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The Analysis of Seismic Response Characteristics of Tight Thin Inter-layer Reservoirs

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SUMMARY

Analysis of the seismic response characteristics has been one of the hottest topics of reservoir prediction. However, seismic response of tight thin reservoirs is much more complicated than normal reservoirs. The author construct different kinds of forward models for tight thin inter-layer by collecting parameters from well and rock physical parameters of a gas field with a lot of tight thin reservoirs. And then use the seismic data to analyse pre-stack seismic response. The studies show that the seismic response is complicated in thin layers especially for inter-layer. The pre-stack seismic response is different from conventional AVO type and the post-stack seismic section also has its own features. The seismic responses of dry and gas-bearing layers process significant difference. The analysis for tight thin reservoirs' response will provide more detailed information to guide reservoirs prediction.

Introduction

With the rapid development of exploration and technology, researches of tight thin sand gas reservoirs attract increasing attentions (Jing et al., 2012). In the early days of research work, the approach to predict reservoirs in the areas with a lot of tight thin reservoirs is under the constraint of seismic or sediment phase, try to find the sand body and analyze favorable reservoir, then carry out the reservoir prediction work. This kind of research approach can effectively overcome the adverse effects caused by the multiplicity of reservoir prediction (Da et al., 2012). However, the quick growth of exploitation technology requires a higher level of reservoir prediction. DND gas field is a gas field with many tight thin sandstone reservoirs. The previous work on this gas field includes a lot of seismic exploration methods and reservoir prediction under the constraint of seismic or sediment phase. But the research results still vary from drilling results, which cannot meet the requirement of well deployment. Therefore, a set of data can be simulated based on such gas field, to make AVO attribute analysis and post-stack sensitive seismic attribute analysis more powerful and guide the reservoir prediction.

Theory

This study used Zoeppritz equation and parameters from real gas field to analyse AVO response characteristics. It also considered improving the method with such geological condition in target area. The seismic response of thin bed is much more complicated than large thickness layers (Yin and Douglas ., 2003). This is because of tuning effect, the reflected wave of thin bed is composed of the P-wave, S-wave, converted wave and multiple wave from both top and bottom boundary of thin bed. Besides the thin inter-layer tuning effect can also affect post-stack section (Jing et al., 2009), so combining pre-stack seismic response and post-stack section to analyse the seismic response of target area is the preferred choice.

Examples

The AVO forward models include two-boundary model and multi-boundary model. Since our research focus on thin reservoirs, we should design some layers with large thickness and some thin layers which are thinner than 1/4 wave length, and compare their seismic response. All the parameters are based on log data of DND gas field. We set three double bounding surfaces model and two thin inter-layer models. Model 1 is a gas-bearing tight sandstone reservoir between two mudstone cap rocks. Model 2 is a low-production tight sandstone gas reservoir between two mudstone cap rocks, Model 3 is a non-gas-bearing tight sandstone layer between two mudstone cap rocks. We only show the seismic response of large thickness layer (140m) and the thinnest bed(10m) in this paper. While the two thin inter-layer models are also based on practical data of target area.

Figure 1(a) and Figure 1(b) show the seismic response of Model1. When the thickness of reservoir is 140 meters, the seismic response of both top and bottom are completely apart. With the thickness of reservoir decreasing, the tuning effect appears. But the overall trend of AVO feature is not affected by thickness changes of reservoirs, which shows a typical gas reservoir AVO features, bigger the offset is, stronger the amplitude becomes. Figure 1(c) and Figure 1(d) show the seismic response of Model 2. When the thickness of reservoir is 140 meters, the amplitude changing with offset first shows a descending trend （with phase reversing at 2500m) and then begin to increase. When the thickness of reservoir become thinner, the tuning effect appears, the phase reverses gradually. Figure 1(e) and Figure 1(f) show the seismic response of Model 3. The phase reversing appears at large offset, and the total change trend is similar with Model 2, the seismic response of thin layer is extraordinary complicated.

Figure 1(g) and Figure 1(h) shows two thin inter-layer models, Figure 1(g) includes a gas-bearing sandstone reservoir while Figure 1(h) includes a low-production sandstone gas reservoir. Even though the tunning effect is obvious, Figure 1(g) shows a typical gas reservoir AVO features and the phase reverses gradually according to Figure 1(h). Figure 1(i) is the pre-stack data from target area, Figure 1(i) shows a tight thin gas-bearing sandstone reservoir and Figure 1(j) depicts a tight thin low-yield sandstone gas reservoir (as shown in red circle). Though the AVO response for these thin inter-layers are extraordinary complicated, the total change trend is similar with forward modeling analysis.

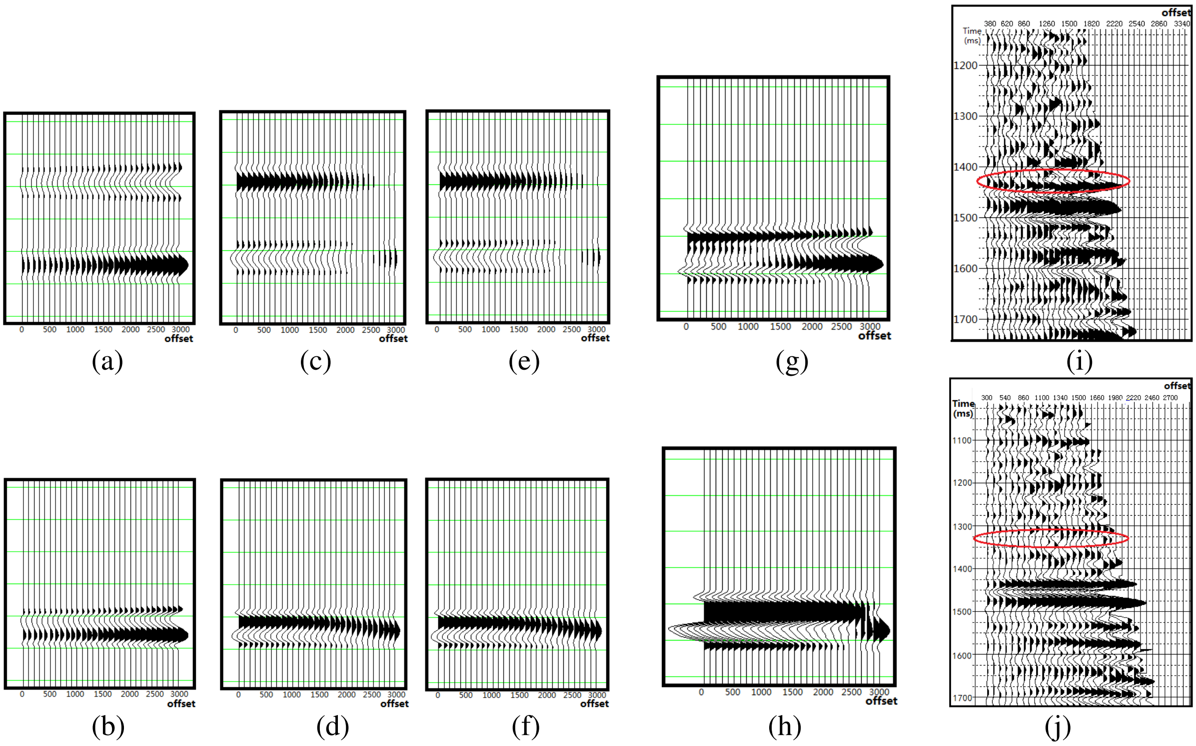

***Figure 1** seismic response of forward model and pre-stack data from target area; (a)seismic response of Model 1(140m);(b)seismic response of Model 1(10m);(c)seismic response of Model 2(140m);(d)seismic response of Model 1(10m);(e)seismic response of Model 2(140m);(f)seismic response of Model 1(10m);(g) thin inter-layer model(with a gas-bearing sandstone reservoir);(h)thin inter-layer model(with a low-production sandstone gas reservoir);(i)pre-stack seismic data(with a gas-bearing sandstone reservoir);(j)pre-stack data(with a low-yield sandstone gas reservoir).*

Conclusions

Reservoir prediction for tight thin reservoir is difficult, it need to make more pre-stack attribute analysis. The tuning effect will cause a dynamic response feature, which makes the post-stack attribute much more complicated. Therefore, we design a series of thin inter-layer models to apply AVO forward modeling and analysis. Besides we suggest to strengthen the pre-stack and post-stack comprehensive analysis for thin inter-layer reservoirs prediction.

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).

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