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Quantitative Predication for Reservior Porosity via AVO

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Summary

Daqing Changyuan Fuyu pay is the focus target pay for the next exploration and development, sand thickness is generally less than 5 meters, porosity less than 10%, permeability about 1md, is a typical thin reservoir with low porosity and permeability, it is difficult for effective reservoir prediction as seismic data resolution is low. To address this problem, we try to apply the inverse Q filtering method to improve the resolution of seismic gathers; AVO information in the far offset traces is prominent. With high-resolution CRP gathers, AVO multi-attributes forward modeling was performed; results show that porosity changes are more sensitive to AVO attribute compared with saturation, there is good positive correlation between |G|/P and porosity, so it is possible for quantitative prediction of porosity via AVO attribute, the method is applied to the actual data, and good result was achieved, predication coincidence rate is more than 80%. X11 well deployed via the result achieved 40 tons / day.

Introduction

The main factors affecting the thin layer resolution include: first is the 60% -90% loss of seismic waves pass energy attenuation, and this part of the energy mainly includes the high-frequency signal; second is strong interference effects on high frequency signal caused by the adjacent layers, it is difficult to effectively maintain AVO characteristics, as well brings the problems to perform pre-stack inversion. For this reason, on the basis of the preserved amplitude processing, we try to apply the inverse Q filtering method to improve the high-frequency effective information as well expand the range of available of CRP gathers and lay the foundation for effective reservoir prediction.

For Thin sand body reservoir prediction, we studied the variation law between AVO attribute parameters and reservoir properties, and then determined the quantitative interpretation chart for porosity by using the AVO attribute, and good result was achieved, predication coincidence rate is more than 80%. X111 well deployed via the result achieved 40 tons / day.

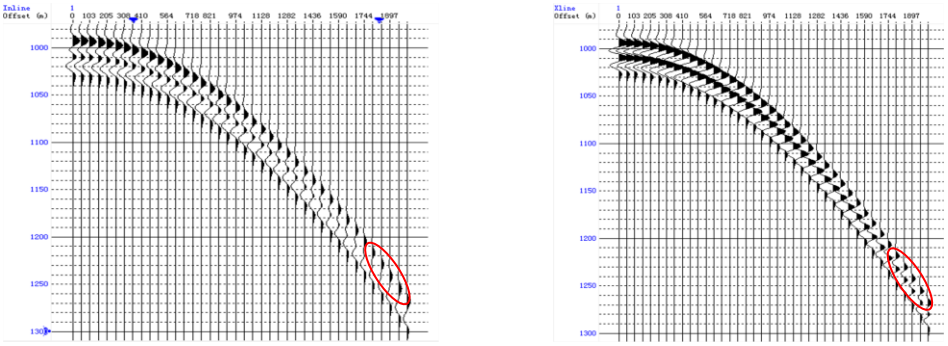
Method

CRP gathers optimizing technology by inverse Q filtering method

Optimization of CRP gathers is very important before carrying out pre-stack inversion. The quality factor Q itself reflects the physical characteristics of the formation rock, inverse Q filtering method works well in eliminating the dispersion absorption of seismic waves energy in the underground medium, as well improving the vertical resolution of seismic data. In this paper, we use the attracting Q value in CMP gathers method (Chang, 2002) and Hale algorithm Q compensation (Hale, 2002).

With a view to verify the effectiveness of the method, a double-layer geological model is designed, for a two-layers CMP gathers(figure 1a,1b), two reflection traces are tuned by interferences and formation absorption in the far offset traces(as shown in the circle) .

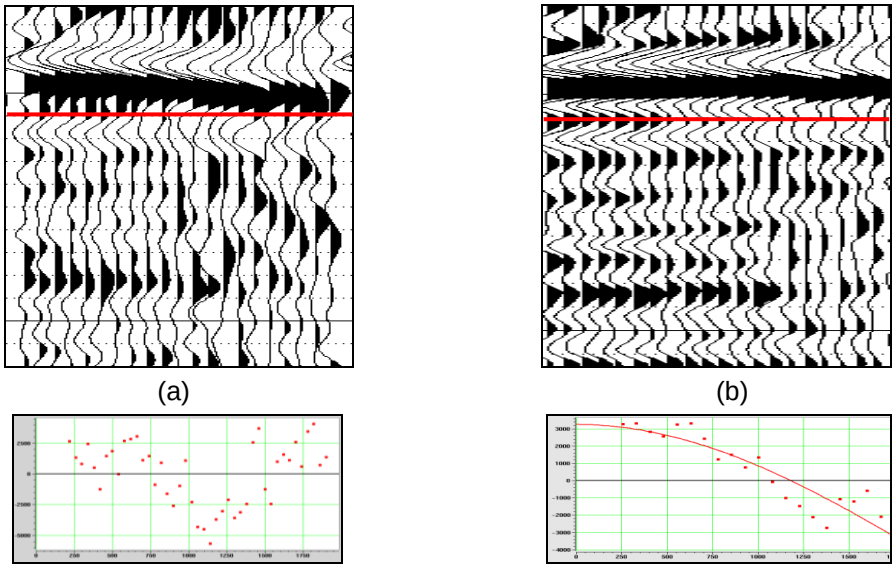
As shown in Figure 1, after compensation, the wavelet phase obtains good correction, due to the dispersion caused by the phase delay is eliminated, wavelet frequency is also improved, the reflection phase traces are compressed in the time domain, the two layers due to the tuning effect can also be identified, as well as improve the resolution of the far offset traces, and also expand the available range of AVO gathers, is of great significance for the identification of oil information. Meanwhile, this method is used for the actual data, as shown in figure2, AVO gathers resolution has been markedly improved after the processing, more important is the elimination of the distortion of the AVO curves, AVO characteristics are effectively maintained.



(a) (b)

Figure 1: CRP Comparison before Q filtering and Q filtering for model data

(a) Model CRP gathers before Q filtering (b) Model CRP gathers before Q filtering



(a) (b)

(c) (d)

Figure 2: CRP Comparison before Q filtering and Q filtering for actual data

(a) Actual CRP gathers before Q filtering (b) Actual CRP gathers after Q filtering

(c) AVO Curve before Q filtering (d) AVO Curve after Q filtering

AVO Forward Modeling and Quantitative Predication

The reservoirs are generally exists in the area of high abundance of high porosity and permeability, so how to highlight the favorable reservoir effectively has been a major problem in the geophysical

interpretation of the physical properties of sands. This paper presented a new AVO attribute to conduct the predication of physical properties quantitively. As we know, Changes relationship between amplitude and offset is very complex, mainly due to the ways of different offset seismic waves through the stratigraphic structure, elastic medium, lithology combination is different. lithology and physical properties could be described by analyzing the variation of seismic amplitude versus offset offsets. The AVO type of fuyu pay is Class I, there is almost no difference between oil sand and non-oil sand, and nevertheless, we still conducted multi-parameters AVO forward modeling to study the variation law between AVO attribute and physical parameters, trying to find some variation relationship between AVO attributes and reservoir properties.

Based on this, we designed two forward models, the first one is the saturation model with the same thickness sand (3m), but filled with different saturation by using Gassman replacement method, and then take advantage of the wave equation to perform the AVO forward, observe the AVO characteristics changes with saturation changes; the second one is the porosity model with the same thickness sand (3m), but filled with different porosity by using Gassman replacement method, and then take advantage of the wave equation to perform the AVO forward too, observe the AVO characteristics changes with porosity changes; P-wave velocity of sand is 3900 m/s, S-wave velocity is 2300 m/s ,Density is 2.5g/cm^3, S-wave velocity of sand is 3300 m/s, S-wave velocity is 1600 m/s ,Density is 2.46 g/cm^3, Figure 3 for saturation forward results, Figure 4 for porosity forward results.

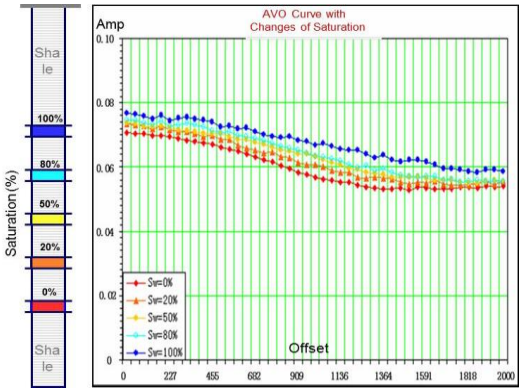


Figure 3: Saturation forward results

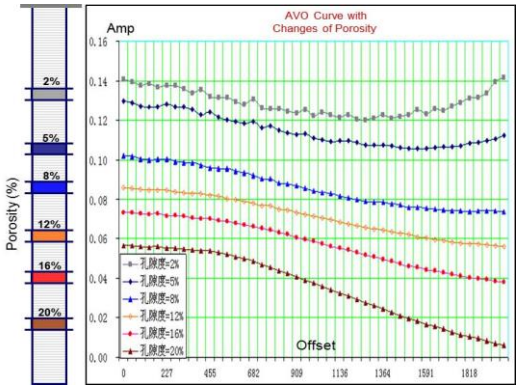


Figure 4: Saturation forward results

From the saturation simulation results, with the increase of water saturation, the AVO curve type are for Class I, intercept (P) decreases slightly, while the slope (G) substantially no change, we know compared with intercept (P), the slope (G) can indicate the oil information more effectively and sensitively, and in this example, the slope is substantially constant, so it is difficult to identify the oil from water.

From the simulation results of the porosity, as the porosity increases, intercept (P) decreases and slope (G) increases as well. Although the P, G changes caused by changes of physical properties are evident, but this change is the opposite, we found that neither a single parameter intercept (P) slope (G) attribute, nor a combination of multi-parameters, like Poisson's ratio property (P+G), shear wave reflection coefficient the attributes (P-G) the hydrocarbon detection properties (P*G) can better describe the reservoirs.

According to P and G, we adopted the (|G|/P) attribute, because it can enlarge the high porosity, and thus highlight the effective reservoir. Figure 5 shows the (|G|/P) profile cross X69 well. It can be found that in the profile the 20th pay (porosity is 13.6%) in X69 (Figure 6) is portrayed clearly, with a small and lens like channel sand.

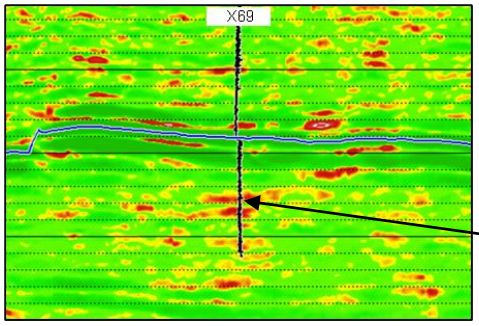


Figure 5: (|G|/P) profile cross X69

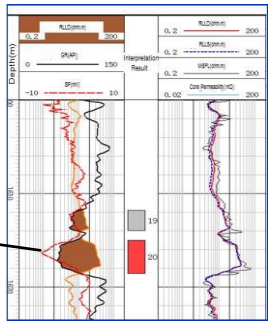


Figure 6: log Interpretation of X69

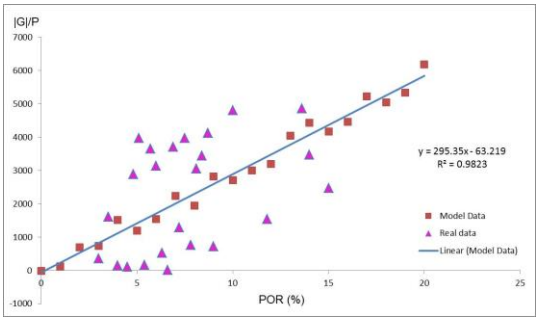


Figure 7: Cross plot between (|G|/P) and porosity

In order to achieve the purpose of the quantitative description of the reservoir, the porosity model is refined, the interval is set to 1, and re-simulated, (|G|/P) value of each sample is obtained, and cross-plot is drawn.

Figure 7, the X axis is the porosity, and the Y axis is (|G|/P), as from the cross plot results, with the porosity increases, (|G|/P) and the porosity have a linear correlation relationship, fitting this trend, correlation coefficient is over 98%. To further verify the accuracy of the model, we conduct the same forward by using a total of 24 samples of the coring in the area of 18 wells. Most of porosity of the cores distribute from 5 to 10, the similar cross plot can be obtained (figure 7). From the results, although the trend is not as evident as model, they have roughly linear relationship too.

This provides the possibility to predicate reservoir physical property quantitatively. The lower limit of effective porosity of fuyu pay is 8%, from figure 7, we can easily check the corresponding (|G|/P) value is 2330, set the value as the effective reservoir cutoff; the value is greater than 2330 for effective reservoir, is less than 2330 for tight reservoir. So the quantitative interpretation results of the porosity of this whole region can be drawn (as shown in figure 8), red color shows the area of high porosity and blue color for low porosity region.

From the predicted results, the high porosity and permeability reservoir distributes stripped, respectively located in the western, central and eastern parts of the work area. We conduct a statistics about predication coincidence rate, 13 wells are involved, the average coincidence rate is over 80 %(as shown in Sheet 1).

Especially in the central part, there is X69 well (as shown from figure8), we can see some meandering river sedimentary characteristics, clear meandering river and point bar can be found, which is consistent with geological research. X69 has 7.6 m pay in the target layer, porosity is 13.7% (Figure 6, 20th layers), the daily oil production of 18 tons / day, so it can be drawn a preliminary conclusion that it is a high oil enriched zone. Therefore based on the result ,another well X11 well(figure8, the black dot) was deployed in north of X69, the well has been completed, which encountered 16.8 m pay in the target layer, the porosity of 14.3%, is consistent with the predication result, the well testing production is 40 tons/day, which also verify the effectiveness of the method.

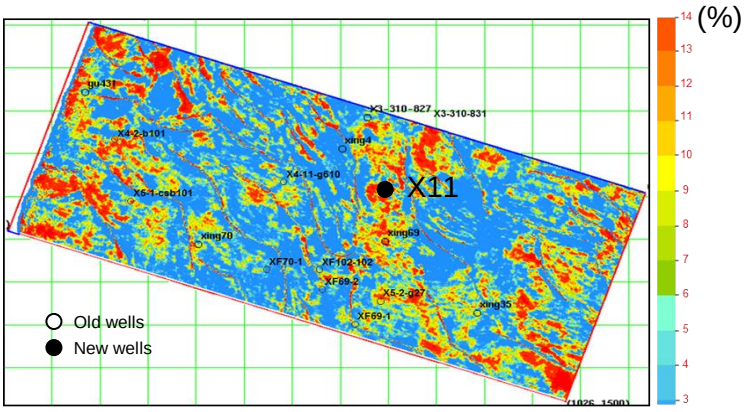


Figure 8: Quantitative predication result for the whole zone

Sheet 1: Statistics about predication coincidence rate for the whole zone

Well / Result	X69	X35	X70	GU431	X70-1	X69-2	X69-1	X5-2-G27	XF102-102	X4-11-G610	X3-310-827	X6-1-CSB101	X4-2B101
Real	13.7	7.4	5.5	6.5	4.4	3.8	6.9	8.6	5.9	7.5	6.4	10.9	12.9
Predication	13.1	9.1	7.2	7.1	4.6	5.4	8.5	9.5	6.1	8.3	7.7	13.5	14
Coincidence Rate	0.96	0.77	0.69	0.91	0.95	0.58	0.77	0.90	0.97	0.89	0.80	0.76	0.91

Conclusions

- Quality factor Q itself reflect the physical characteristics of the formation rock, inverse Q compensation is an effective measure to improve the resolution, by using Q compensation processing, interference effect was weakened for the far offset traces, as well expand the available range of AVO gathers, AVO characteristics were preserved.
- AVO forward shows porosity is more sensitive to AVO attribute compared with saturation, that (|G|/P) attribute is an effective method to describe the effective reservoir.
- Quantitative prediction chart was determined through the study about the relation between reservoir physical properties parameters and AVO attribute, good result was achieved, predication coincidence rate is more than 80%. X11 well deployed via the result achieved 40 tons/day.

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