Study of Hydrocarbon Detection Methods in Offshore Deepwater Sediments, Gulf of Guinea*

Guoping Zuo[1], Fuliang Lu[1], Guozhang Fan[1], and Dali Shao[1]

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[1]Offshore Research Center, Petrochina Hangzhou Research Institute of Geology, Hangzhou, China (zuogp_hz@petrochina.com.cn)

Abstract

Offshore oil and gas exploration has become the main venue of exploration now and in the future, however offshore oil and gas exploration is mainly based on seismic data, thus it is significance to detect hydrocarbon in offshore deepwater exploration using seismic data.

Using seismic data to detect hydrocarbons is a process of inversion which is ambiguous and uncertain. This article illustrates five methods to detect hydrocarbons in order to reduce the uncertainty: Seismic amplitude attribute, frequency attribute, spectrum decomposition method, waveform classification, and cross plot analysis.

(1) When a reservoir contains hydrocarbon, it often has strong amplitude, the RMS seismic attribute and Max seismic attribute are effective to distinguish hydrocarbons. The results indicate that the hydrocarbon boundary is close to the strong amplitude on attribute maps extracted along the horizon; (2) Frequency of the reservoir decreases in terms of the gas and oil accumulated in the reservoir. Thus, the changes of frequency in the lateral directions can be used to detect hydrocarbons. The instantaneous frequency attribute achieved good effect in the study area; (3) Seismic data was converted into six cubes from 10 Hz to 60 Hz as the interval of 10 Hz. It was observed that the gas layer shows strong amplitude on the 10 Hz and 20 Hz profiles, however the water layer did not have strong amplitude, the amplitude decreases fast from 40 Hz to 60 Hz, and there is no strong amplitude on the 50 Hz and 60 Hz profiles. This study indicates that the phenomenon of resonance in low frequency and attenuation in high frequency occurs in the oil and gas layers; (4) A neural network algorithm is used in the waveform classification to depict the form of seismic traces quantitatively. The waveform is divided into 10 types in the study area. The results show that some types are sensitive to hydrocarbons, and the boundaries coincide with known hydrocarbon distributions and drilled wells; (5) Different types of AVO are located at different areas on the cross plot. Oil and gas also have distinguishing features on the cross plot.

The combined application of these methods greatly reduces the ambiguity and uncertainty. According to this research, the results of hydrocarbon detection coincide with drilled wells and the known hydrocarbon distributions. It achieved better effect in study area, and formed a series of methods of hydrocarbon detection in offshore deepwater oil and gas exploration.

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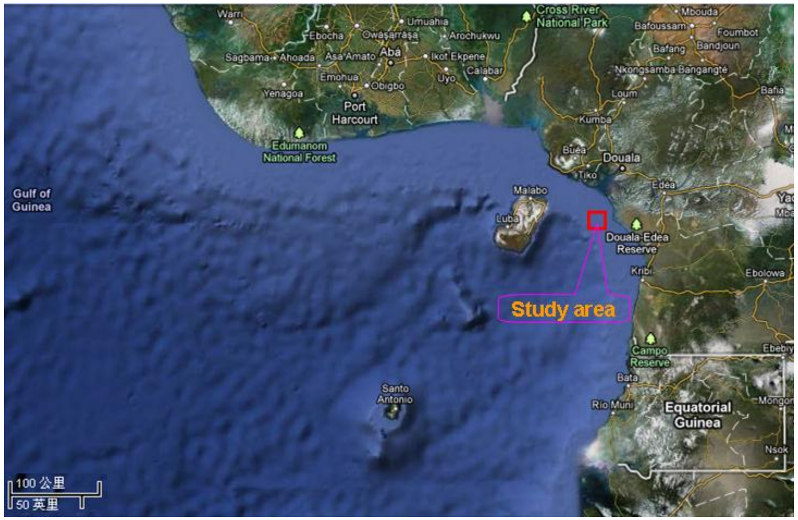
OUTLINE

1. Introduction
2. Hydrocarbon Detection Methods
3. Conclusions

1. Introduction

- The oil and gas exploration field has changed significantly with the development of exploration. The major areas changed from onshore to offshore, especially from shallow water exploration to deepwater exploration.
- Offshore deepwater exploration features: much more technology, features higher risk and challenge operation . In addition, less drilled wells in the most part of exploration areas, thus, at present, the offshore deepwater exploration mainly based on seismic prospecting.
- Therefore, it has great significance to use seismic data to detect hydrocarbon directly in the offshore deepwater exploration.

1. Introduction

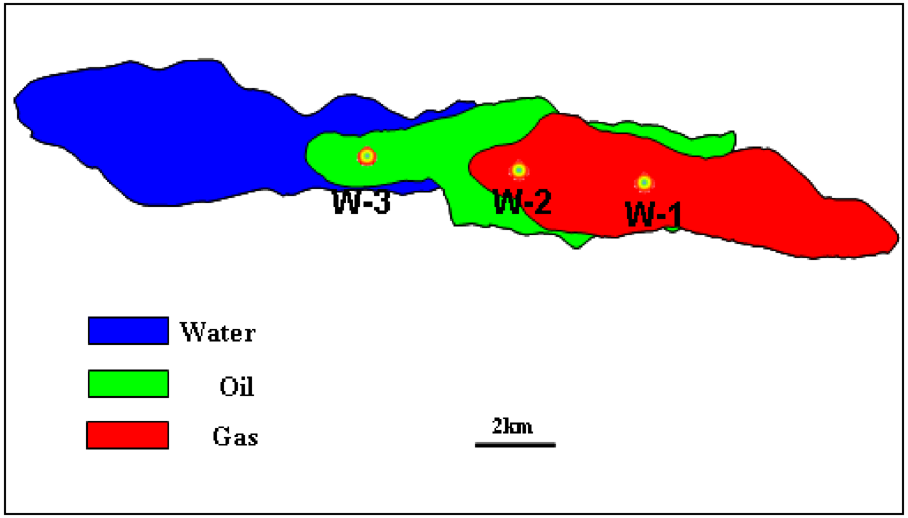


Location of study area

Location: Offshore deepwater area of West Africa

Reservoir: Deepwater sandbody

Trap type: Stratigraphic trap



Distributions of oil, gas and water

Well W-1: Gas well

Well W-2: Gas and Oil well

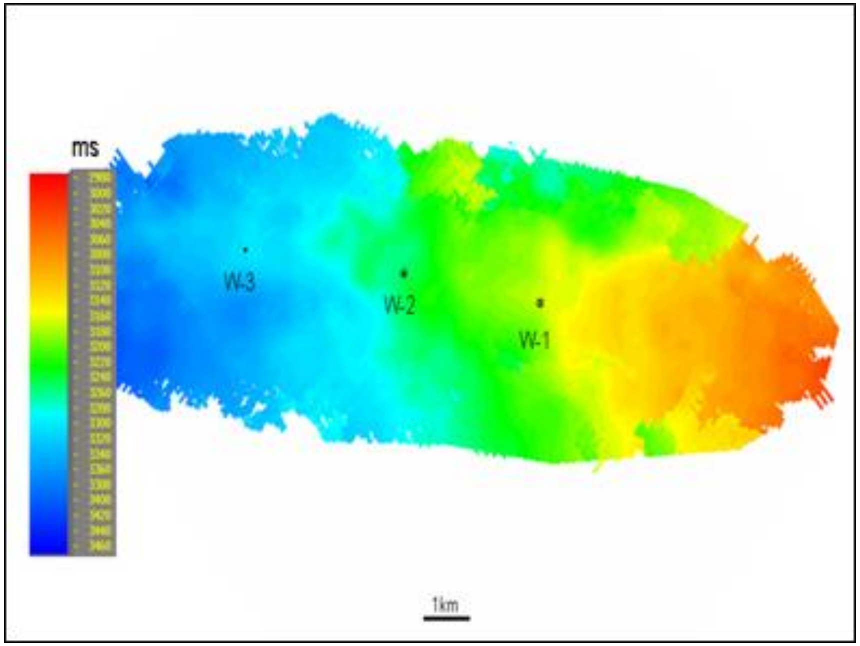
Well W-3: Oil and Water well

2. Hydrocarbon Detection Methods

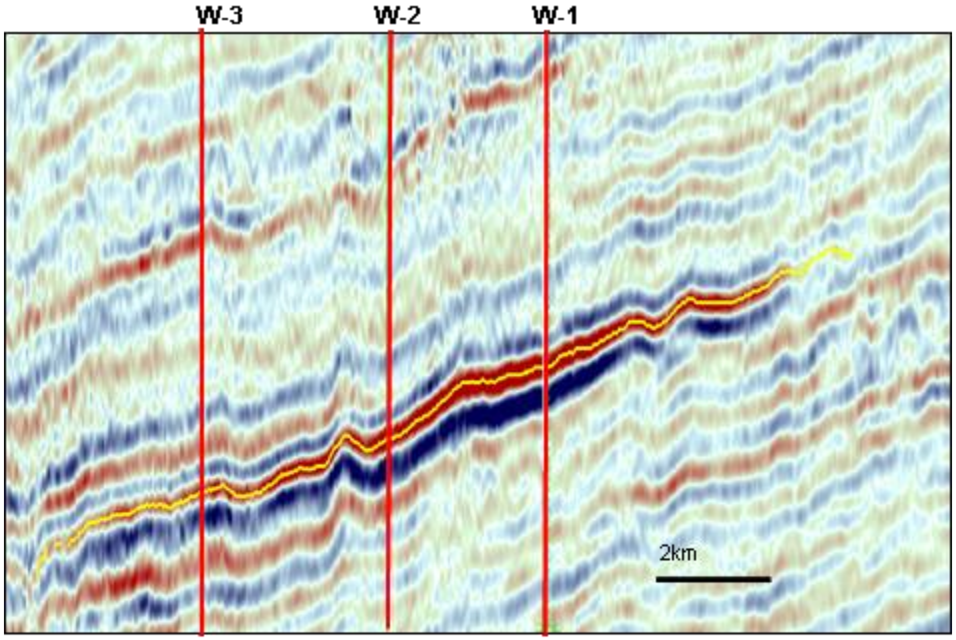
- Amplitude attribute method
- Frequency attribute method
- Spectrum decomposition method
- Waveform classification method
- Cross plot analysis

2. Hydrocarbon Detection Methods

Map of two way travel time



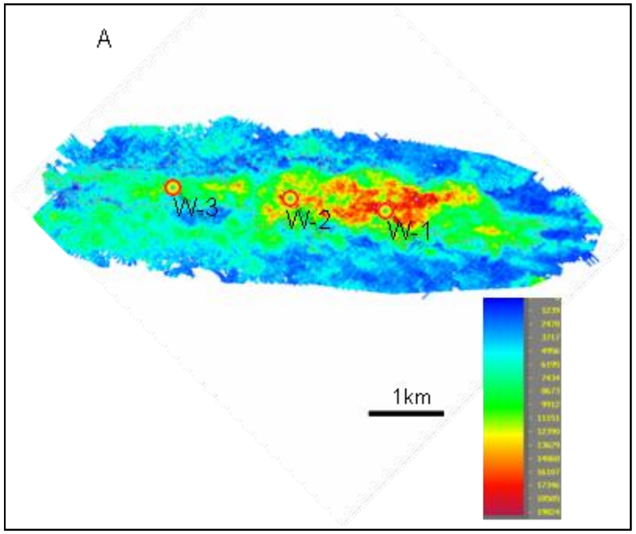
Correlation section of W-1-W-2-W-3



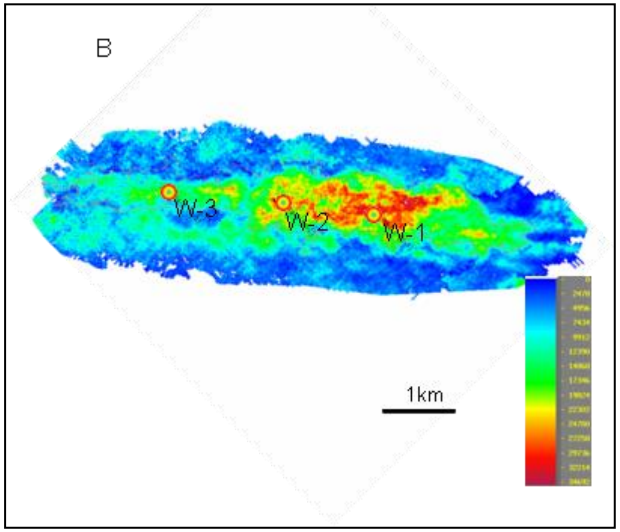
- W-1: on the top of the slope, high amplitude, bright spot
- W-2: in the middle of them, weaker amplitude
- W-3: on the lower part, represents the weakest amplitude
- These amplitudes have good corelation with the distribution of hydrocarbon

2. Hydrocarbon Detection Methods

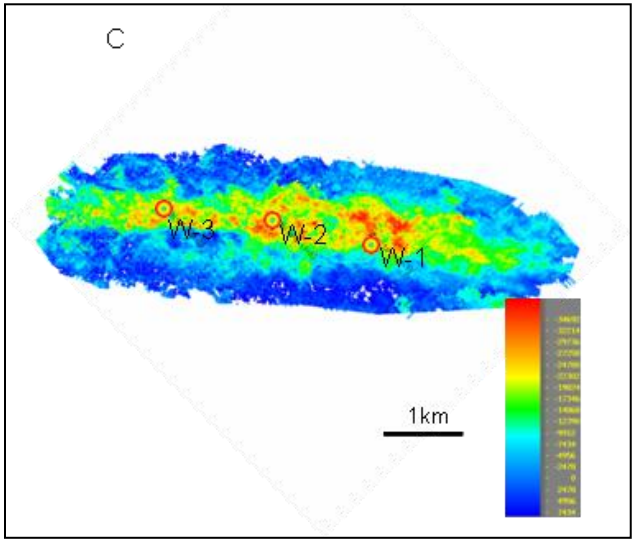
Map of RMS attribute



Map of Max attribute



Map of far-near offset attribute

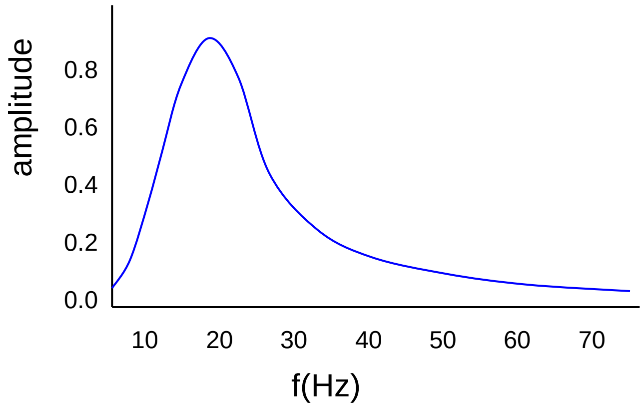


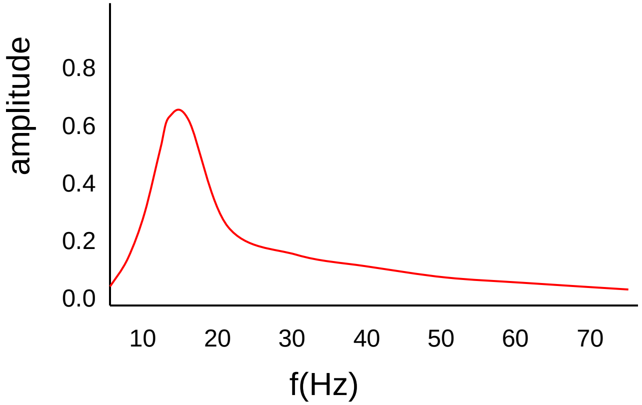
- **The RMS seismic attribute is similar to the Max seismic attribute.**
- **The high amplitude coincides with the distribution of hydrocarbon.**
- **The difference of far offset stack data and near offset stack data represents type 3 AVO anomaly. It can be well used to portray the range of hydrocarbon.**

2. Hydrocarbon Detection Methods

- Amplitude attribute method
- Frequency attribute method
- Spectrum decomposition method
- Waveform classification method
- Cross plot analysis

2. Hydrocarbon Detection Methods

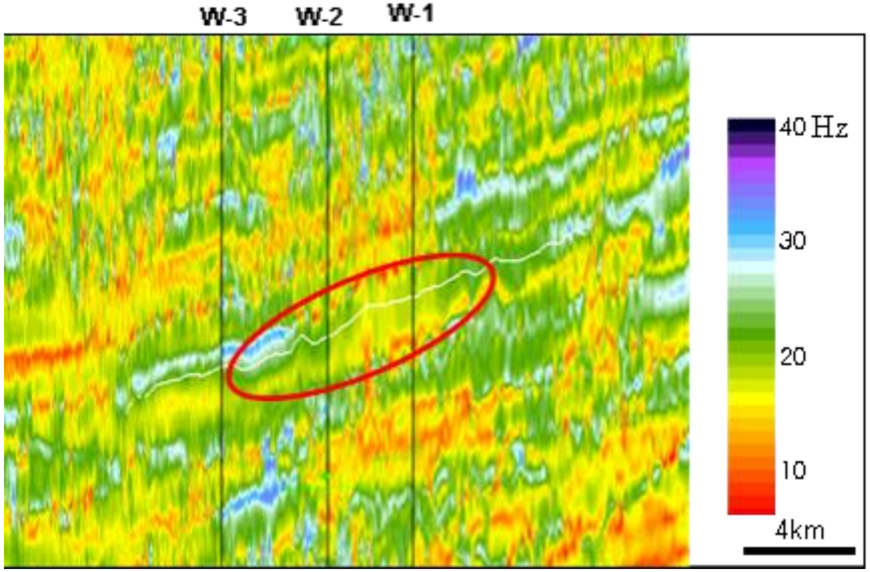




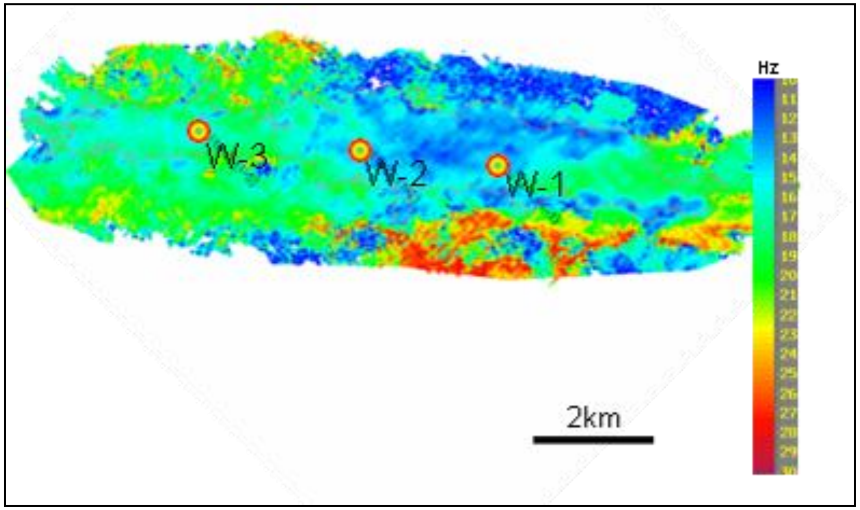
- **When reservoir contains fluid, such as water, oil and gas, it features scattering of seismic wave and attenuation of seismic energy and frequency.**
- **The frequency decreases faster in the gas reservoir than surrounding rocks.**
- **Thus， the changes of frequency in the lateral can be used to detect hydrocarbon.**
- **Generally, the hydrocarbon layers show lower frequency than that of water layers.**

2. Hydrocarbon Detection Methods

Attribute profile of instantaneous frequency



Attribute map of instantaneous frequency

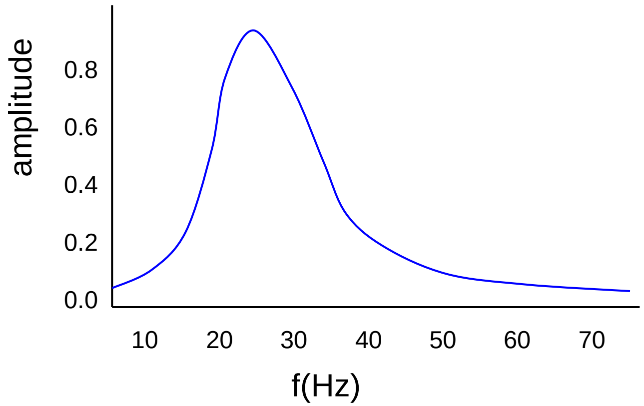


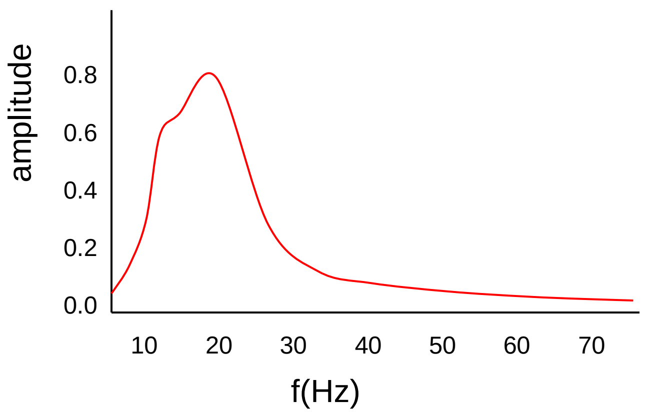
- The gas reservoir shows significant low frequency.
- This phenomenon doesn't appear distinctly on the location of water zone.
- The range of relatively low frequency delineates the distribution of hydrocarbon. It is coincided with the hydrocarbon distribution.

2. Hydrocarbon Detection Methods

- Amplitude attribute method
- Frequency attribute method
- Spectrum decomposition method
- Waveform classification method
- Cross plot analysis

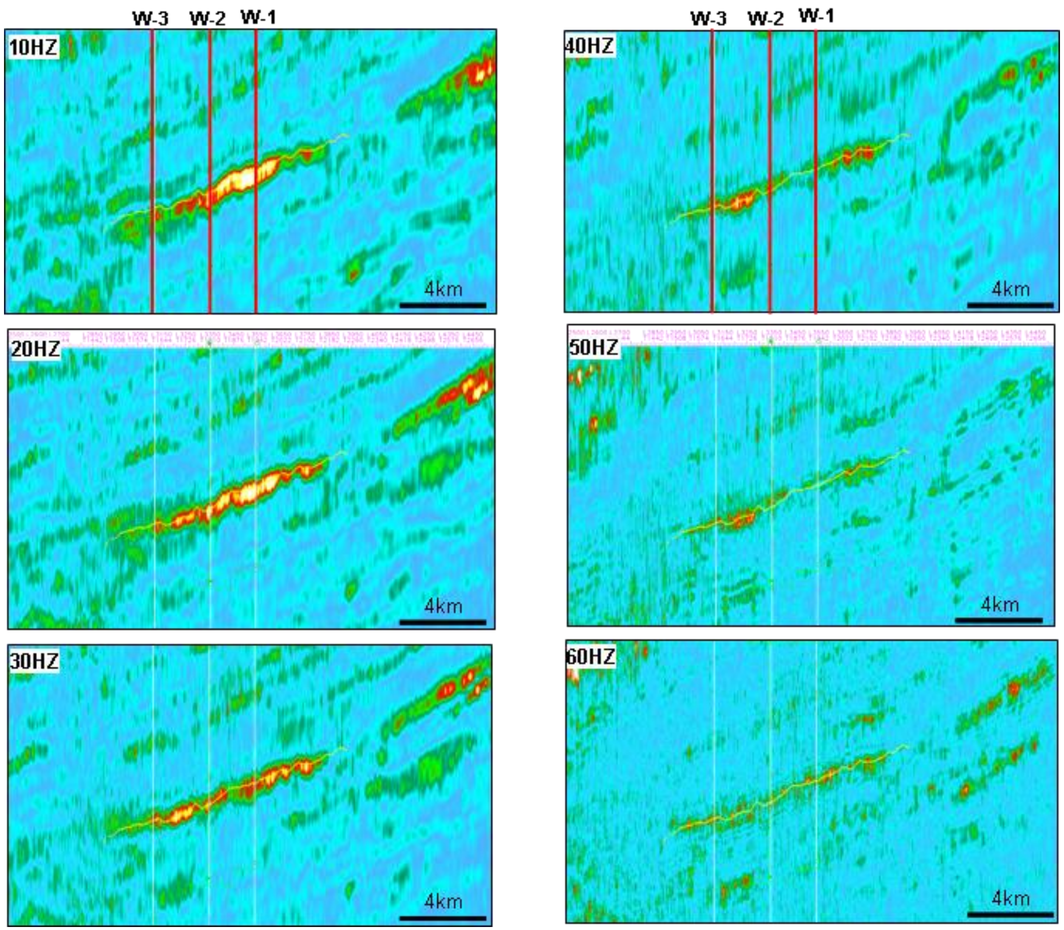
2. Hydrocarbon Detection Methods





- **The frequency of reservoir decreases in terms of the gas and oil accumulated in the reservoir.**
- **Resonance of the seismic wave in low frequency enhances the energy. The attenuation and absorption occur in the high frequency, and the energy of it decreases.**
- **Generally speaking, the oil and gas layer appears lower frequency, the water layer shows high frequency, features higher energy in lower frequency and lower energy in higher frequency.**

2. Hydrocarbon Detection Methods

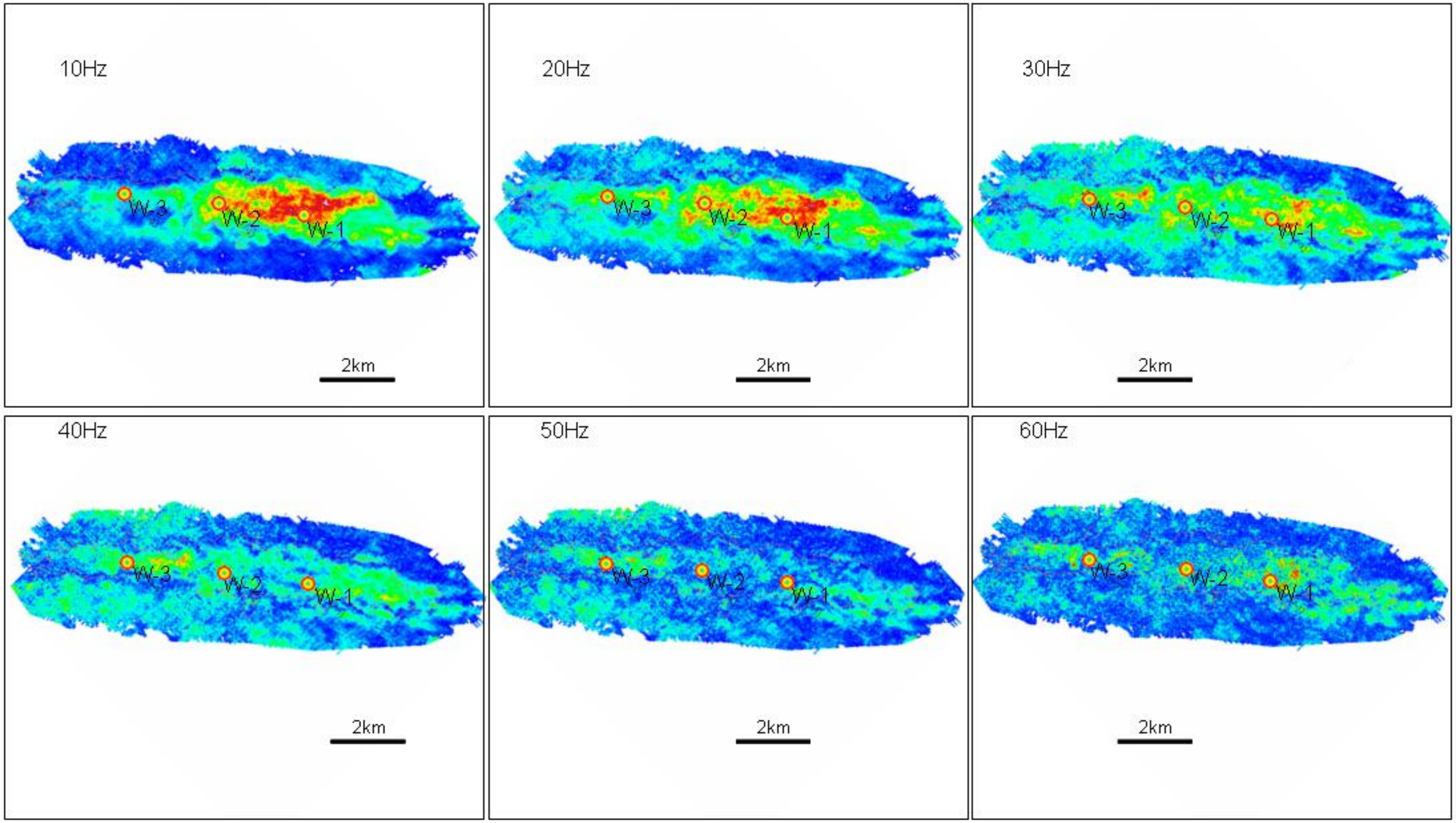


Profiles of spectrum decomposition attribute

- The gas layer shows high amplitude on 10Hz profile, oil layer indicates a little weaker amplitude, and water layer appears low amplitude.
- The profiles of 20Hz and 30Hz look alike to that of 10Hz, amplitude decreases slightly, but still represent high amplitude.
- The amplitude decreases fast from 40Hz to 60Hz, and disappears on the profiles of 50Hz and 60Hz.

2. Hydrocarbon Detection Methods

Maps of spectrum decomposition attribute

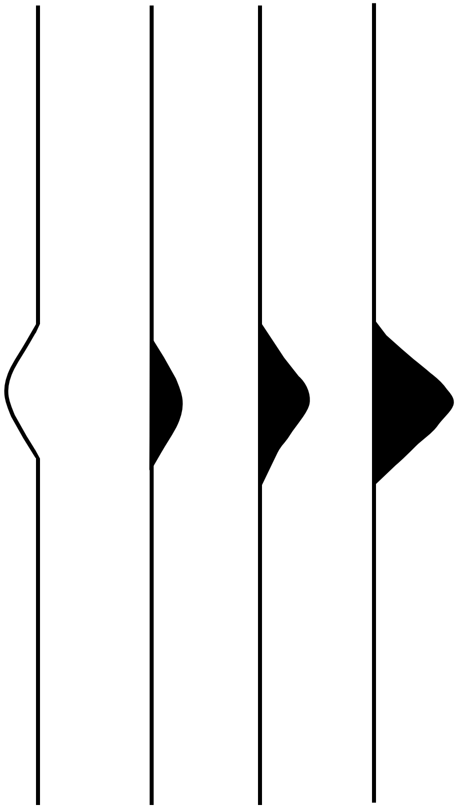


- **Amplitude attribute are extracted along horizon using different cubes .**
- **The maps of 10Hz to 30Hz denote the distribution of hydrocarbon.**
- **They coincide with the drilled wells and the distributions of oil, gas and water.**

2. Hydrocarbon Detection Methods

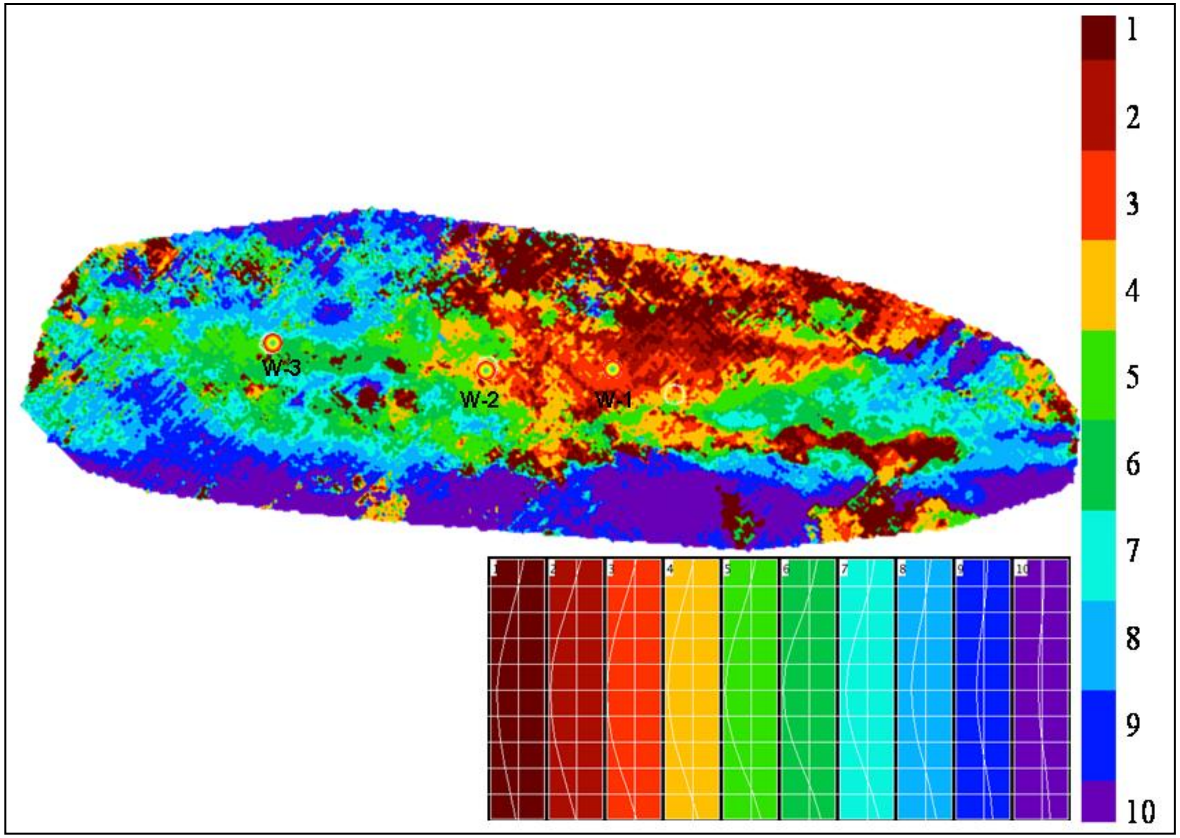
- Amplitude attribute method
- Frequency attribute method
- Spectrum decomposition method
- Waveform classification method
- Cross plot analysis

2. Hydrocarbon Detection Methods



- The changes of seismic waveform are the mirror of amplitude, frequency and phase.
- Base on the abundance information of seismic data, neural network algorithm is used in the waveform classification to depict the form of seismic traces.
- Lateral changes of seismic data can be delineated by the comparison and classification of seismic traces, especially when reservoir contains hydrocarbon.
- Therefore, waveform classification can be used to identify hydrocarbon.

2. Hydrocarbon Detection Methods



Map of waveform classification

- The waveform is divided into 10 types.
- The result appears that the amplitude decreases and the width narrow down from type 1 to type 10.
- Gas layer represents high amplitude, just like the waveform from type 1 to type 3, however, water layer shows low amplitude, just like the waveform from type 7 to type 10. And type 4 to type 6 stand for oil layer.
- The results are coincided with drilled wells and distributions of hydrocarbon.

2. Hydrocarbon Detection Methods

- Amplitude attribute method
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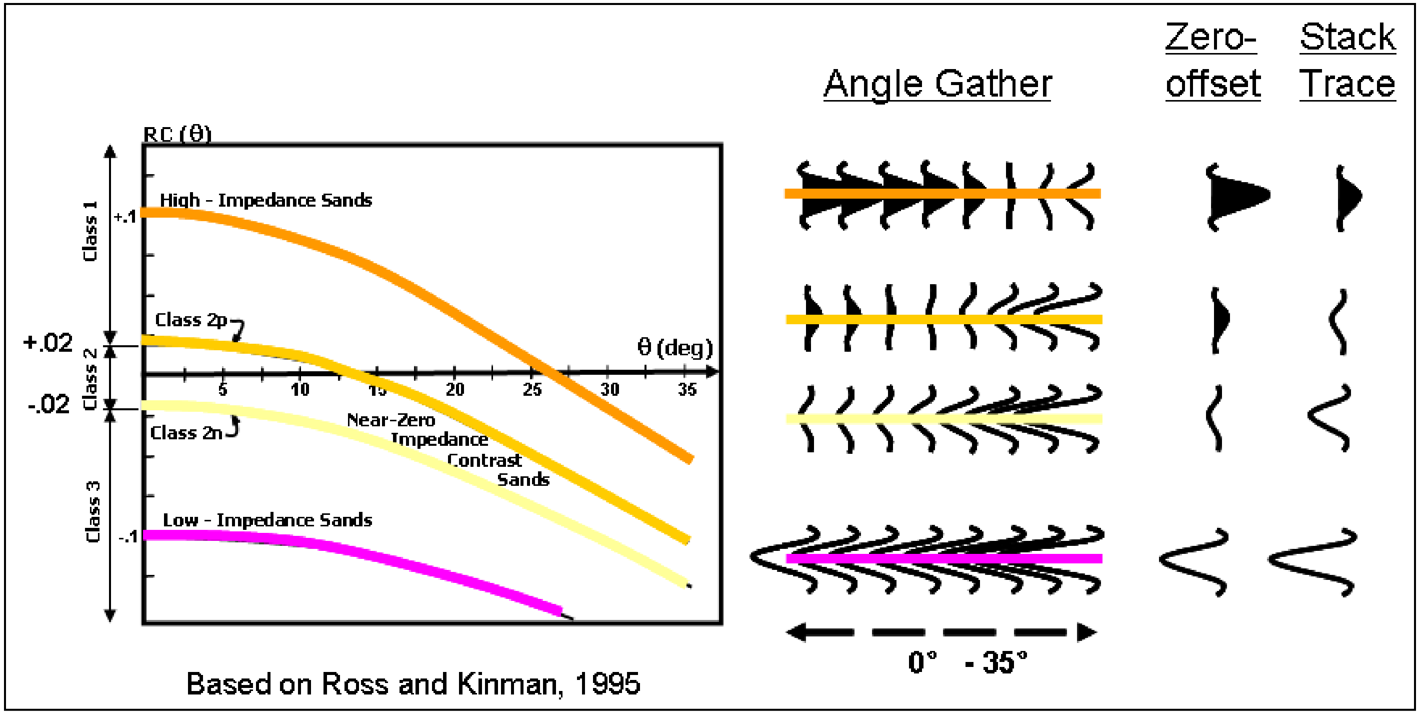
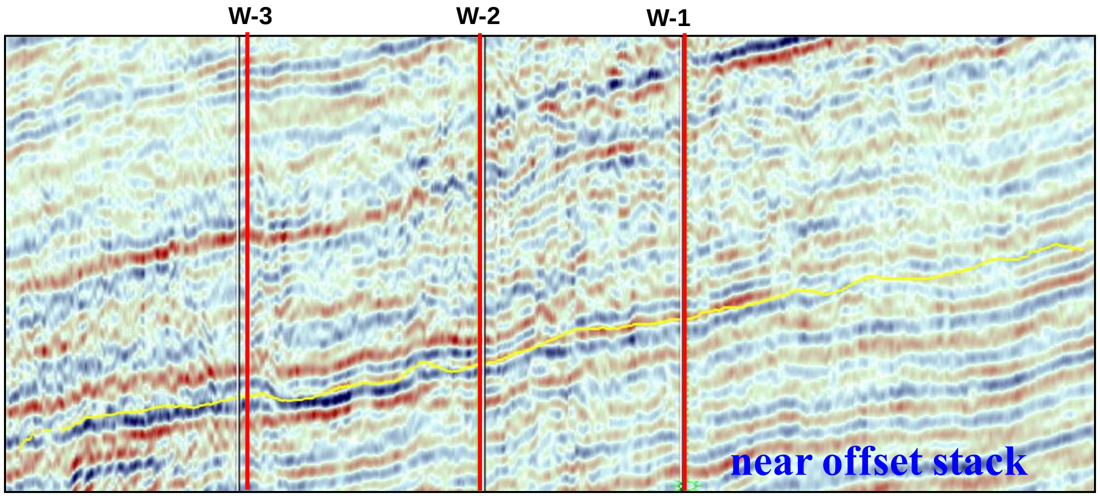
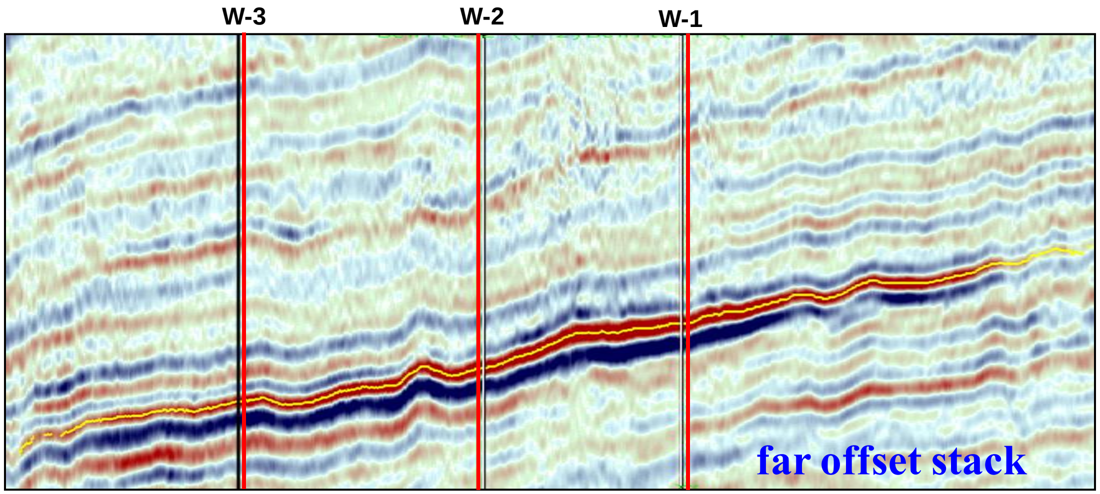
2. Hydrocarbon Detection Methods



- Amplitude changes with offset due to hydrocarbon contained in reservoir.
- The typical types are type 2 and type 3 AVO response. Type 3 features that amplitude increases with offset. Amplitude of far offset stack is higher than that of near offset stack. Type 2 represents reverse polarity, amplitude changes from positive to negative or from negative to positive.
- Thus, the comparison of far offset stack data and near offset stack data can be used to identify hydrocarbon.

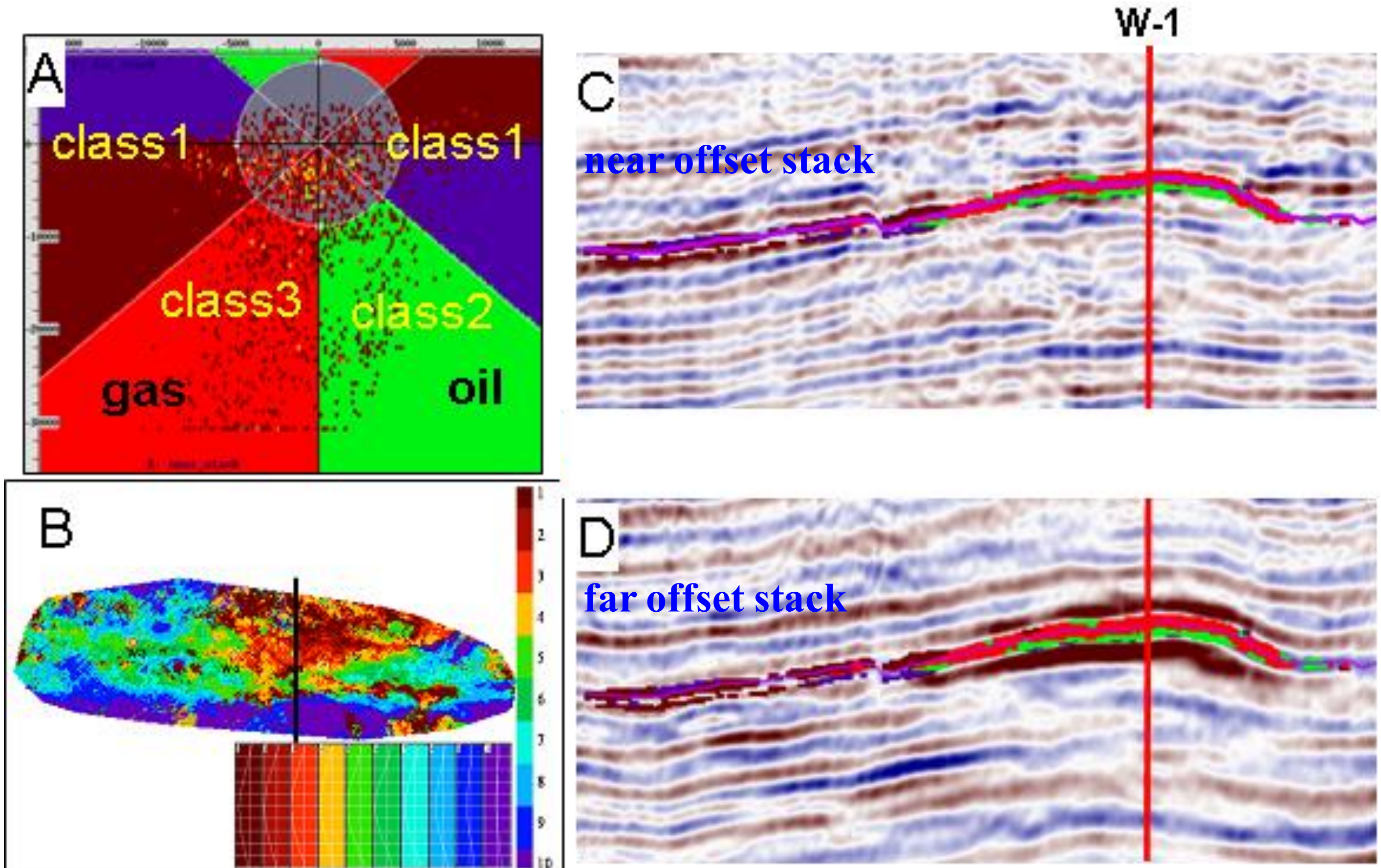
2. Hydrocarbon Detection Methods





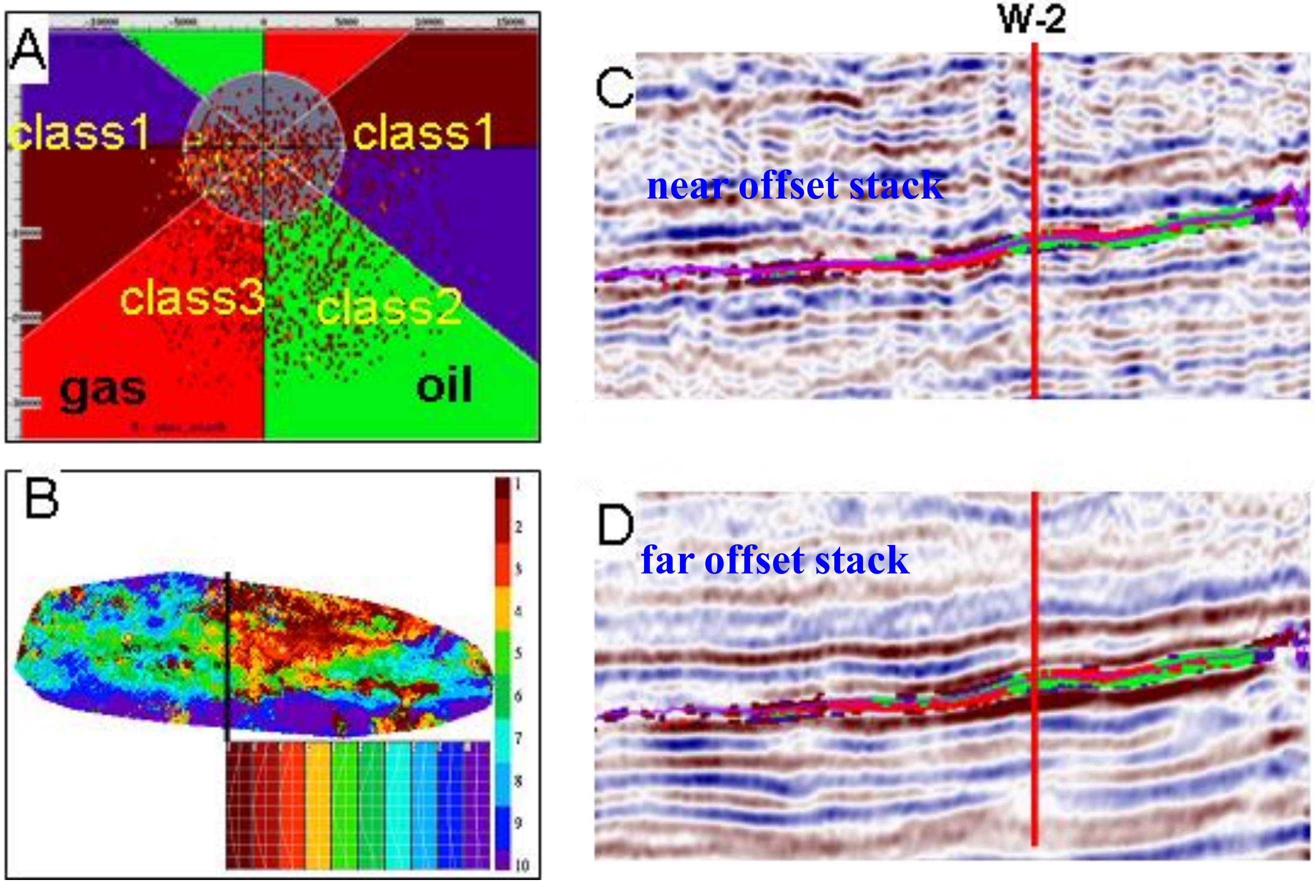
The gas layer shows much higher amplitude on the far offset profile than that of near offset profile, and presents obvious type 3 AVO response characteristic.

2. Hydrocarbon Detection Methods



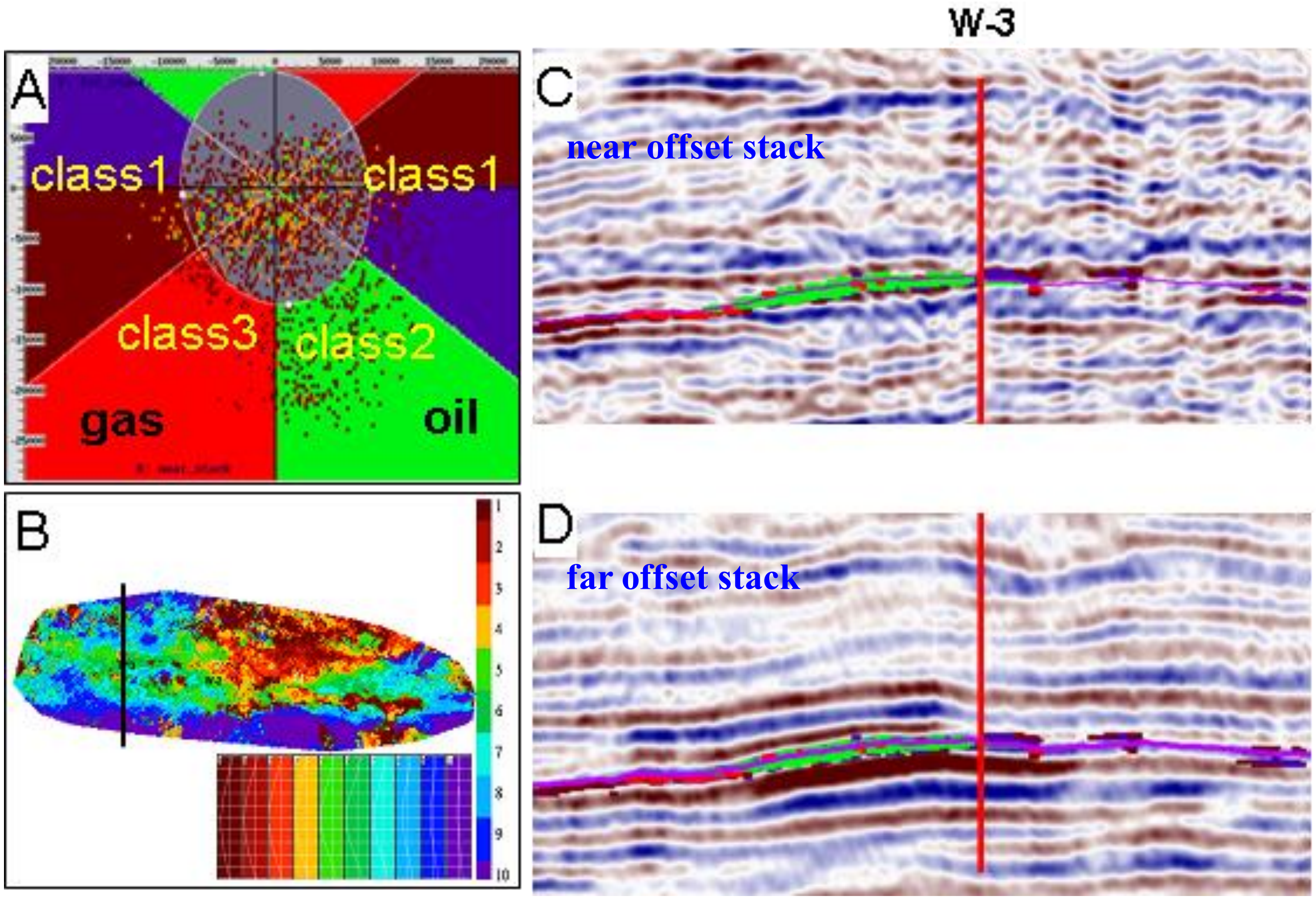
The anomalies concentrate on the red colored area. It indicates that far offset stack appears higher amplitude, featuring type 3 AVO, whereas the green color represents reverse polarity, features type 2 AVO. On the seismic profiles, most of them show red color , appear obvious gas features. Distributions of the anomalies have fine correlation with the results of waveform classification and gas well W-1.

2. Hydrocarbon Detection Methods



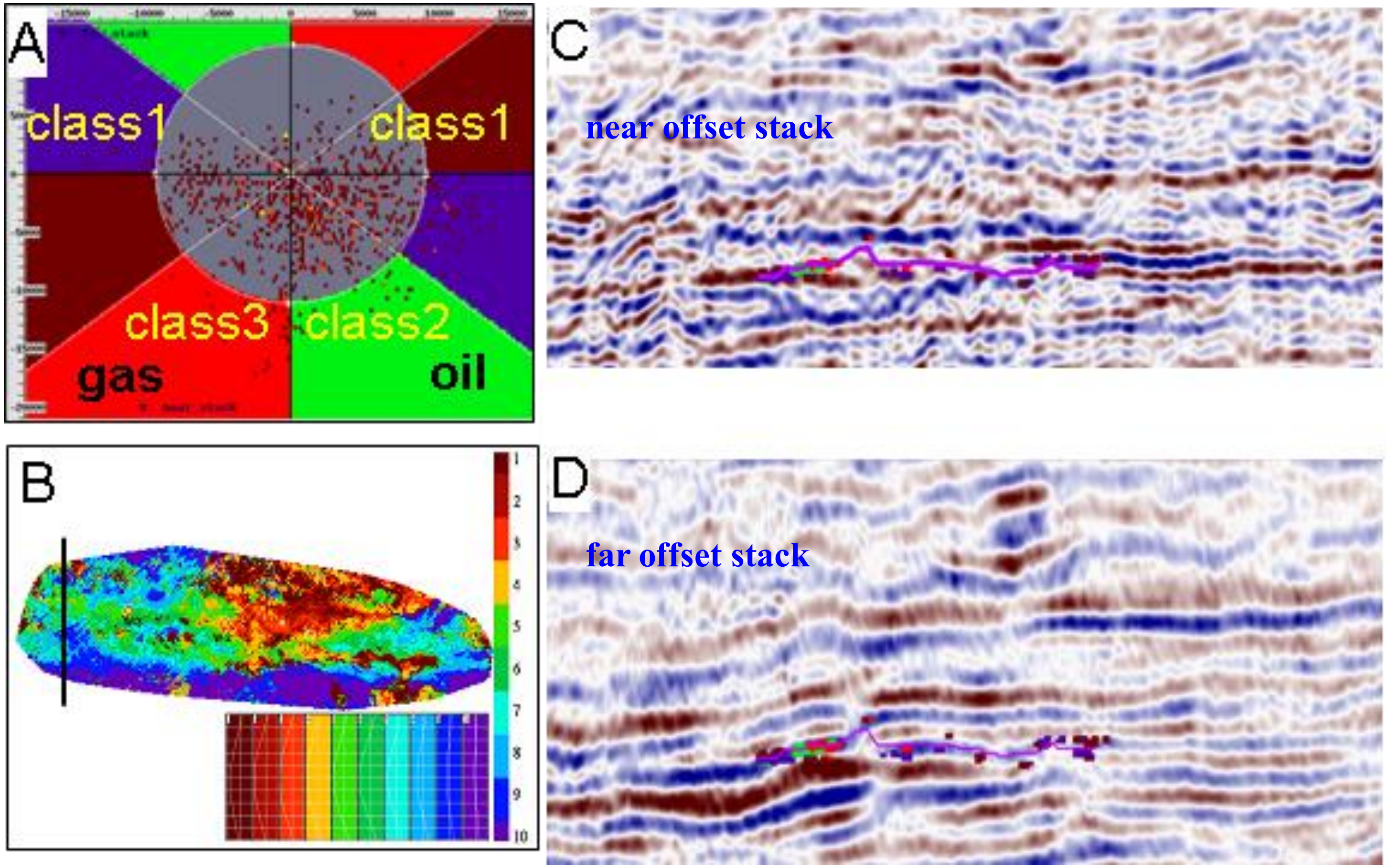
The anomalies concentrate on both the red colored and green colored areas, representing type 2 and type 3 AVO anomalies. On the seismic profiles, they appear both red color and green color in the location of well W-2. The results are coincided with oil and gas well W-2, and the distribution of anomalies looks alike to the results of waveform classification.

2. Hydrocarbon Detection Methods



The anomalies concentrate on the green colored area, representing type 2 anomalies. On the seismic profiles, most of them appear green color in the location of well W-3, expressing oil. The results coincide with oil well W-3, and the distribution of anomalies is similar to the results of waveform classification.

2. Hydrocarbon Detection Methods



No obvious amplitude anomaly.

3. Conclusions

(1) Due to the bright spot characteristics of reservoir, hydrocarbon can be detected by RMS amplitude attribute , Max amplitude attribute and the comparison of far offset stack and near offset stack data.

(2) Regarding to the absorbed effect of hydrocarbon to seismic wave, the lateral comparison of frequency attribute can attain the objective of hydrocarbon detection.

(3) The hydrocarbon layer features resonance in low frequency and attenuation in high frequency. Therefore, hydrocarbon can be detected by the analysis of different frequency cubes.

(4) Seismic wave form changes due to the fluid (oil, gas and water) contains in reservoir. Thus, the combination of waveform classification and calibration of wells can be used to detect hydrocarbon.

(5) Hydrocarbon layer appears AVO features. Different AVO anomalies can be identified by the cross plot of far offset stack and near offset stack data.


The end!
Thank you for your attention!