PS Application of Geophysical Technology Assemblage in Evaluation of Deepwater Gas Fields in the Northern South China Sea*

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Abstract

Several big deepwater gas fields (such as Liwan, Liuhua and Linshui) have been discovered in northern South China Sea. These discoveries have proven the excellent hydrocarbon accumulation in this area. However, because of complicated seafloor topography and reservoir inhomogeneity, it is difficult to precisely image, evaluate and effectively develop these deepwater gas fields. This paper provides a set of geophysical technologies and workflows that have proven to be effective in addressing these problems. Firstly, to solve the problem of seismic imaging, anisotropic pre-stack depth migration process provided high quality and precise depth-domain seismic data. Full 3D visualization and interpretation of the prestack depth-migrated seismic data helped characterize the structural features and build the spatial concept of regional depositional setting and geometry in the study area. Comparisons with analogs of worldwide deepwater reservoirs then helped establish the depositional model. The visualization and interpretation of 3D seismic data indicated that three types of deepwater reservoirs including basin floor fan, confined channel and channel complexes are developed in this area. Petrophysical properties of these reservoir sands and encasing shales are remarkably different in the different parts of the depositional system. Prestack seismic inversion provides the link between petrophysical properties and seismic data and was used to accurately describe the lateral distribution and thicknesses of the main gas-bearing sands. Analysis indicates that different kinds of AVO anomalies occur in the Liwan and Liuhua gas fields and these are useful for delineating the gas-bearing areas. Finally, based on the integrated depositional, structural and reservoir information, 3D geological models were built to conduct reservoir simulation. Based on these models, the original gas in place (OGIP) and recoverable resources were calculated, and the appraisal and development wells were designed. This paper illustrates the effectiveness of these geophysical technologies and workflows using two examples from the Liwan and Liuhua gas fields. The prognoses matched the actual drilling results quite well. It reduced the evaluation risk and pushed forward the process of the deepwater gas development. Liwan gas field went into production in 2014 and the production dynamics so far are as predicted.

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AAPG Annual Convention & Exhibition 2016

Introduction

Several big deepwater gas fields (Liwan, Liuhua, Linshui and so on) have been discovered in the northern area of the South China Sea. However, because of the complicated geological rules, strong heterogeneity of deepwater reservoirs, and low-quality seismic data of this area, it is difficult to precisely evaluate and develop the deepwater gas fileds. In order to solve this problem, this paper provides an effective geophysical technology assemblage and its workflow. At first, broadband 3D seismic survey and anisotropic pre-stack depth migration processing are used to obtain the high quality data with both time and depth domain in the rough seafloor deepwater area. Secondly, on the basis of the seismic data, full 3-D visualization seismic interpretation is available to confirm the accurate structural features and help to build the spatial concept of depositional setting in this deepwater area. Furthermore, by analogy with the world-wide deepwater reservoirs, depositional model is established, and further indicates three types of deepwater reservoirs of this area including basin floor fan, channel and channel complex. Subsequently, rock physics analysis is applied to finding reservoirs. The result can be used to help accurately describe the lateral distribution and the thickness of the main gas sand by using pre-stack deterministic inversion results. The gas bearing area is also predicted by subsequent AVO analysis. The geophysical technologies assemblage is applied in several gas fields. The prognosis matches well with the actual drilling results, which proves the effectiveness and feasibility of this method.

Ⅰ. Regional Background

The research area locates in the northern South China Sea (Fig1). Rough seafloor (Fig2) and strong heterogeneous reservoirs result in the difficulties of seismic imaging and reservoir prediction.

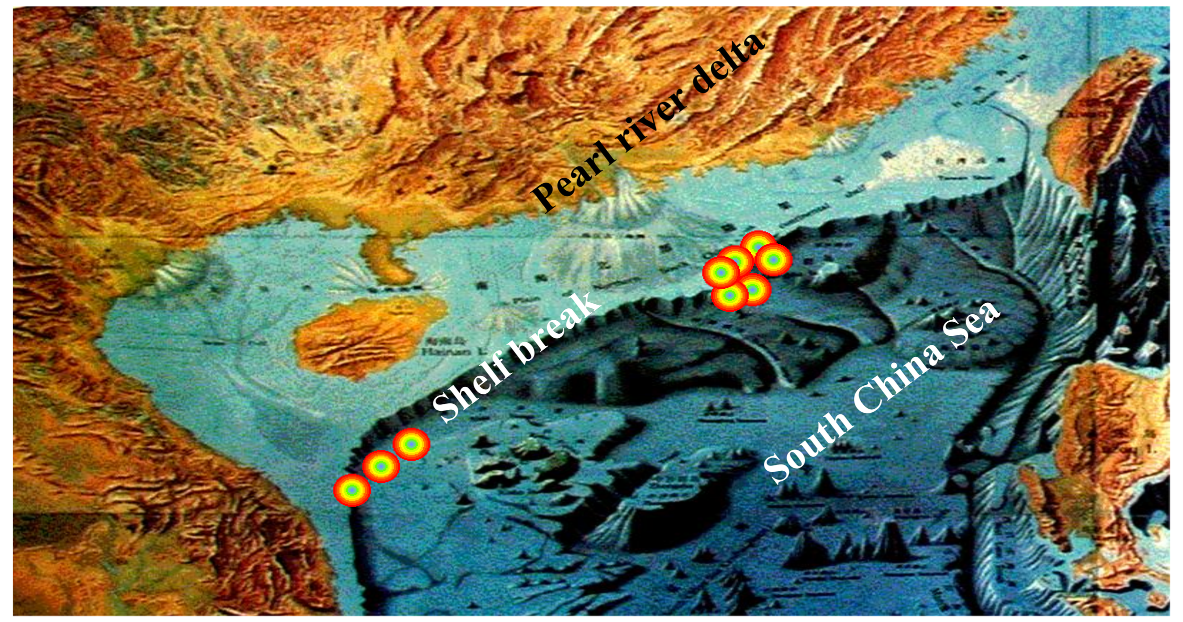

Fig.1 The regional geological background of research area   Discovery

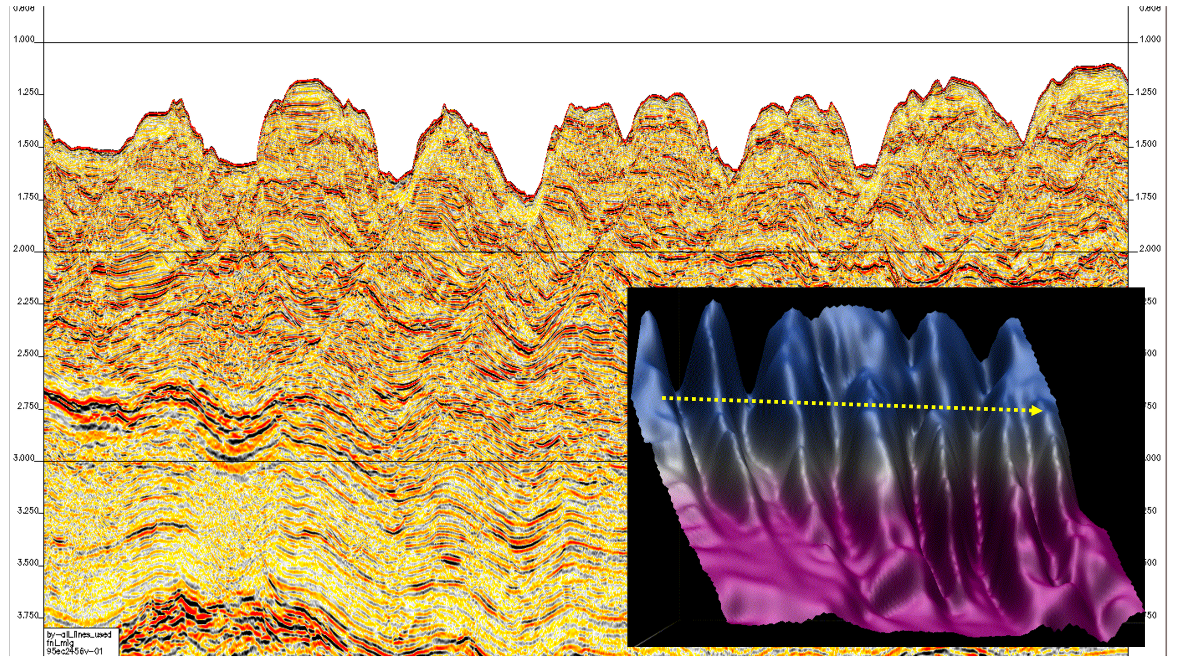

Fig.2 The rough seafloor of research area

Ⅱ. Acquisition and Processing

The variable depth streamer acquisition is exploratory to the deep water of the South China Sea. Fig3 is a schematic map of regular level-streamer and variable depth streamer seismic acquisition. The advantages of the variable depth streamer acquisition are wider frequency , higher resolution and higher S/N.

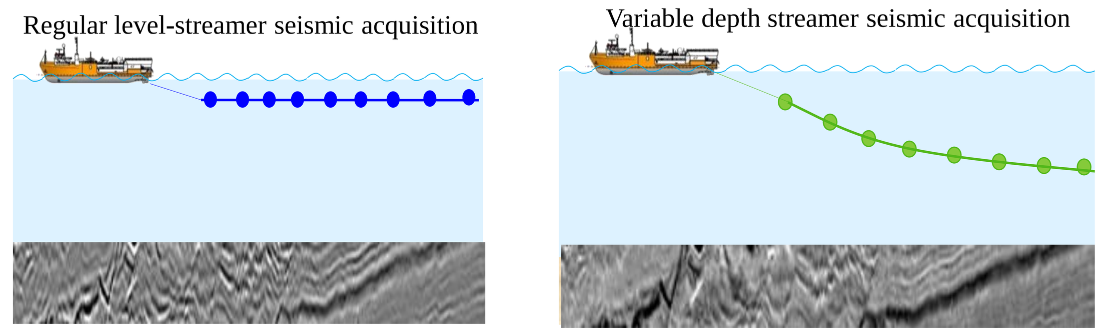

Fig.3 Schematic map of regular level-streamer and variable depth streamer seismic acquisition

Fig4 shows that variable depth streamer seismic data has higher resolution and more outstanding detail. In addition, it is much closer to the zero phase section.

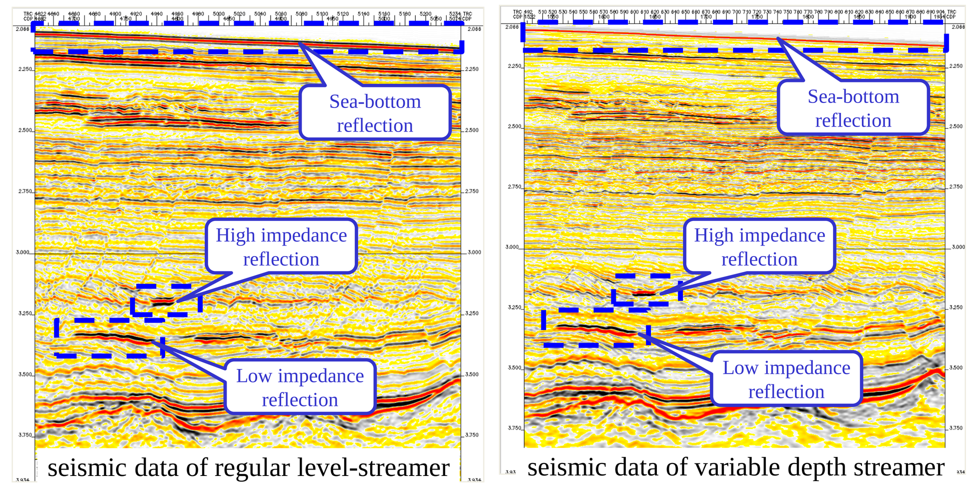

Fig.4 The seismic data of regular level-streamer and variable depth streamer

Variable depth streamer seismic data has wider bandwidth (3-110 Hz, 5 octave), and its effective low-frequency signal can reach 3-5HZ (Fig5).

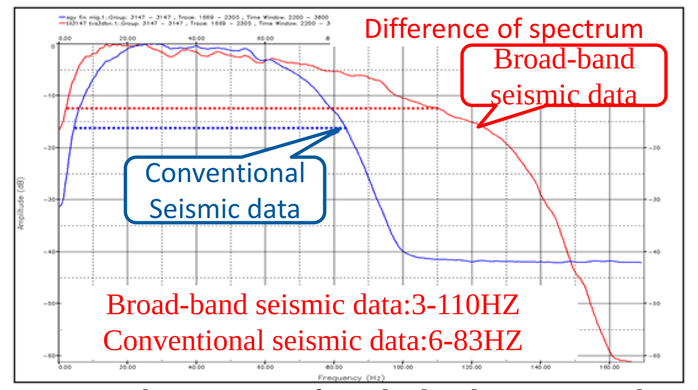

Fig5. The spectrum of regular level-streamer and variable depth streamer seismic

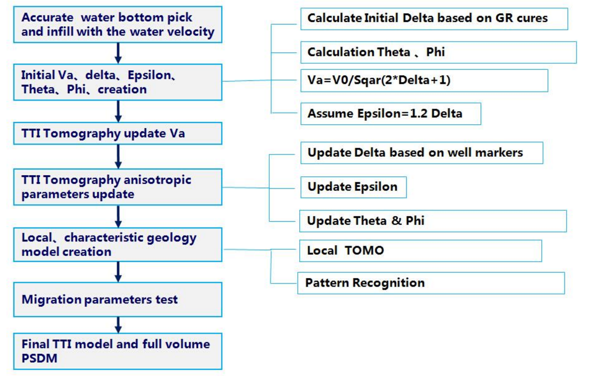

Fig6. The flow chart of anisotropic PSDM

Fig6 is the flow chart of anisotropic PSDM. Compared with the isotropic PSDM seismic data, the anisotropic PSDM seismic data (Fig7) has higher resolution, clearer fault planes, better imaging, more balanced energy and more reasonable formation horizontal distribution.

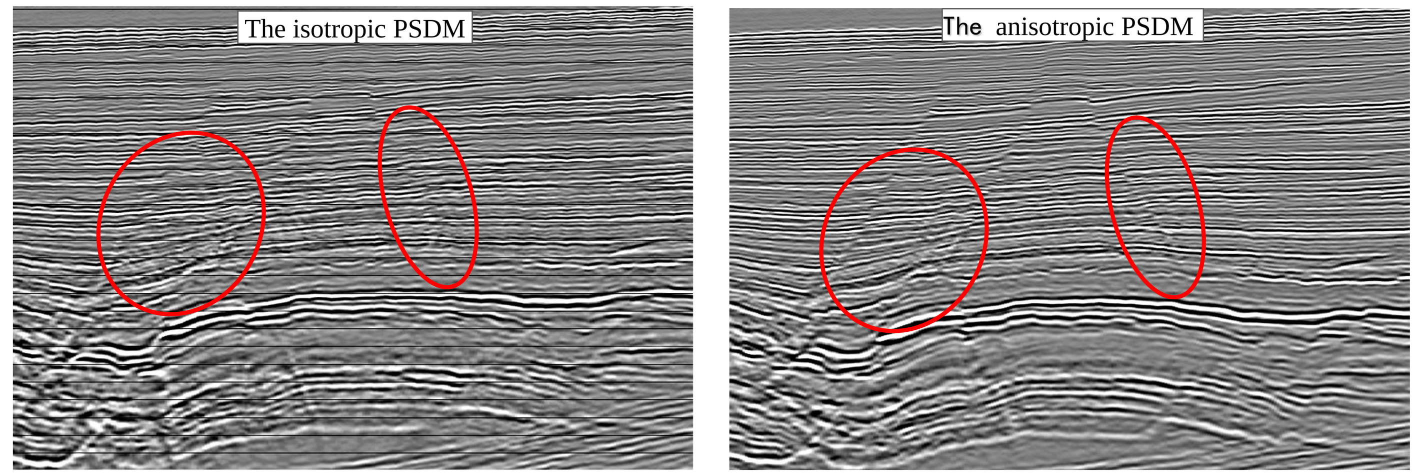

Fig7. Contrast of isotropic and anisotropic PSDM seismic data

Ⅲ. 3D Visualization

Fig8 shows how to define the spatial distribution of sand body through 3D visualization. Fig9 is a display of amplitude anomaly, clearly showing shelf-edge delta, gravity flow channels and shelf break. Fig10 shows a profile of shelf-edge delta deposited over the shelf break and deep-water gravity flow channels deposited below the shelf break.

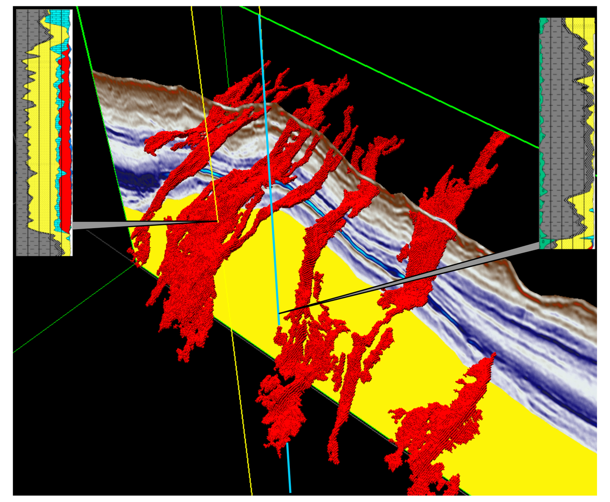

Fig8. Distribution of sand bodies in 3D visualization

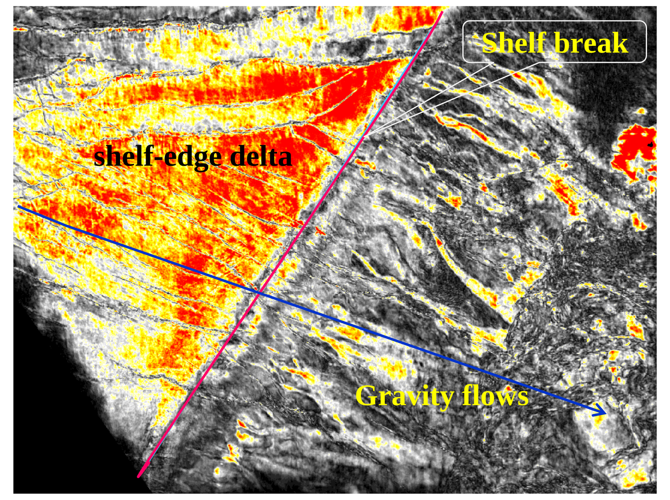

Fig.9 Amplitude anomaly

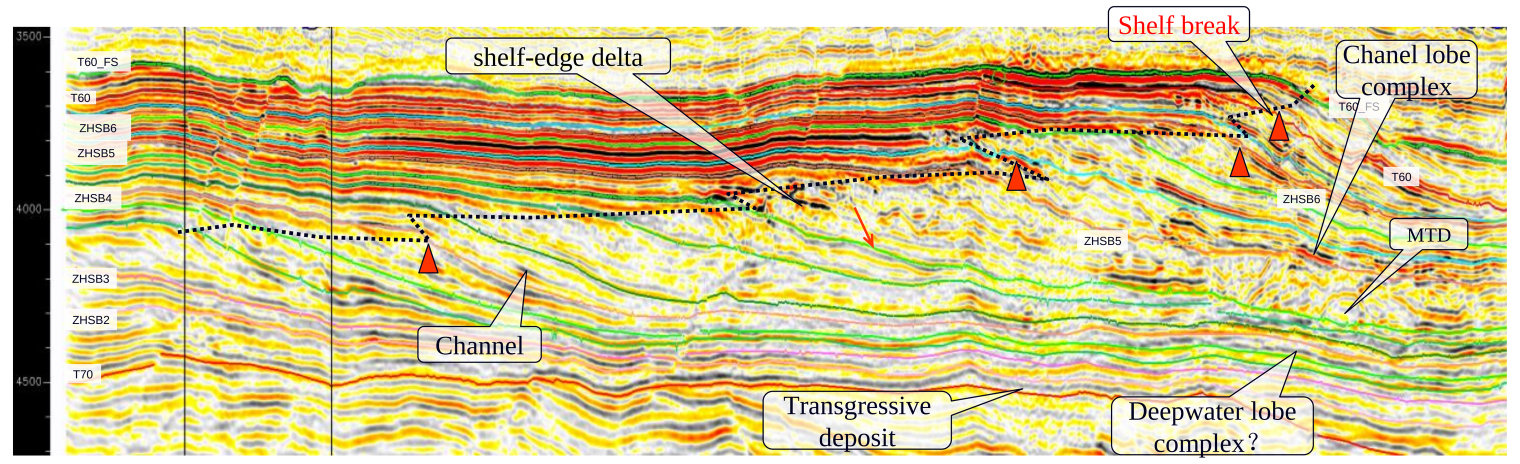

Fig.10 A variety of sedimentary facies in a seismic profile

Ⅳ. Rock Physics and Reservoir Inversion

Rock physics can discriminate reservoirs, furthermore, it helps in fluid prediction. Fig11 shows the rock physics template in the study area.

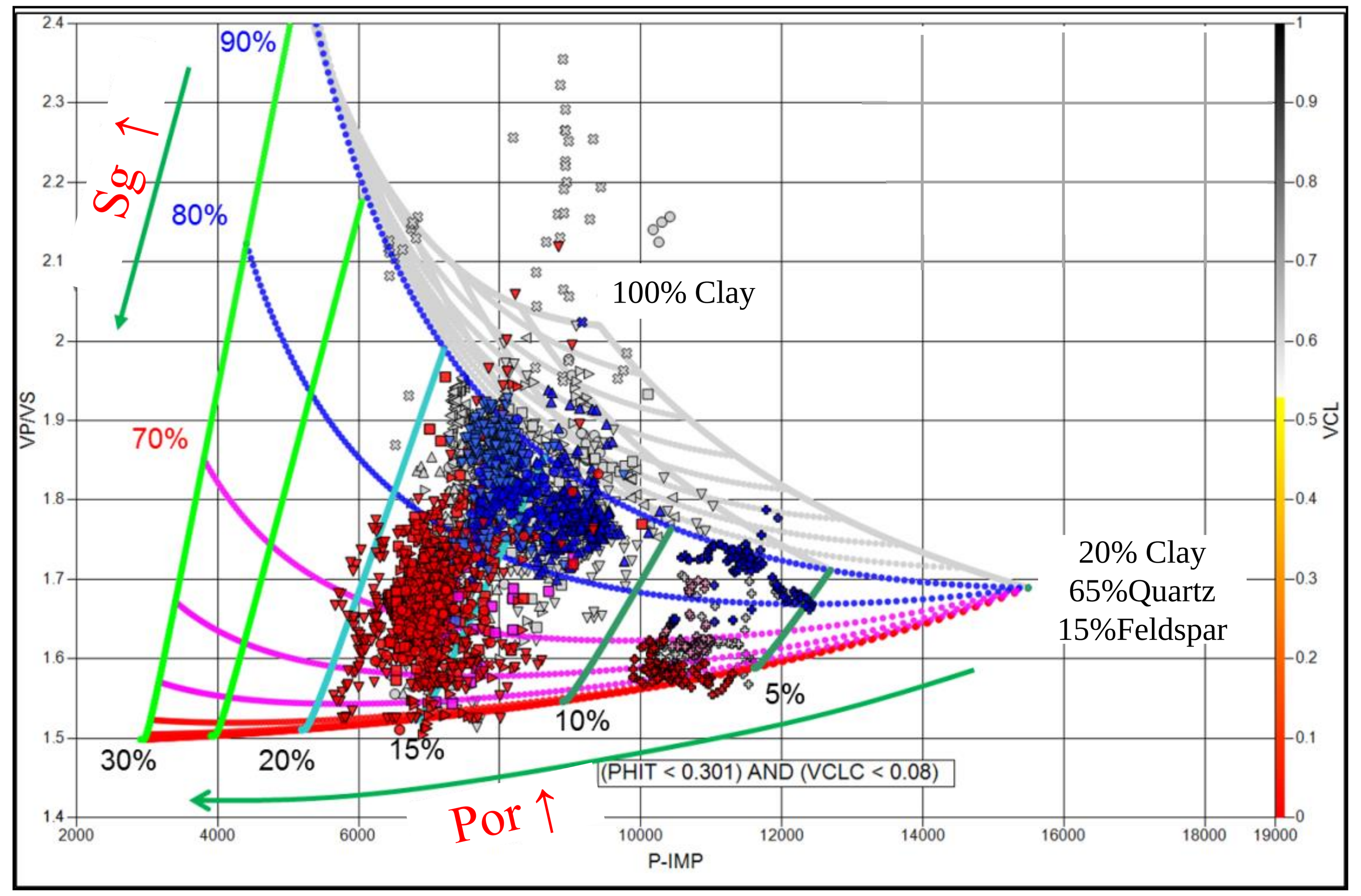

Fig.11 The rock physics in study area

Fig12 is the inversion results of regular level-streamer (left) and variable depth streamer seismic data (right). Obviously, the variable depth streamer results present more details and higher resolution.

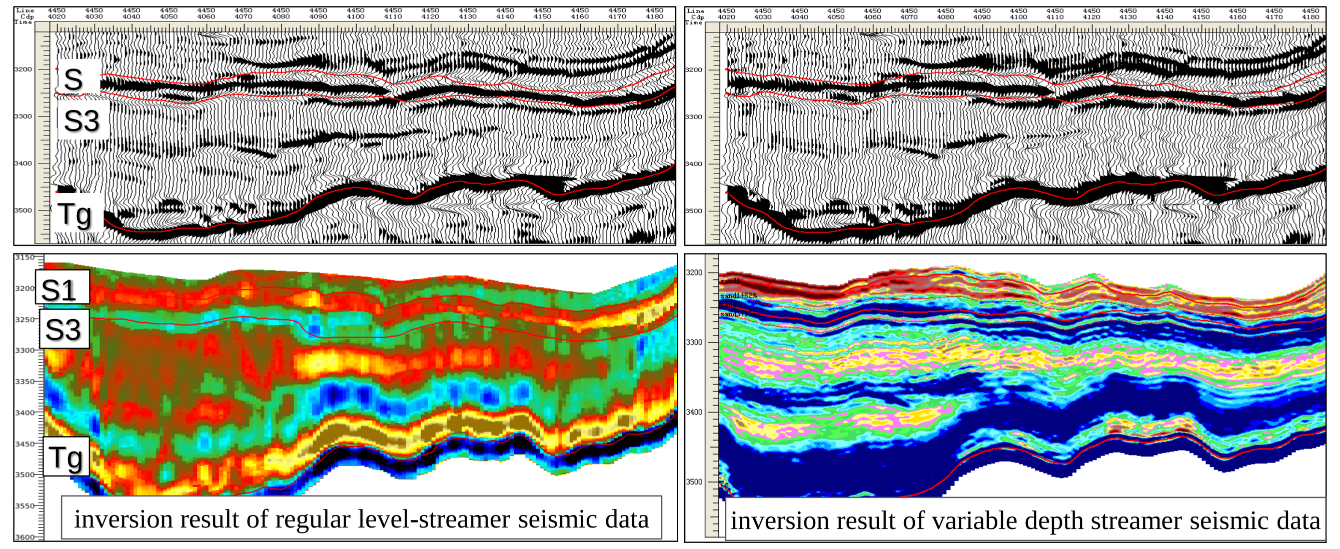

Fig.12 The inversion results of regular level-streamer and variable depth streamer seismic data

Ⅴ. Applications

Fig13 shows the seismic section of target E1, its main horizon ZJ210 is over 300m deeper than those in target A1 and A2. There is no obvious bright spot characteristic on the seismic section and amplitude anomaly response is weak (Fig14). By using above techniques, λρ pre-stack inversion section is obtained, and it shows E1 has a significant fluid response and gas bearing sand is predicted (Fig15). Fig16 is a plane view of λρ attribute showing target E1 has obvious λρ anomaly as gas field A. Drilling result proved ZJ210 is a gas reservoir (>30 m), hence, the prediction is correct.

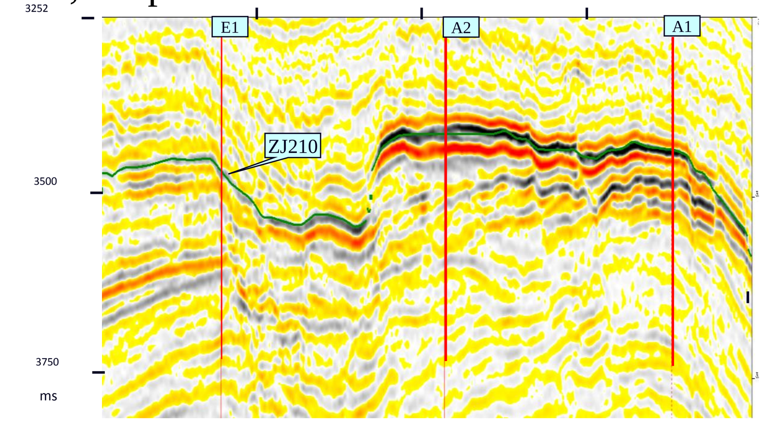

Fig.13 The seismic section of target E1

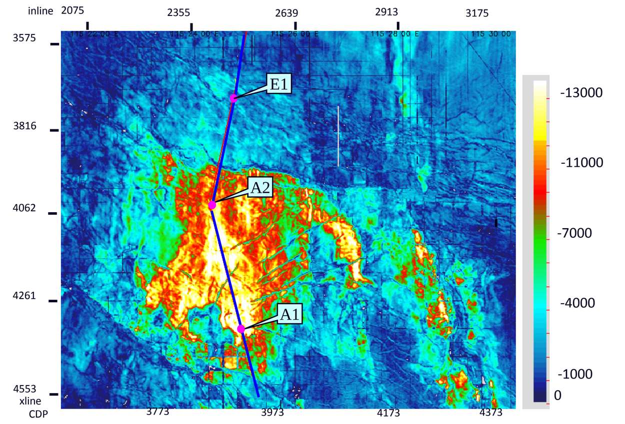

Fig.14 The RMS amplitude map of ZJ210 of target E1

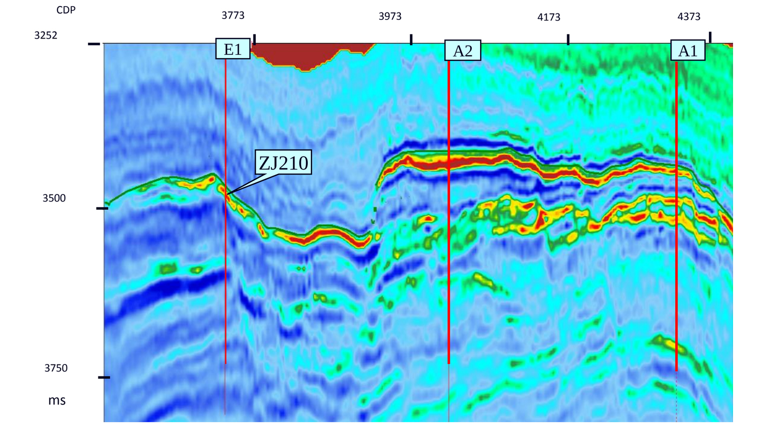

Fig.15 λρ inversion section of target E1

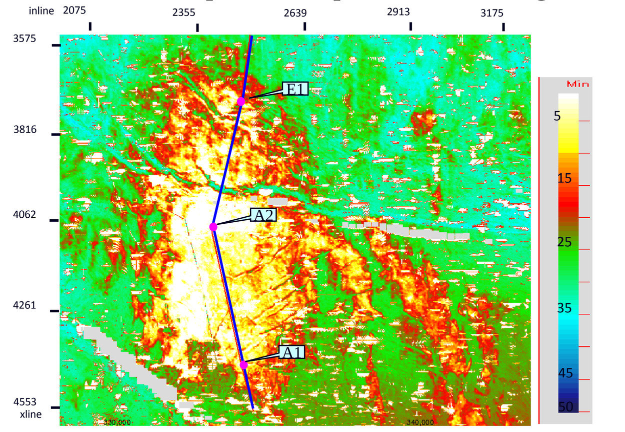

Fig.16 λρ attribute map of ZJ210 in target E1

Ⅵ. Conclusion

1. The seismic data of variable depth streamer acquisition has wider bandwidth and higher resolution than conventional seismic data;
2. Anisotropic PSDM can resolve the seismic imaging difficulties in the deep-water, rough seafloor and strong heterogeneous reservoirs setting, then accurate depth domain seismic data is obtained .
3.Full 3-D visual seismic interpretation is available to confirm the accurate structural features and help to build the spatial concept of depositional setting in this deep-water area.
4.The inversion result based on variable depth streamer data has higher resolution and accuracy.
5.The geophysical technology assemblage is applied in the deep water of the northern South China Sea. The prognosis matches well with the actual drilling results, and proves the effectiveness and feasibility of this assemblage .