin and poor reservoir, the sparse and uneven area;

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