Amsterdam '14

Tu SP4 11

The Analysis of AVO Dispersion Attributes in Thin Tight Inter-layer Reservoirs

W. Hu* (Jilin University), L.G. Han (Jilin University) & P. Zhang (Jilin University)

SUMMARY

Analysis of AVO dispersion has been one of the hottest topics of reservoir prediction, it can improve the precision of hydrocarbon detection. The previous researches show that strong velocity dispersion and dissipation will appear in petroleum and hydrocarbon reservoir, it also can be a new fluid indicating parameter used to detect hydrocarbon. Horizon interpretation is complicated and difficult in thin inter-layer reservoirs. Therefore, thin inter-layer models are constructed to confirm the usefulness of AVO dispersion value in such layers, and frequency division processing is used to help reservoir prediction. Then make dispersion analysis for a gas field to further confirm its availability in real data.

Introduction

Thin inter-layer tuning effect will make reservoir description much more difficult and complicated. The research shows that change of reservoir type will lead to changes of dynamical characteristics of seismic wave in thin bed and thin inter-layer, especially for the change of frequency with velocity. Although the specific mechanism cannot be presented clearly so far,the researchers in Colorado School of Mines have shown dispersion phenomenon in their laboratory (Batzle et al., 2001). A great number of researchers try to define dispersion phenomenon theoretically. Some researchers build models which are composed of two elastic layers and one layer filled with fluid in the middle, to confirm dispersion phenomenon (Chapman et al., 2002, 2006). Researchers in University of Houston have confirmed this phenomenon by theoretical calculation and experimental observation (Ren et al., 2009). AVO dispersion theory shows that dispersion phenomenon can be found in oil&gas reservoir.Spectral decomposition is becoming a distinctive reservoir description technology. Conventional time frequency analysis techniques is limited by time-frequency resolution, so it can difficult make fine description for thin bed. Besides Inversion spectral decomposition is used for extracting reflection coefficient which is related to frequency by sparse inversion. Relevance between amplitude and frequency of reflection is conducive to AVO dispersion analysis. It can reduce uncertainty of reservoir prediction, and improve the prediction precision.

Method

The stratigraphic structure will cause dissipation of seismic energy, thus decreasing the amplitude and modifying the frequency content of the propagating wavelet, which provides theoretical basis for quantitative calculation of dispersion. Strong velocity dispersion and dissipation will appear in petroleum and hydrocarbon reservoir, so it can be a new fluid indicating parameter used to detect hydrocarbon. AVO dispersion analysis is based on simplified formula of Zoeppritz equation. Smith and Gildlow approximate equation is used in this analysis, the reflection coefficient is

$$R(\theta) \approx A(\theta)\frac{\Delta V_p}{V_p} + B(\theta)\frac{\Delta V_s}{V_s} \tag{1}$$

Then use Taylor series expansion and other method to get expressions of the value of dispersion.

$$I_a = \frac{d}{df}(\frac{\Delta V_p}{V_p}); I_b = \frac{d}{df}(\frac{\Delta V_s}{V_s}) \tag{2}$$

I_a is the value of dispersion of P wave and I_b is the value of dispersion of S wave. I_a and I_b can be achieved by the least square inversion. finally we get

$$\begin{bmatrix} I_a \\ I_b \end{bmatrix} = (E^T E)^{-1} E^T R \tag{3}$$

Propagation process of S-wave would not cause dispersion phenomenon, therefore only the dispersion value of P-wave is used to detect hydrocarbon.
Besides frequency division processing can be used in processing seismic data, to determine the frequency band range of different reservoirs. In effective frequency band range, frequency division processing can decrease image blur and make the image of thin layer much clearer. Frequency division processing can also be conducive to hydrocarbon detection. In thin and thin inter-layer layer, it will not cause obvious P-wave anomalous energy attenuation but can lead to low frequency shadow. With the frequency increasing, low frequency shadow gradually disappears. This phenomenon is useful for hydrocarbon detection.

Examples

All the parameters in this research are from DND gas field. We make a gas-bearing thin inter-layer forward model and a non-gas-bearing thin inter-layer model to get seismic single shot records. Then calculate their value of dispersion. The result shows that dispersion value of gas-bearing reservoir is much higher than non-gas-bearing layer, as shown in Figure 1(a). D15 well is a gas well in DND gas

field, DK17 and DK6 well are just near D15 well, but they are non-gas-bearing in the same layer. So we make frequency division and dispersion analysis for the through-well seismic profile. Figure1 (b) and Figure1 (c) are the frequency division profiles through D15 well, Figure1 (b) is the division profile of 40Hz, and Figure1(d) is the division profile of 30Hz . Figure1 (d) is an AVO dispersion profile through DK17, D15 and DK6 well. In the target layer, data in the location of D15 well shows abnormal high value, but the data in the location of DK17 and DK6 well do have high value(as shown in white circle). Besides the great quantity of abnormal high value beyond 1400ms is caused by coal seam, which has no relations with this study.

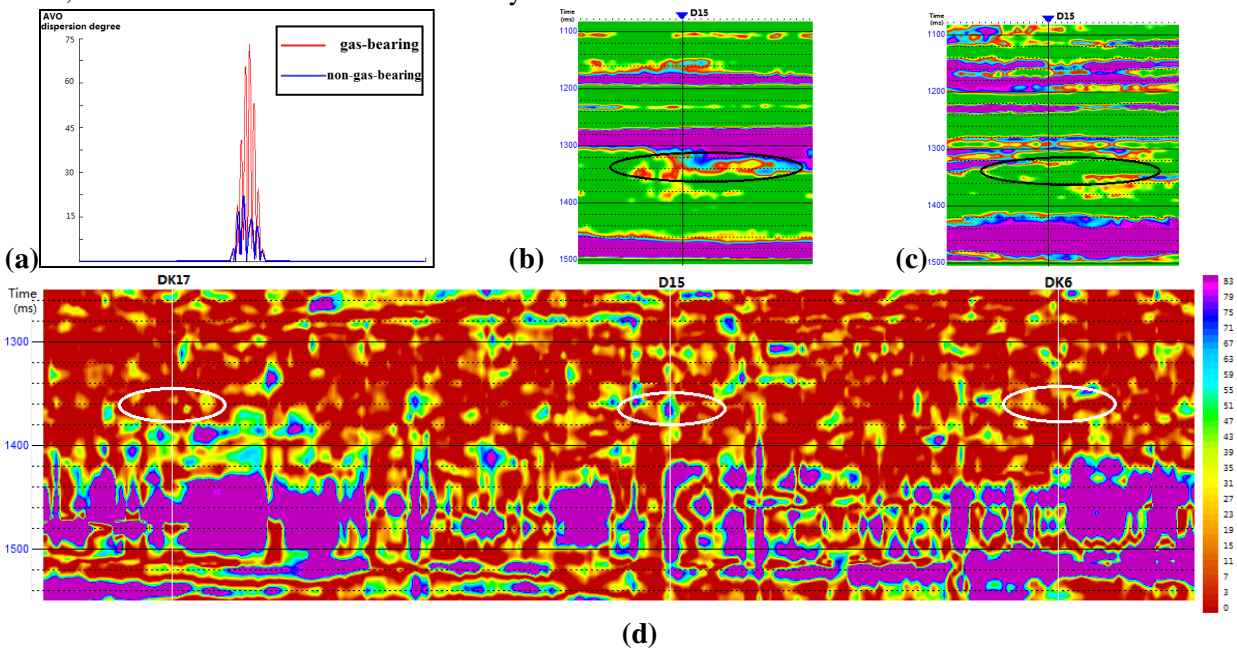

Figure 1 *AVO dispersion value and frequency division analysis(a) dispersion value of gas-bearing reservoir and non-gas-bearing layer ;(b) frequency division profiles through D15 well(40Hz);(c) frequency division profiles through D15 well(35Hz); (d) AVO dispersion profile through DK17, D15 and DK6 well.*

Conclusions

AVO dispersion analysis is conducive to reservoir prediction in tight inter-layer. Time-frequency and forward analysis is the basis of dispersion analysis, and frequency division processing can also be used to help it. Horizon interpretation is complicated and difficult in thin and thin inter-layer layers. The method combined with AVO dispersion and other horizon interpretation method can be used in such field, so that the prediction precision of reservoir can be improved.

Acknowledgements

This research has been supported by the sub-project of the Major Projects of the National Science and Technology of China "Large gas and oil field and coal seam development" (2011zx05045).

Reference

Batzle, M., Hofmann, R., Han, D-H. and Castagna, J. [2001] Fluids and frequency dependent seismic velocity of rocks. *The Leading Edge*, 20,168-171, doi: 10.1190/1.1438900.

Chapman, M., Zatsepin, S.V. and Crampin, S. [2002] Derivation of a microstructural poroelastic model. *Geophysical Journal International* **151**(2), 427-451, doi: 10.1046/j.1365-246X.2002.01769.x.

Chapman, M., Liu, E. and Li, X. [2006] The influence of fluid-sensitive dispersion and attenuation on AVO analysis. *Geophysical Journal International,* **167**(1), 89-105, doi:10.1111/j.1365-246X.2006.02919.x.

Ren, H., Gennady G. and Fred, J.H. [2009] Poroelastic analysis of amplitude-versus-frequency variations. *Geophysics*, **74** (6), 41–48, doi: 10.1190/1.3207863.