PS Multi-cycles Sequence Stratigraphy Analysis and the Application of Seismic Waveform Classification Technique for Sandstone Prediction in Shallow Lake Basin*

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Abstract

The waveform analysis of seismic facies can be a good solution to the prediction of the sand body problems. Previous researches and applications of waveform seismic facies in oil exploration mostly include the depositional and provenance systems; the relationship was not established between lithologic characteristics and waveforms. This article tries to establish the links between lithologic and seismic waveform in the context of shallow-water delta deposits. Any change in physical parameters of seismic signal is always reflected in changes of seismic waveform. Seismic facies classification processing is based on reflection changes in waveform through self-organizing neural network algorithms. First, the algorithm obtains the model trace and utilizes the shape of seismic trace (i.e. wave characteristic) to contrast the actual seismic data in the layer interval and then describe the lateral variation of seismic signal.

According to the statistics of 22 drilled wells in pss2 in block A, HHK depression (Neogene) four combinations of sandstone and mudstone are summarized: thin sandstone and mudstone, medium thickness of interbedded sandstone and mudstone, thick sandstone mudstone and large sets of mudstone. These combinations are based on the relationship between well trace waveform characteristics, waveform classification and combination mode of sandstone and mudstone in the research area. Statistics indicated that the existing relationships fall within the following four categories: 1) low-frequency, medium-strong amplitude bell-shaped reflection wave: the anti-cycle of mudstone and fine sandstone, sandstone distributes intensively, single layer thickness, channel and distal bar-distributary channel complex facies; 2) high-frequency, strong amplitude reflection wave backspin: mudstone with thin fine-grained sandstone compose anti-cycle, delta front distal bar or shallow lake sand bar; 3) high-frequency, strong amplitude reflection wave top spin (higher wave peak): mudstone interbedded with medium-thick sandstone, distal bar and underwater distributary channel system; and 4) low-frequency, low amplitude flat-shaped reflection waveform: large set of mudstone with gray, green and purple, the characteristics are large sets of mudstone lithology, shore-shallow lake facies. Based on established relationships of lithologic characteristic and seismic wave by way of waveform classification analysis, excellent results were achieved by prediction of sand bodies in the shallow-water basins.

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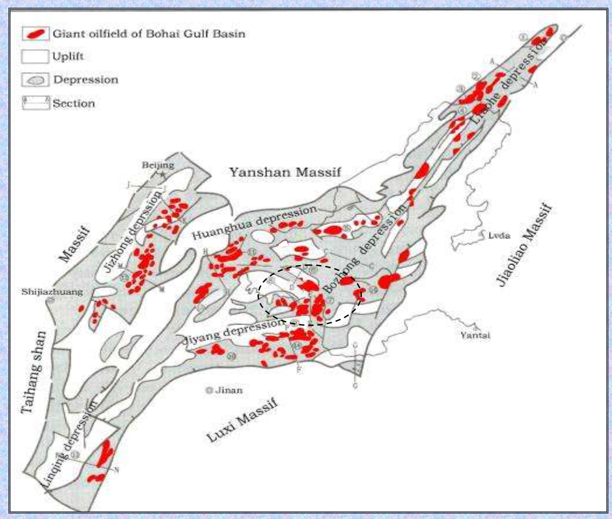
1、Geological setting



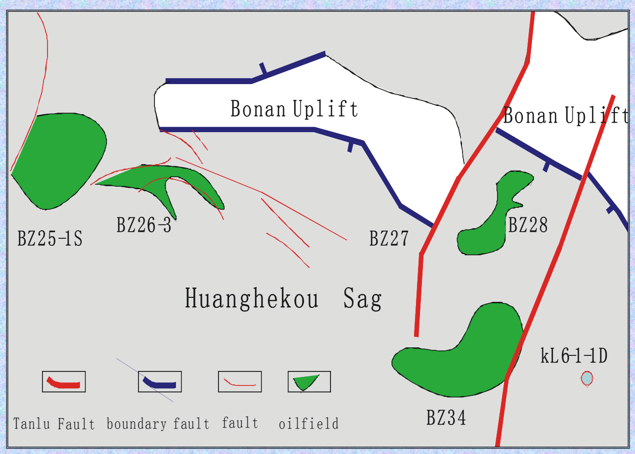


Fig.1/2 The regional structural location of Huanghekou Sag.The theory of sequence stratigraphy was originated from the passive continental margin basin, and the research methods of marine sequences were very mature. Many scholars have introduced sequence stratigraphy theory into the continental basins and summarized the research methods of continental sequence stratigraphy according to the different types of continental evolution features. But the model application of sequence stratigraphy to shallow basin during shrinkage stage when peneplain deposits were widespreadly developed has always been a problem due to many reasons as follows.

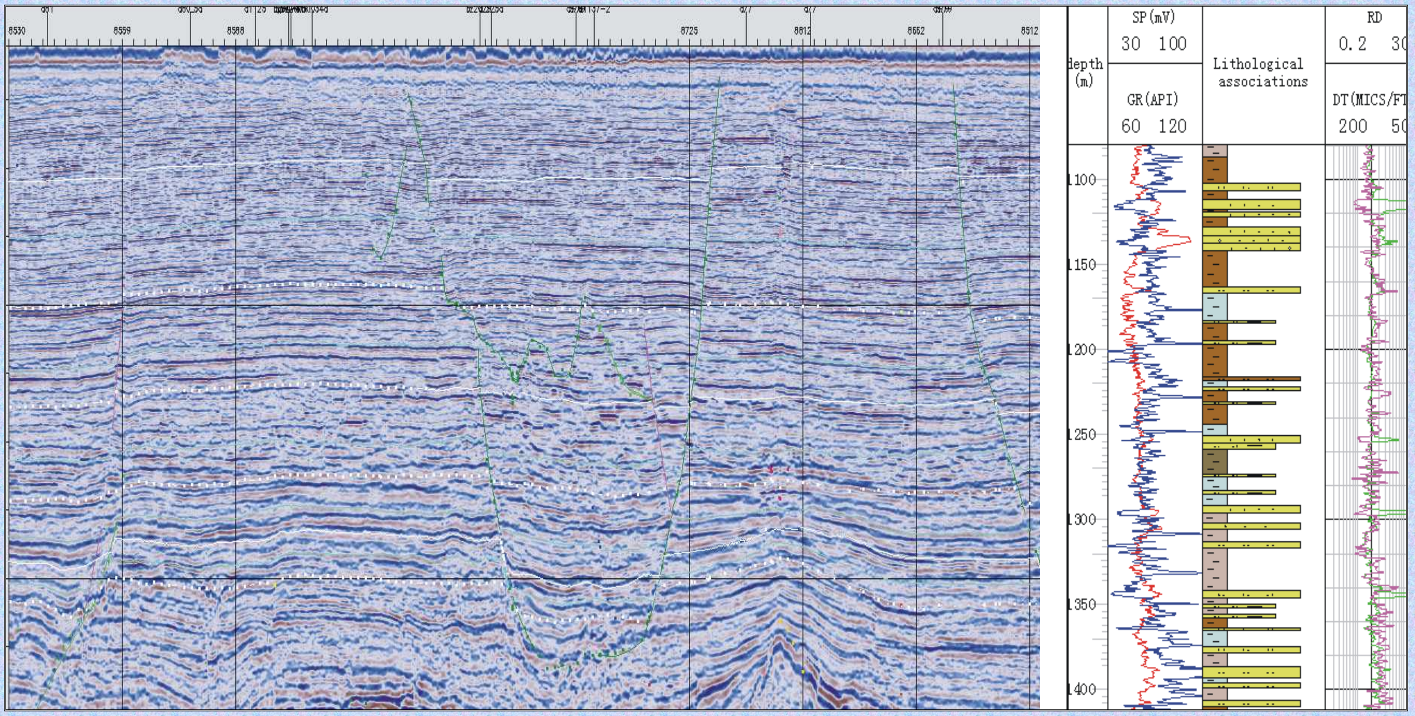
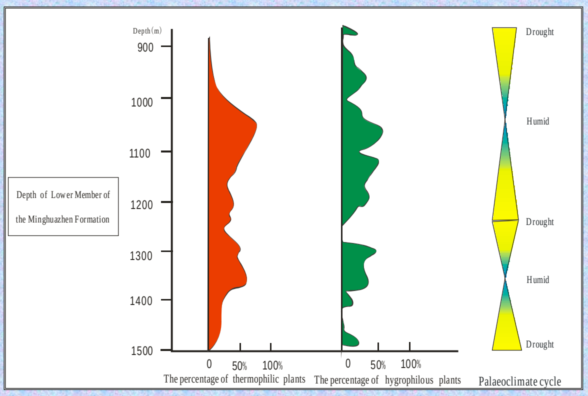
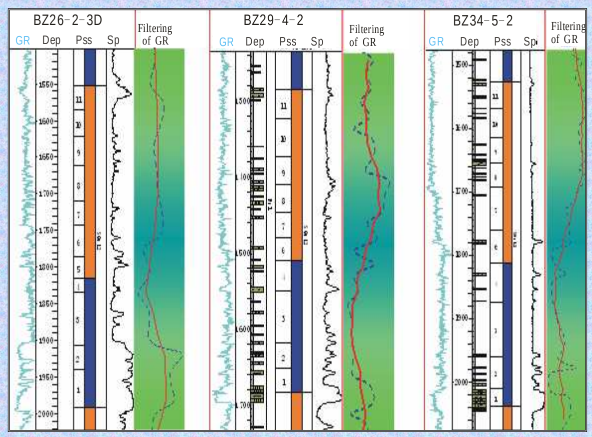


Fig.3 The subsidence of the basin during shrinkage stage was mainly influenced by the up-down concussion movement and the topography was flatter than faulted basin. Paleontology index and algae abundance were not rich enough to show the lake level changes due to shallow lake. Lithological associations were mainly dominated by sand interbedded with shale layers due to frequent transgression-regression of shallow water and thick lacustrine mudstones similar to transgressive tract in rift period was rare. It is also difficult to observe typical seismic reflection termination phenomenon,such as truncation,onlap, downlap,which can be used as the standard of seismic sequence division. So it is very difficult to carry out the sequence stratigraphy research on shallow basin during shrinkage stage using traditional well-seismic combination methods.

2、Palaeoclimate cycling and multi-cycles sequence





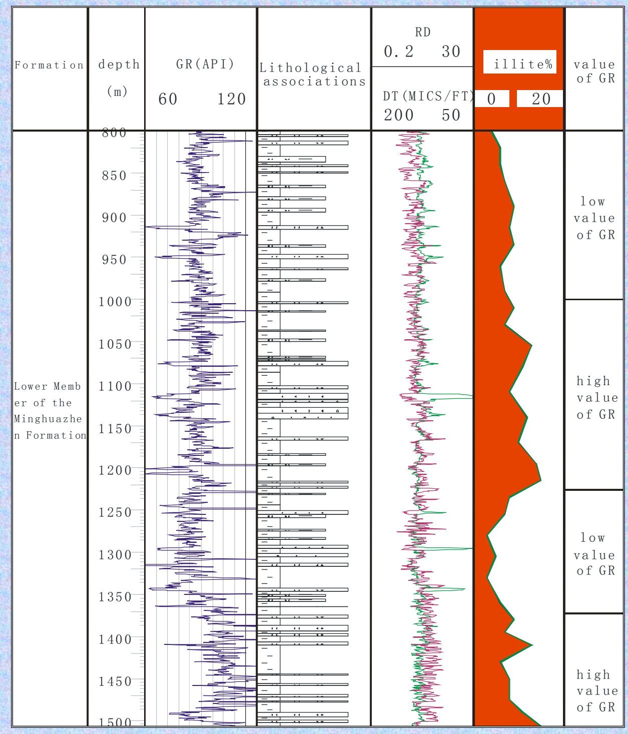


Fig.4/5/6 Taking the Lower Member of the Minghuazhen Formation of Neogene in Huanghekou sag of the Bohai Bay basin as an example, the research method of sequence stratigraphy during shrinkage stage in extremely shallow water area which was controlled by palaeoclimate cycling was studied. The palaeoclimate cycle of "drought-humid-drought-humid" in the Lower Member of the Minghuazhen Formation was identified based on the research of pollen and phytoplankton records. The conversion position between drought and humid corresponds to the sequence boundary and the maximum flooding surface. No illite generated by diagenesis has been found due to shallow burial depth of Neogene, and the transformation of kaolinite and illite in the clay minerals is the result of weathering, which can indicate climate changes. The enrichment of illite indicates that the palaeoclimate was dry and cool, and the enrichment of kaolinite means the palaeoclimate was relatively damp and hot. The type of clay minerals in rocks can influence the value of gamma ray logging (GR): High GR value refers to enrichment of illite and low GR value refers to enrichment of kaolinite. Multi-cycles sequence stratigraphy analysis aslo include， drilling cycling,log cycling,seismic reflection feature cycling .

3、Multi-cycles sequence stratigraphy analysis mainly dominated by palaeoclimate cycling

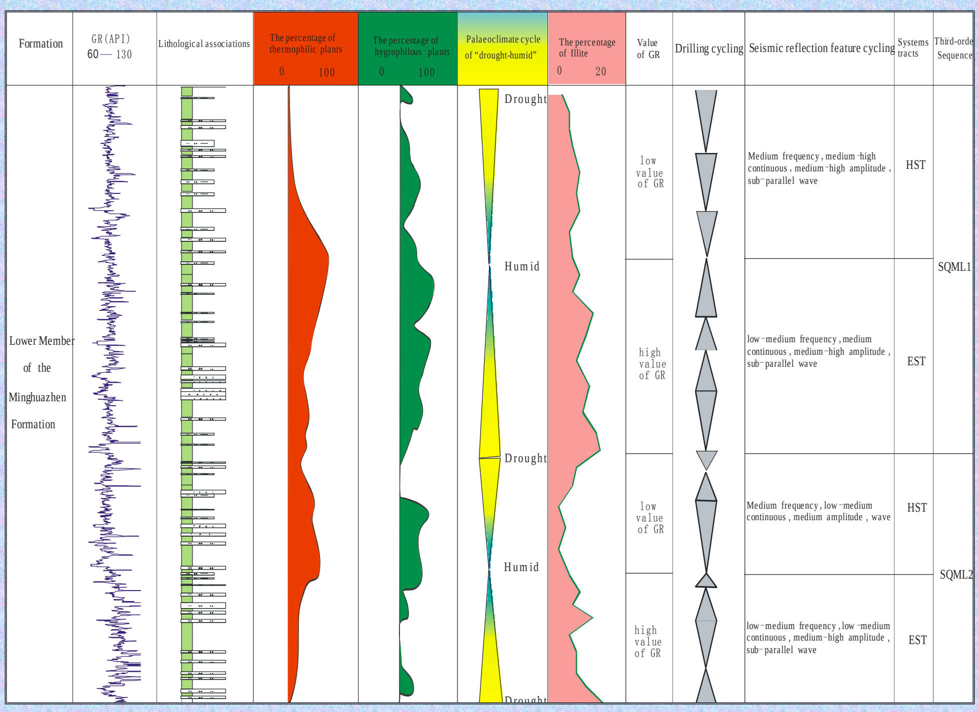


Fig.7 2 third-order sequences have been classified in Neogene of Huanghekou sag based on the study of palaeoclimate，cycling, drilling cycling,log cycling,seismic reflection feature cycling, in which 2depositional system tracts can be identified.

4、The application of seismic waveform classification technique for sandstone prediction in shallow lake basin

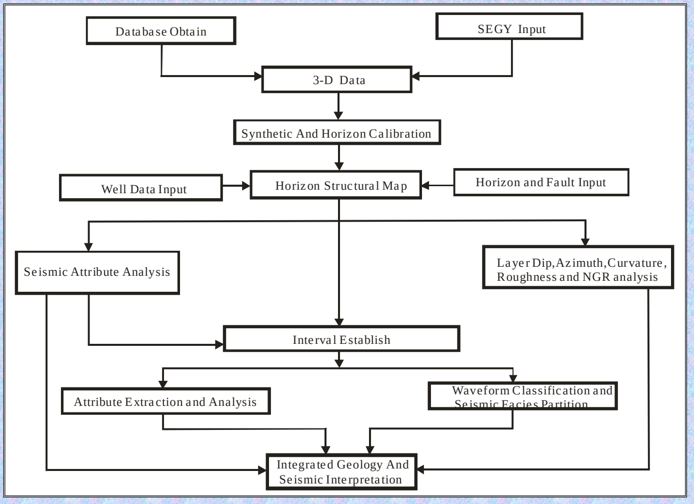


Fig.8 Workflow graph of seismic facies analysis. The refined analysis of sequence stratigraphy is the basis of prediction of the sandbody. The waveform analysis of seismic facies can be a good method to describe sandbody in the isochronal sequence framework.Previous researches and applications of Waveform seismic facies in the oil exploration mostly include the depositional systems and provenance systems, the relationship was not established between lithologic characteristic and waveforms. This article try to establish the links between lithologic and seismic waveform at the context of shallow-water delta deposits.

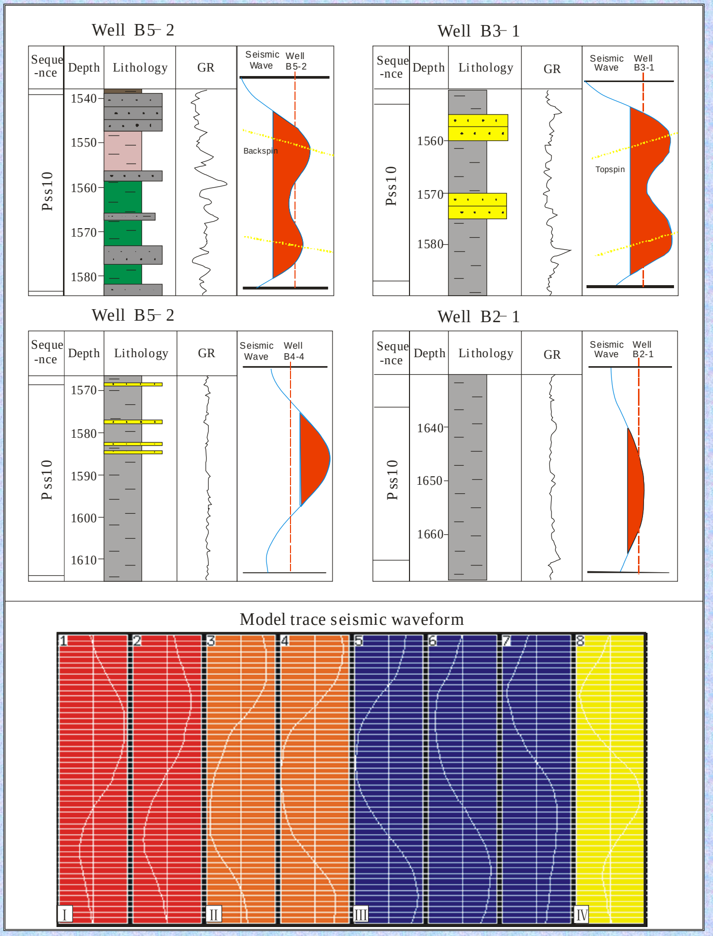


Fig.9 According to the relationship between well trace waveform characteristics, waveform classification and combination mode of sandstone and mudstone in research area. Statistics found that the relationship existed have the following 4 categories:

1. Low-frequency,medium-Strong amplitude Bell-shaped reflection wave: the lithologic association behaves the anti-cycle of mudstone and fine sandstone, sandstone distributes intensively, single Layer thickness, Mainly reflects the waveform characteristics of distributary channel and distal bar-distributary channel complex facies.
2. High-frequency,strong amplitude reflection wave backspin (lower wave peak): The performance of lithologic association is mudstone with thin fine-grained sandstone compose Anti-cycle. Mainly reflects the waveform characteristics of the delta front distal bar or shallow lake sand bar.
3. High-frequency,strong amplitude reflection wave topspin (higher wave peak): The performance of lithologic association is mudstone interbedded with medium-thick sandstone. Mainly reflects the waveform characteristics of distal bar and underwater distributary channel system.
4. Low-frequency, low amplitude Flat-shaped reflection waveform: lithologic mostly are large set of mudstone with gray, green and purple. The characteristics are large sets of mudstone lithology. Mainly reflects the waveform characteristics of shore-shallow lake facies.

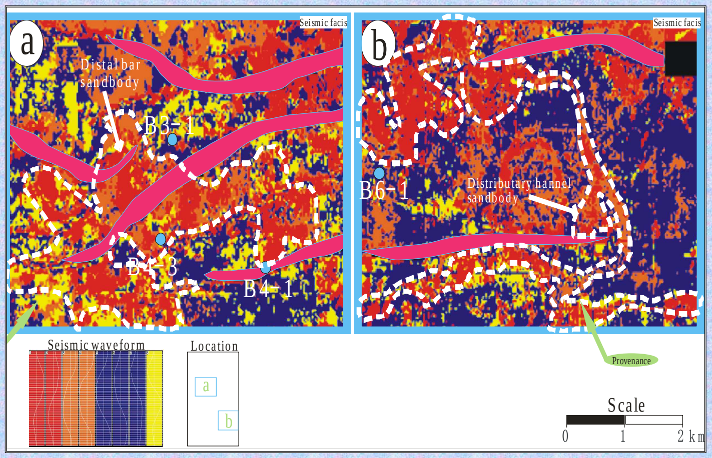


Fig.10. Seismic facies characteristics based on waveform classification.

(a:In Well B3-1,B4-3 and B4-1,lithology combinations are mid-thick sandstone and mudstone interbeded,and both are located in distal bar upon Ⅱ-type waveform or between Ⅱ type waveform and Ⅲ-type form;b:In this region,distributary channel system is obvious and sandstone of distributary channel is located upon Ⅰ or Ⅱ-type waveform.Well B6-1 shows the charactoristic of thick mudstone located upon shallow lake mudstone of Ⅲ-type except distributary channel)