PS Study on Intercalation of Shallow Water Delta by Integration of Logging and Seismic Data*

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Abstract

Intercalation is one of the main reasons for reservoir heterogeneity and plays an important role in the waterflooding and distribution of remaining oil. In consideration of sparse well spacing and imperfection of well pattern in offshore oilfield, we carried out detailed analysis on shallow water delta by integration of logging and seismic data to clarify the types, well-to-seismic responses and spatial distribution of intercalations. The results show that distributary channels are widely distributed during the period of Nml Formation. Muddy intercalation is the main type of intercalations, characterized by mudstone and siltstone with low values of GR and RT. Controlled by sedimentation, the formation of muddy intercalations are of three origins: (1) mud deposits during the intermission of flood periods (flood plain), (2) fine-grained deposits during the weakening period of flow (interdistributary bay deposits), and (3) migration of distributary channels (architectural boundary). Integrated analysis shows that seismic waveform, coupled with instantaneous frequency and minimum amplitude are in well response to the development of intercalations as the reservoir thickness ranges from λ/4 to λ/2. The intercalations with thicknesses over 4 m show asymmetric waveforms and a reduction of instantaneous frequency and minimum amplitude, whereas unapparent change in instantaneous frequency and minimum amplitude but asymmetric waveform with thickness less than 4 m. Accordingly, by attribute computation and calibration of waveform and logging, the intercalations were quantitatively delineated and the 3D model was ultimately established. This technique helps reveal the internal structure of distributary channels, improve the precision of numerical simulation, and provide the geological basis for enhancing oil recovery.

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Abstract

Intercalation is one of the main reasons for reservoir heterogeneity and plays an important role in the waterflooding and distribution remaining oil. In consideration of sparse well spacing and imperfection of well pattern in offshore oilfield, we carried out detailed analysis on shallow water delta by integration of logging and seismic data to clarify the types, well-to-seismic responses and spatial distribution of intercalations.

The results show that distributary channels are widely distributed during the period of Nml Formation. Muddy intercalation is the main type of intercalations, characterized by mudstone and siltstone with low value of GR and RT. Controlled by sedimentation, the formation of muddy intercalations are of three origins: (1) mud deposits during the intermission of flood period (flood plain); (2) fine-grained deposits during the weakening period of flow (interdistributary bay deposits); (3) migration of distributary channels (architectural boundary). Integrated analysis shows that seismic waveform, coupled with instantaneous frequency and minimum amplitude are in well response to the development of intercalations as the reservoir thickness ranges from λ/4 to λ/2.

The intercalations with thickness over 3 m show asymmetric waveforms and a reduction of minimum amplitude,while a increasement in instantaneous frequency,whereas unapparent change in instantaneous frequency and minimum amplitude but asymmetric waveform with thickness less than 3 m. Accordingly, by attribute computation and calibration of waveform and logging, the intercalations were quantitatively delineated. This technique helps to reveal the internal structure of distributary channel, improve the precision of numerical simulation, as well as provide geological basis for enhancing oil recovery.

1.Geological Settings

1.1 Location and structural characteristics

- Bohai Bay basin is located in northern China,which covers an area of 200,000 square kilometers.
- Bohai Bay basin is characterized by tectonics with steady and slow subsidence,resulting in low-relief,low gradient and large scale shallow water delta deposits during the Neogene.

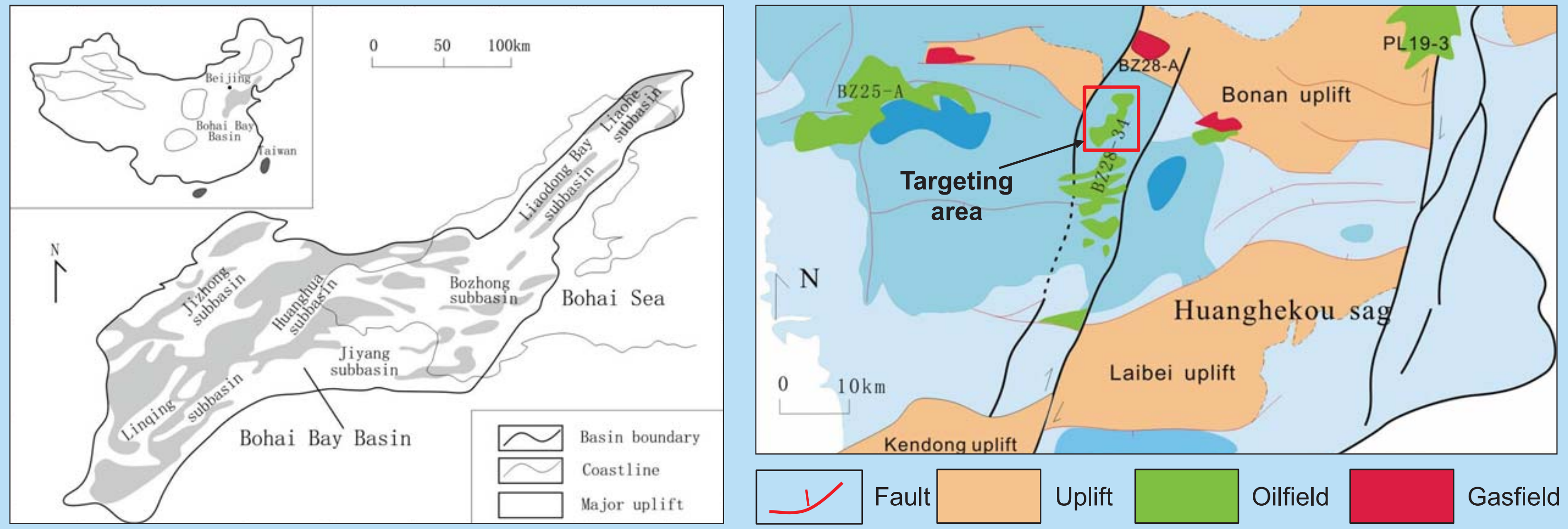

Fig.1 Location of targeting area

1.2 Stratigraphy

- Target stratum is Neogene Lower Minghuazhen formation,which can be divied into 5 oil group.
- The burial depth of reservoir varies from-900 to -1700m.

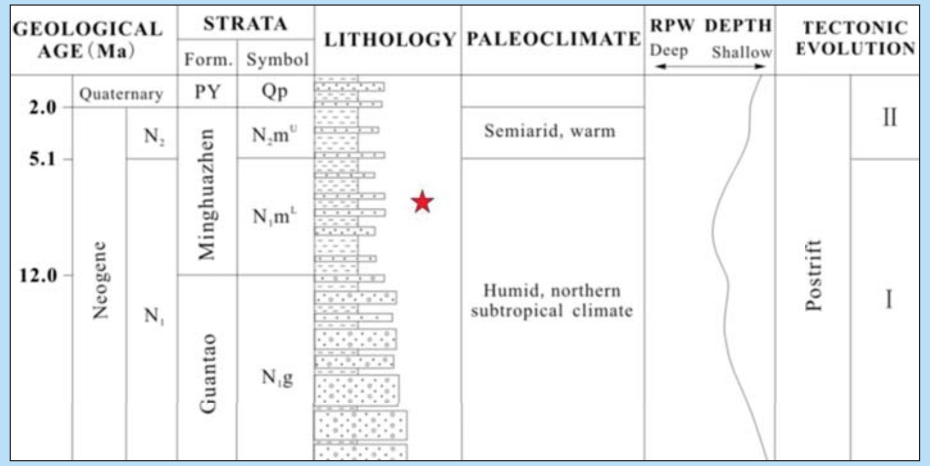

Fig.2 Strata schemes of targeting area

1.2 Sedimentation

- Distributary channel is dominant in shallow water delta system,presenting 2 distribution patterns according to the change of A/S.

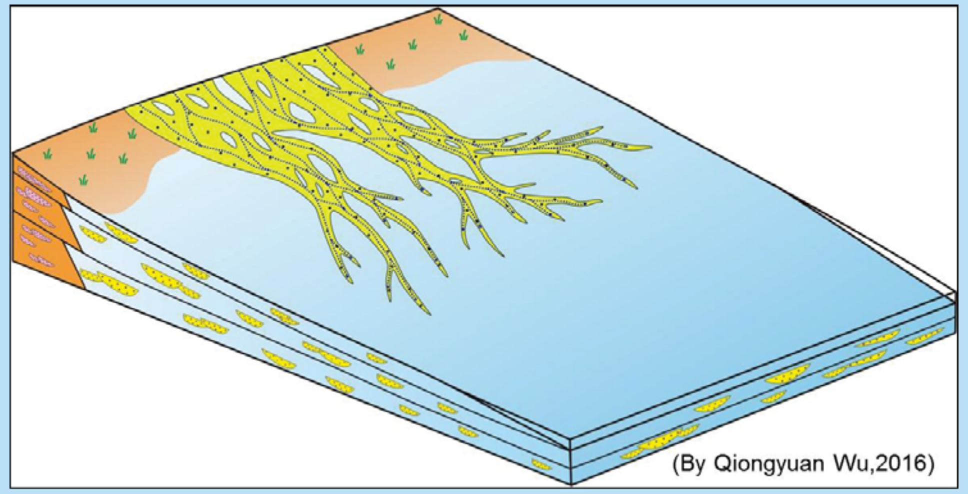

Fig.3a Interweave-striped distributary channel of shallow water delta

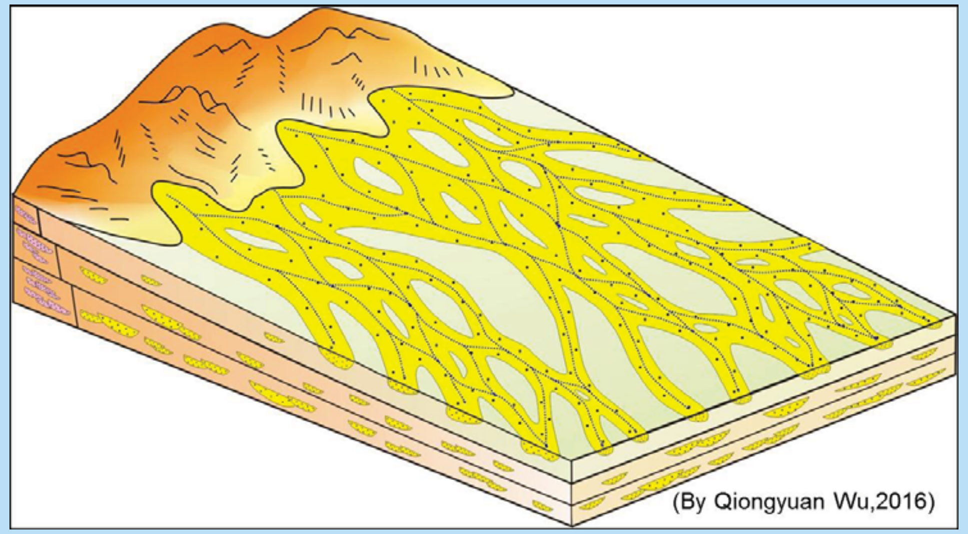

Fig.3b Interweave-continuous distributary channel of shallow water delta

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2. Types and characteristics of Intercalation

2.1 Types and formation mechanism

- 3 different types of intercalation were identified based on core and logging data, presenting as muddy,calcareous and petrophysical.
- Muddy intercalation is dominant , characterized by mudstone and siltstone.

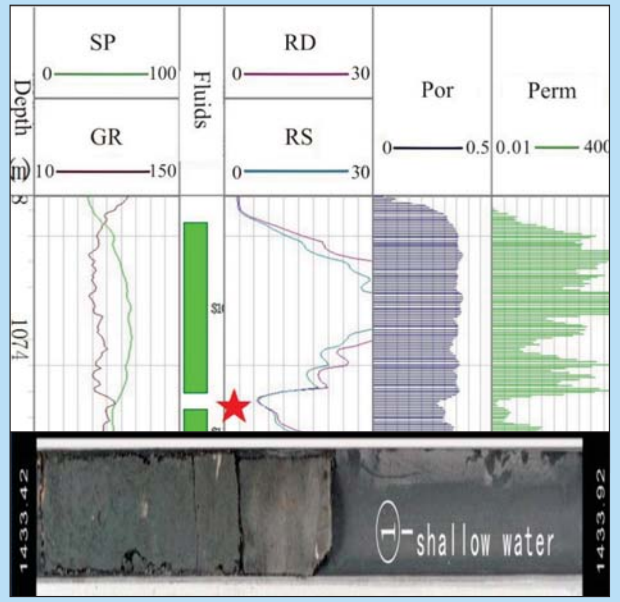

Fig.4a Muddy

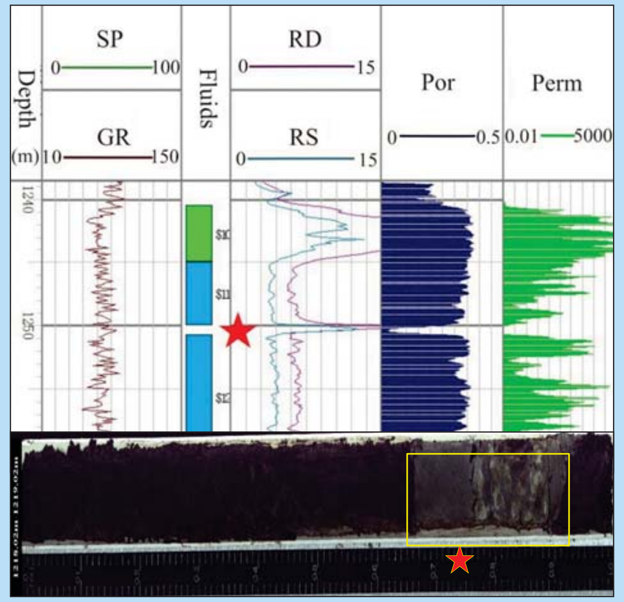

Fig.4b Calcareous

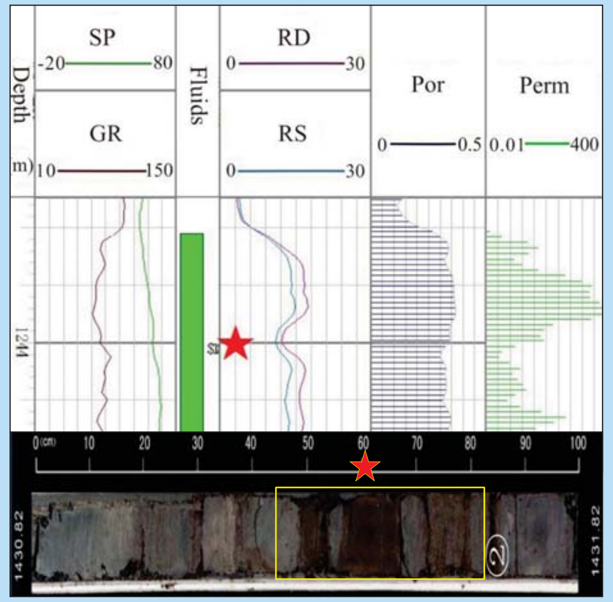

Fig.4c Petrophysical

- The formation of muddy intercalations are of three origins, the first two are the targert.
  (1) mud deposits during the intermission of flood period (flood plain)
  (2) fine-grained deposits during the weakening period (interdistributary bay deposits)
  (3) migration of distributary channels (architectural boundary)

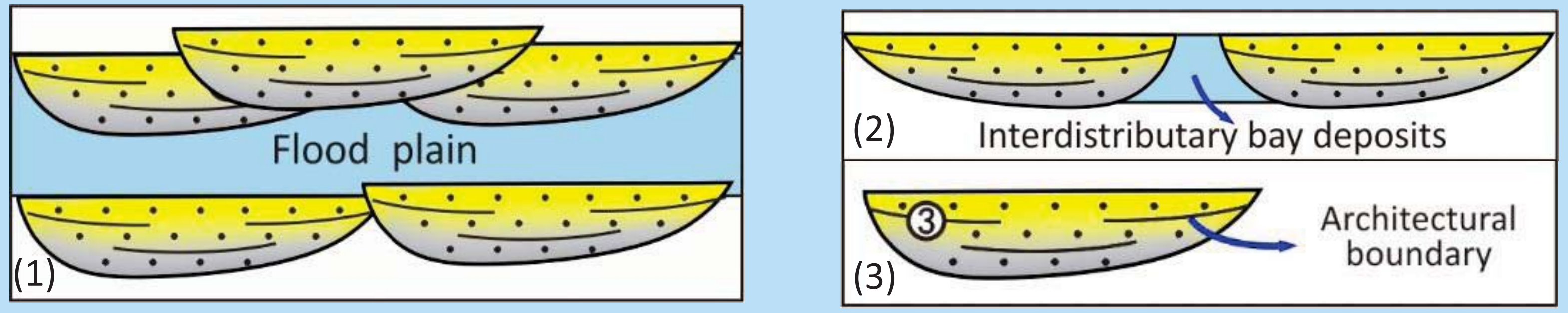

Fig.5 Formation mechanism of muddy intercalation

2.2 Electrical characteristics

- GR,RD,AC and Vsh is relatively sensitive to muddy intercalations and can be used to identify the muddy intercalation.

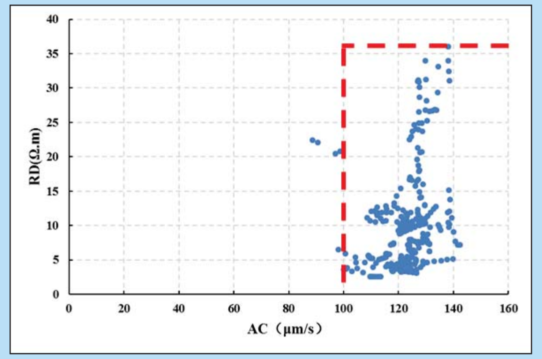

Fig.6a Plot of AC vs RD

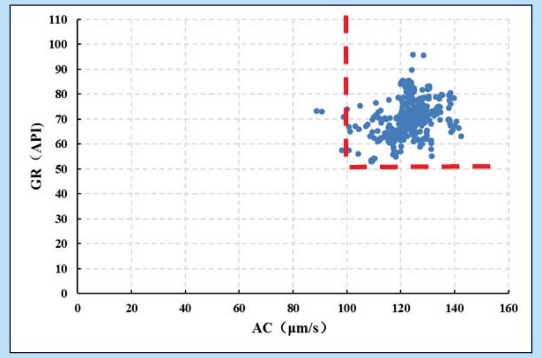

Fig.6b Plot of AC vs GR

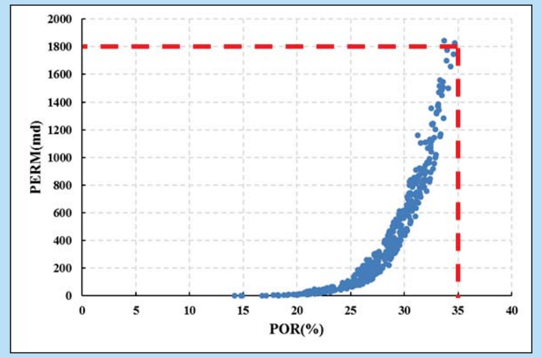

Fig.6c Plot of Por vs Perm

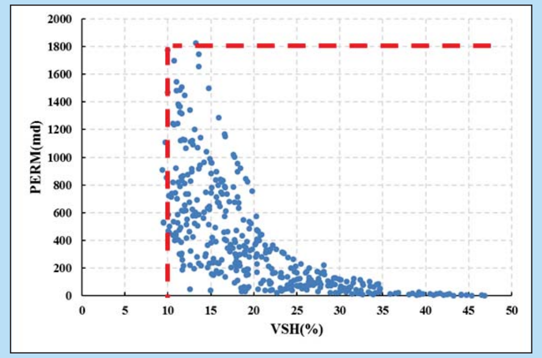

Fig.6d Plot of Vsh vs Perm

- Standard for muddy intercalation is established based on core and electrical calibration.

AC:>100μm/s	RD:<35Ω•m
GR:>50API	Vsh:>10%
Por:<35%	Perm:<1800mD

3. Prediction and distribution

3.1 Forward modelling

- The thickness of intercalation varies from 0.5m to 10m.
- The dominant frequencye of 3D seismic data is about 50 Hz,making it feasible for predicting the distribution of intercalation.

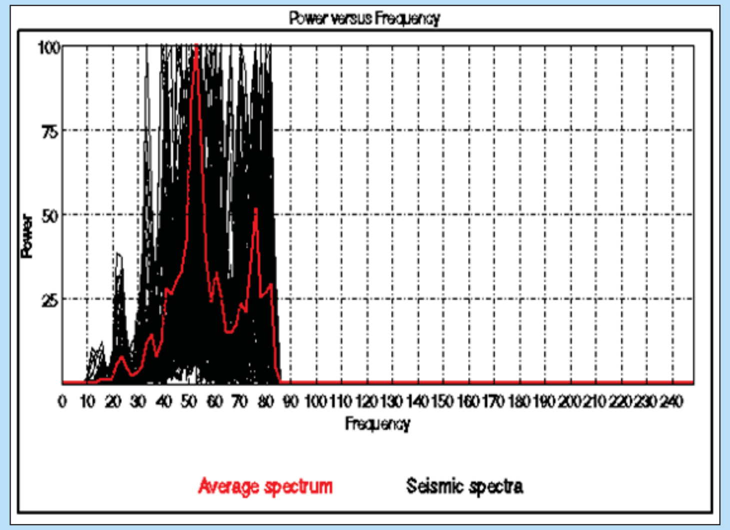

Fig.7 Frequency distribution

- The intercalation show a reduction in minimum amplitude,while increase in instantaneous frequency.
  - surrounding rock & intercalation ρ:2350kg/m^3 v:3100m/s
  - Reservoir→ ρ:2100kg/m^3 v:2600m/s

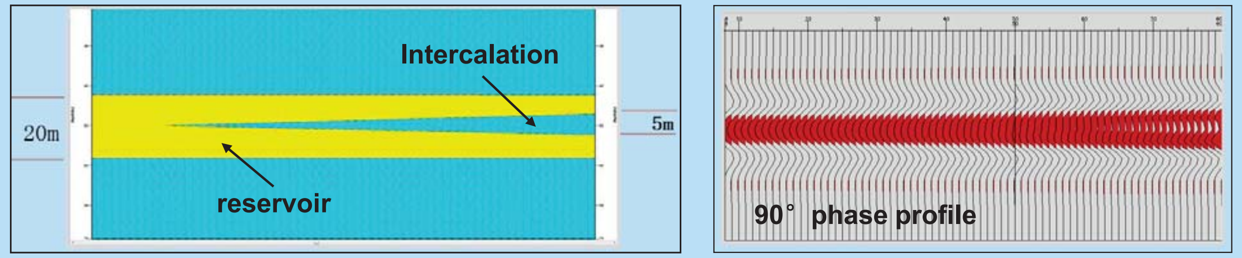

Fig.7 Theoretical model

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3.1 Forward modelling

- Intercalation with thickness over 3 m show asymmetric waveforms and reduction in minimum amplitude,while increasement in instantaneous frequency.

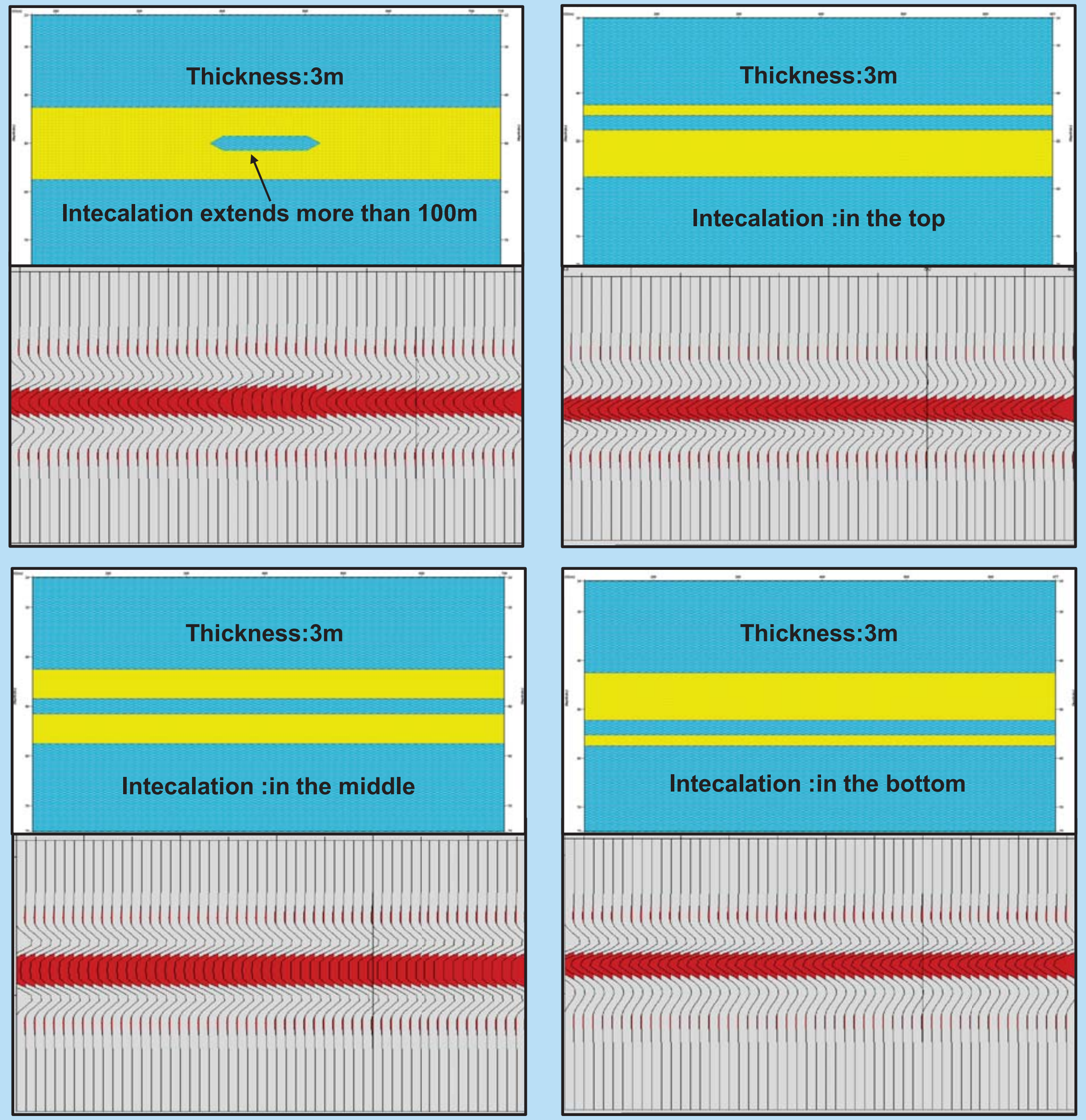
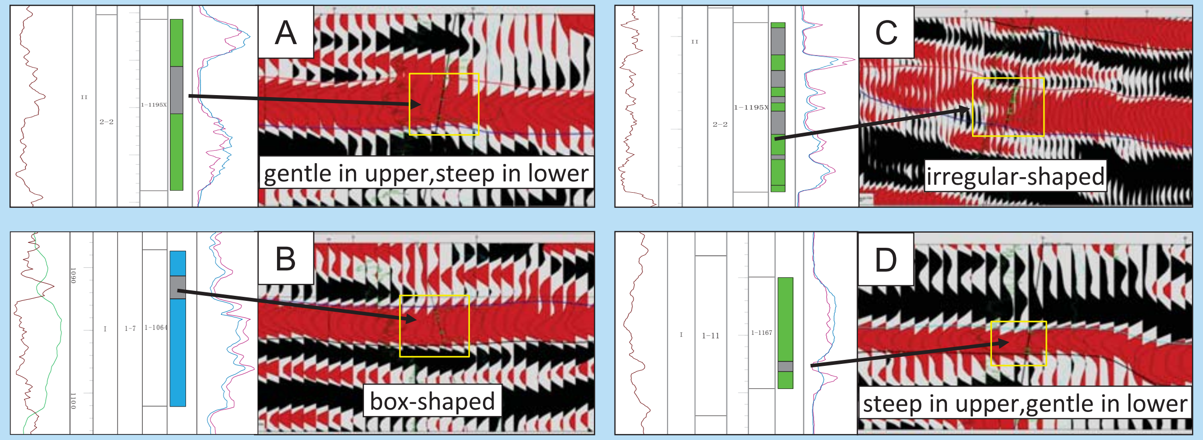


Fig.8 Forward modelling result

3.2 Qualitative prediction

- Identification of intercalation was conducted based on modelling results and log calibration.It can be classified into 4 types according to the shape.



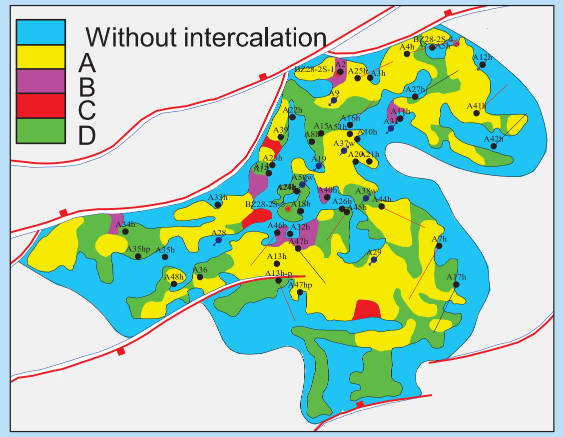
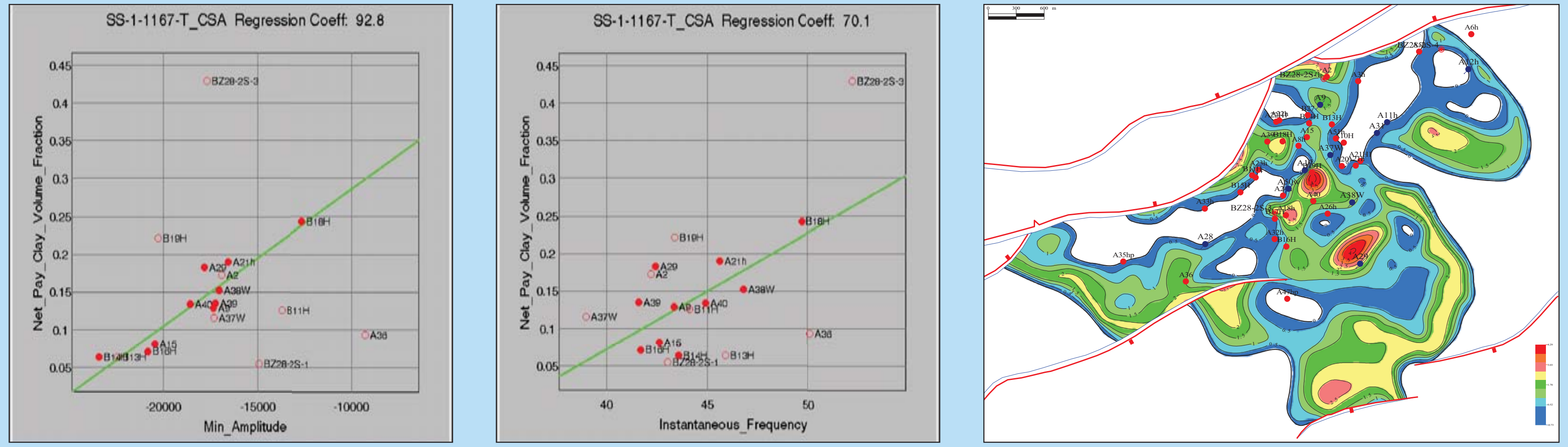


Fig.9 Identification of intercalation　　Fig.10 Distribution of waveforms

3.3 Multiple attribute clustering analysis

- Multiple attribute clustering analysis was carried out ,with the help of which the distribution of muddy intercalation was quantitatively studied.



□ *Intercalation= 5.321498 -0.00615687 * Instantaneous_Frequency-3.26317e-08 * Min_Amplitude*

Fig.11 Quantitative distribution of intercalation

4. Application

4.1 Application

- Geological model was established based on the study mentioned above,followed by numerical simulation.
- Numerical simulation reveals the spatial distribution of remaining oil,making the deployment for adjustment well much more reasonable.

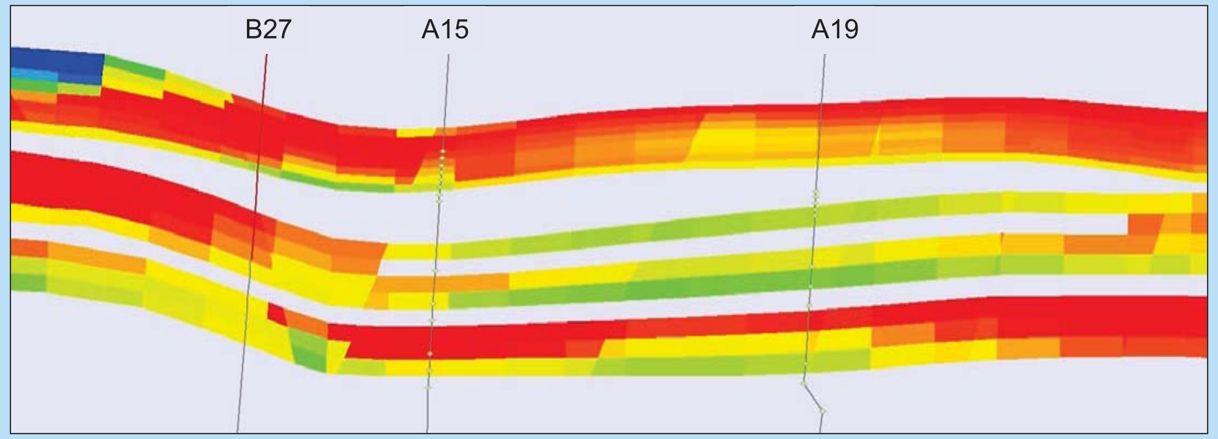


Fig.12 Numerical simulation result

5.Conclusion

- Muddy intercalation is widely developed in Neogene Lower Minghuazhen formation.Intermission of flood period and fine-grained deposits during the weakening period are the main origins for intercalation.
- Intercalation with thickness above 4m can be identified by Integration of logging and seismic data.
- The area where intercalation is well developed should be the target for later development of oilfied.